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Editor and Distributer:
Alfred Toepfer Akademie für Naturschutz
Hof Möhr, D-29640 Schneverdingen,
Phone +49-5199-9890, Fax +49-5199-989-46

Responsible for the contents of each contribution is the respective author.
Editorial Remark:
The forum was open to various kinds of contributions by participants. Contributions were made in form of statements, abstracts of papers, scientific papers and posters. This publication includes all these various kinds of contributions without attempt to create a unified format. Some texts were slightly modified by the editors, mainly in order to overcome language problems, and the text was not revised again by the author. It was not meant to change the contents, but if the modification resulted in a different meaning, it is solely the responsibility of the editors.

Editors: Dr. Jutta Poker, Inge Stein

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NNA-Reports

Volume 12, Special Issue 1, 1999

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Forests in Focus

within the framework of "WELTFORUM WALD", official project of the World Exposition 2000

A series of fora focusing on global forests issues aims at achieving consensus among relevant interest parties on tools and concepts to sustainably develop the world's forests. The project 'Forests in Focus' adds operative recommendations for solving environmental problems concerning forests to current political negotiations and scientific meetings in the field of forestry. The fora act as an agent between politics, economics, science and public and provide condensed up-to-date knowledge as well as agreed upon proposals for action adequate to target groups. Thus, 'Forests in Focus' supports the local implementation of guidelines on forest management and enforces the forest related parts of the Agenda 21 process.

Background

The World Exposition 'EXPO 2000 Hannover' presents the concept of sustainable development as agreed upon in the Agenda 21 at the UNCED 1992 in Rio de Janeiro. EXPO 2000 includes various worldwide decentralised projects. One of these, 'WELTFORUM WALD' (World Forum on Forests) has been initiated by authorities of the district Soltau-Fallingbostel, Northern Germany, the Association for the Protection of Forests and Woodlands (SDW), the Forestry Commission of Lower Saxony and the Alfred Toepfer Academy for Nature Conservation (NNA).

The project includes various activities and exemplary projects demonstrating sustainable management and use of forests to local people and international visitors (reafforestation of degraded heathland, redevelopment of former military areas, environmentally sound wooden buildings, thermal use of wood, use of non-timber products, management of a nature reserve and tourism, etc.).

Within this frame, 'Forests in Focus' forms the professional backbone. The fora address institutions and social parties concerned with forests, particularly those which

- are directly connected to forests,
- play an active role in forest management
- are affected by forest management.

The fora intend to encourage the relevant social parties to participate efficiently in decision making on forest issues, thus promoting the worldwide implementation of the recommendations of the Agenda 21.

Auspices

'Forests in Focus' is performed under the auspices of the Federal Minister of Food, Agriculture and Forestry, Mr. Karl-Heinz Funke.

Time Schedule

Between 1998 and 2000, five fora take place. With respect to the multiple functions of forests, the fora focus from different perspectives on the worldwide sustainable co-existence of mankind and forest:

Forests and Energy (To what extent can forests contribute to the world's future energy supply?) January, 1998

Biodiversity – Treasures in the World's Forests (Prospects of conservation, use and sustainable development of biodiversity in forests) July, 1998

Forests – Source of Raw Material (Potentials of forest products' use and marketing) May, 1999

Forests and Atmosphere-Water-Soil (Regulation of energy and matter cycles with respect to climate change, water cycles and soil degradation) July, 1999

Forests and Society (Interrelation of cultures and environment, public awareness, public participation; integration of recommendations of the former fora) November, 1999

The final events will be the presentations of the results and recommendations of all fora at the EXPO 2000 in Hannover in Summer 2000 and at the congress **Sustainability in Time and Space** – in cooperation with PRO SILVA (Implementation of forest management guidelines in divergent forest types.) June, 2000.

Forum "Forests and Energy", 17–20 Jan 1998

Auspices

The forum took place under the auspices of

- the German Federal Minister of Food, Agriculture and Forestry, Mr. Jochen Borchert
- the German Federal Minister for the Environment, Nature Conservation and Nuclear Safety, Dr. Angela Merkel
- the Minister for Food, Agriculture and Forestry of Lower Saxony, Karl-Heinz Funke.

Objective

The forum focused on the potentials of forests to contribute to future energy supplies in different regions of the world. It aimed at achieving consensus among different interest groups on a set of recommendations for action concerning use of woodfuels at the regional and local levels.

Working Programme

It was envisaged that the meeting would organise its work into four workshops with the following respective focuses:

WS I : Energy systems in transition (situation e.g. in eastern European regions)

WS II : Energy systems in construction (situation e.g. in less developed regions)
WS III: Energy systems in extension (situation e.g. in Asian 'tiger countries')
WS IV: Energy systems in modification (situation e.g. in industrial regions)

At the time of the meeting, the organisers decided, however, in agreement with all chairpersons, to merge WS I with WS IV, likewise WS III was integrated into WS II, would better serve the interest of achieving the objectives of the forum. Thus, the forum concentrated on woodfuel potentials in highly industrialised and less developed regions of the world.

Congress Recommendations

Chairperson of the plenary sessions: Ms. Elisabeth Barsk-Rundquist, UN-CSD, Intergovernmental Forum on Forests (IFF), New York, USA

120 participants from 23 nations world-wide representing the energy as well as the forestry sector, environmental organisations, technical aid institutions and scientific branches gathered for 5 days in Schneverdingen, Northern Germany, in order to discuss the prospects of energy from woodfuels.

The very fundamentally different conditions with respect to woodfuel and its use in industrialised countries in contrast to less developed countries prevented the formulations of a common statement. This is a reflection of the very different strategies which needs to be employed in these different types of countries in order to achieve sustainable use of wood as an energy source.

Aspects common to the majority of regions where biomass contributes to the energy supply

Situation

Woodfuels do play a role in all mayor forested parts of the world, partly most prominent, partly of minor importance. Globally, woodfuels contribute a significant amount to the energy supply in formal and often in non-formal markets. This significance is often neglected as

- energy from biomass is considered as traditional and old-fashioned
- political, economic and social framework conditions leave woodfuels out of view
- continuous woodfuel supply is regarded as doubtful and destructive to forests
- adapted conversion technologies on either scale are little known.

Opportunities

Overall, the potentials of woodfuels are seen as very promising, particularly in rural areas. The conversion of fuelwood from plantations, from forestry and agroforestry systems, residues in timber processing industries, waste wood and by-products of the pulp and paper production like black liquor into process or electrical energy offers opportunities for decentralised local energy supply as well as for input into larger scale grids. At the same time, energy from woodfuels contributes to rural development by providing additional job opportunities and increased income.

Furthermore, woodfuel use offers benefits by providing mechanisms to combat greenhouse gas accumulation. One of these is the substitution of fossil fuels by a regenerative resource, an other the sequestration of CO_2 in biomass.

Existing conversion technologies from cook stoves to boilers and power plants make use of biofuels in a highly efficient way. The dissemination and adaptation of modern equipment to local conditions reduces fuel input. Co-firing systems additionally contribute to meet energy demands in regions, where (wood) fuel is scarce. Another advantage of modern technology is the decrease of health risks.

Barriers

Also constraints of producing energy from woodfuels exist on a global level, mainly lack of political awareness, of financial support and lack of training and education. In many regions a conflicting situation between agriculture and forestry hampers the development of a biofuel sector.

Recommendations

Based on common experiences, the forum's recommendations in total aim at:

- internationalisation of biomass energy issues in order to change national policies
- extension of demands in order to stimulate the supply markets
- improvement of framework conditions for the production of energy from biomass.

Detailed recommendations are given in the following workshops' conclusions.

Workshop: Energy Systems in Construction Energy from Timber and Biomass in Developing Countries: Summary of Main Issues

Chairman: K.V. Ramani, Asian and Pacific Development Centre, Kuala Lumpur, Malaysia

Current Situation

This section is based on the most common factors observable in those countries represented in the workshop:

- There is an alarming decline of fuelwood resources due to increasing fuelwood demand and degradation/destruction of forests as a result of agricultural extension and increased demand of construction timber.
- Wasteful fuelwood consumption patterns are often due to the perception of wood as being a cost-free resource in rural areas.
- There is low efficiency of end-use devices and appliances such as cook stoves and other direct combustion equipment.
- There is a predominant role of fuelwood in cooking in rural areas, reaching up to 80% or more of energy demand.
- There is a preference for fuelwood in certain rural industries for process heat (e.g. forges).

Barriers

The following listing of barriers to increased sustainable use of wood fuels reflect those most common among the countries represented, but are not sorted by priorities:

- Lack of political will and policy support for the modernisation of biomass energy.
- Absence of an international 'push' for advanced biomass technologies comparable to some other technologies like photovoltaics.
- Lack of strategic thinking on how to assign a key position to biomass among energy sources.
- Inadequate funding for research development as well as inadequate investment.
- Inadequate delivery mechanisms to ensure the flow of funds to end-users.
- Lack of institutionalisation in planning and management of biomass energy combined with a multiplicity of institutions; several institutions are dealing with very narrow segments of the problem but are not really coming together to look at it in a holistic fashion.
- Lack of human resources for planning and management of biomass energy programmes.
- Lack of proven readiness for operation of some new generations of biomass energy technologies on a scale relevant to developing countries e.g. small-scale gasifiers for energy generation as required in rural areas.
- User preferences of new technologies (e.g. solar/photovoltaic) considering biomass technology as obsolete, old fashioned and dirty.
- Controversial user priorities with regard to investments in the non-energetic sector e.g. devices for entertainment vs. improved cook stoves.
- Lack of reliable information on biomass and the energy systems on medium to large scale, leading to lack of strategic thinking.
- Distorted prices for woodfuel for biomass energy due to direct and indirect subsidies for energy in the agricultural sector.

Opportunities

Increased use of wood as an energy source was viewed by the participants as also providing opportunities for users and policy makers. The following are not sorted in order of degree of potential but reflect the most common examples stated by the participants:

- Improved conversion technologies such as co-generation gasification with specific reference to power generation and process heat in industrial applications.
- Improved end-use devices/appliances such as wood-stoves and cooking utensils.
- Promotion of woodfuel substitutes such as kerosene, biogas (but: woodfuels usually do not have a price; but: millions of people in urban areas have no access to biofuels).
- Employment of small-scale technologies consistent with low levels of demand.
- Mobilisation of financial resources within the developing countries themselves.
- Improved opportunities to use microcredit mechanisms for the financing of small-scale end-users.
- Education, training and awareness building of all parties concerned, from end-user to political decision maker.
- Dissemination of technologies with a close awareness of end-user needs and preferences (instead of offering a solution before looking for the problem).
- Introduction and development of technology in a manner progressing from small to large scale.

Desirable future

This section, which is closely related to the one above is an attempt by the participants to look at the potential benefits of increased use of wood as an energy source in the future:

- Reduced emissions incl. greenhouse gas emissions from fossil fuel replacements.
- Increased C-sequestration through reforestation, tree plantations, etc.
- Recognition of potentials of multiple use of biomass.
- Integration of biomass energy in economic activities in rural areas leading to poverty alleviation.
- Prominence of socio-economic objectives over environmental objectives to motivate future biomass energy actions in developing countries.

Recommendation

Initiate a global partnership incl. the private sector in order to overcome the present situation where the technology is available in the industrialised world and the need is present in developing

countries. This partnership should to begin with be based on three principles:
1. the promotion of national and local self-reliance
2. the alleviation of poverty through greater economic employment of wood energy resources
3. ensuring environmental harmony provided conditions 1 and 2 are met.

Chairman's address:
K. V. Ramani
Co-ordinator, Energy Programme Asian and Pacific Development Center
P.O. Box 12224, Pesiaran Duta
50770 Kuala Lumpur, Malaysia
e-mail: kramani@pc.jaring.my

Workshop: Energy Systems in Modification Situation, Needs for Action and Recommendations in Industrialised Countries

Chairman: Prof. Dr. R. F. Hüttl, Chair of Soil Protection and Recultivation, Technical University of Brandenburg, Cottbus, Germany

The objective of the 1st forum within the series "Forests in Focus" on "Forests and Energy" was to synthesise the current knowledge regarding the state of the art of technologies for the energetic utilisation of wood and of the potential contribution that forests, wood products and biomass from landscape preservation can make towards future energy supply.

During the conference 120 experts from 23 nations presented different approaches and socio-economic conditions for the energetic use of wood, discussed existing fields of conflict and obstacles with regard to the establishment of utilisation of woodfuels as a renewable energy source as an alternative energy carrier besides fossil, i.e. finite energy sources, and other renewable energy sources such as water, wind and solar power. On the basis of this status quo and deficit analyses proposals were elaborated how to overcome the existing legal and political impediments, and how to optimise both the supply systems and transformation technologies.

Wood is a largely CO_2-neutral energy resource. The CO_2 released during combustion and gasification is taken up from the atmosphere and stored in the biomass through the photosynthetic process. During thermal utilisation only the corresponding quantities of CO_2 are released. In this respect the intensified utilisation of wood for energy purposes not only makes a contribution to the conservation of fossil, i.e. finite resources, but in addition facilitates a widely desired reduction of the CO_2 output into the atmosphere. However, it must be considered that a 50 % reduction of the actual CO_2 output in the Federal Republic of Germany due to the utilisation of woodfuels would mean that approx. 40 million hectares of land would be needed for the generation of fast growing tree species on energy plantations. At present the Federal Republic has a forest area of approx. 11 million hectares, which clearly shows that an energy supply based only on woodfuels is little realistic. In view of the advantageous effects mentioned (conservation of resources, CO_2 output reduction) the experts involved were in consensus on the fact that the generation and utilisation of wood and secondary wood products may have a tremendously positive socio-cultural and economic impact especially in rural areas by favouring the establishment of autonomous decentralised energy supply structures for the generation of both heat and electric power. In addition, a decentralised energy supply system may have positive effects on the employment, and may contribute to an increase of the real net product, since costs for the procuring of energy from external sources can be minimised, and, thus, the purchasing power would remain in the region. In addition, if the energy supply from the utilisation of biomass is increasingly regionalised, a reduction of line attenuations and an all in all lower energy demand can be expected.

In the forum representatives of governmental and non-governmental organisations from economy, politics, science and lobbies agreed on the fact that the acceptance and, thus, the prospects of establishing the energetic utilisation of wood can only succeed if the utilisation is considered reasonable from a technical, social, ecological and, in the long run, also an economic point of view. The current situation in the industrialised countries (especially Western and Northern Europe as well as North America) can be described as follows:

Based on the present growing stock and on corresponding increments, the potential of wood that can be used in a technically sound and ecologically acceptable way is considerably larger than what is actually used. However, since wood has a comparatively low energy density due to its high water content (fresh wood 50%, after the natural drying process 30%) the transport over long distances is inefficient and costly. Measures to reduce the volume such as drying, compacting through pelletising or wood liquefaction, mean a considerable energy input in the course of the refining and treatment of the fuel which impairs the energetic balance and causes tremendous additional costs.

Large forest wood areas are also available in countries of Northern Europe and North America. For example, in Germany currently a large potential of usable wood exists if thinning of stands as required by the principles of a sustainable forest management are carried out regularly and if the annual increment of the growing wood stock is used accordingly. In this respect Germany's annual timber production of approx. 35 million m^3 could be considerably increased up to 70 million m^3

without violating the principle of forest sustainability. On the contrary, the excessively accumulated wood stock as well as the regionally increased number of over-aged forest stands counteract the principles of sustainability. In addition to that, forestry may offer a further potential by an enhanced cultivation of fast-growing tree species in so-called short-rotation plantations or as part of agroforestry (e. g. alley-cropping) systems. Regarding the consequences of the European agricultural policy with currently over 1.6 million hectares of agricultural set-aside areas, this kind of land use aiming at a high biofuel productivity for energetic i. e. thermal utilisation will become increasingly important in the future.

The currently used energy potential of wood is primarily based on the utilisation of forest wood, wood residues and waste wood from trade and industry. The corresponding share of already used wood (e. g. furniture, packaging, forms) as well as sulphite "black" liquor from the paper industry currently accounts for approx. 150 PJ per year. The total wood potential available from these areas as well as from short-rotation high production stands and biomass derived from landscape preservation measures exceeds by far the previously used proportion and amounts to approx. 430–495 PJ per year. This results in an additional amount of wood of 280–345 PJ per year. In view of the current recycling economy further potentials result from those wood products which were first of all subject to a material real net output during a product life cycle and which, subsequently, are used for thermal transformation purposes in the last step of the real net output. This includes both slightly as well as heavily contaminated wood.

In the Federal Republic of Germany, the proportion of all renewable energies regarding the total energy budget currently amounts to only 2 %; the proportion of energy generated from biomass is considerably lower than 1 %. However, the technically usable potential of biomass (primarily wood) in Europe and the USA in the next 20 years is estimated at 17–25 % of the total energy demand. In the Federal Republic approx. 70 million tonnes of organic dry matter accumulate every year which corresponds to an energy content of 45 million tonnes coal units. From a technical point of view this potential may be used only to a small extent. If one takes into consideration the overall efficiency of the current conversion technologies, the (theoretically and maximally) usable energy potential is reduced to approx. 26 million tonnes coal units per year. The extent to which this potential is actually utilised decisively depends on the economic outcome and the energetic efficiency (energy losses as well as costs of transport, refining and storing etc.) of the biomass. On this basis, the German Environmental Advisory Council (SRU) assesses the utilisable potential of residual and waste biomass as approx. 6 million tonnes coal units per year and assumes a biomass proportion of 10 % regarding the annual total energy demand in the Federal Republic.

Currently, mainly two technical approaches in energy conversion are being applied. The technology for the *combustion* of wood which primarily serves for the generation and supply of heat is actually the most important one. Power plants based on wood combustion use chips provided by different types of hoes. The combustion takes place in a pre-furnace or directly in the main combustion chamber. In practice, the energy output of wood chip combustion plants ranges from 15 kW to 40 kW. The energy transformation from wood is mainly generated by stationary combustion devices using steam turbines or steam piston machines. Actually in Germany the combustion of wood in heat (power) plants is mainly based on the utilisation of a mixture of woodfuel components where uncontaminated wood from forests and also residual and waste wood as well as little amounts of contaminated wood are used together.

In practice the following kinds of wood are distinguished: fresh wood from the forest as well as from short-rotation plantations, thinnings and wood residues from the forest, uncontaminated waste wood from the wood processing and handling industry as well as sawmills (e. g. chips, furniture, pallets, etc.). According to its degree of pollution used waste wood is divided into contaminated, polluted and unpolluted wood.

The *gasification* of wood in combination with the gas utilisation in combustion engines is a technical alternative to the combustion technology and, in addition to the supply of heat, also facilitates the generation of electricity with a high efficiency. However, for this technology only few big plants have been in continuous operation until now (e. g. in Sweden). As far as smaller wood gasification plants are concerned there is a tremendous need for research and development with regard to very promising approaches in order to find solutions that work in practice. One of the biggest difficulties results from the generally high tar contents in the wood and subsequently in the gas flow which makes engines susceptible to faults and work less reliably.

The composition and constituents of the fuel wood decisively determine the quantity, kind and composition of the gaseous and solid emissions which occur during thermal utilisation. Gaseous emissions are only of importance when polluted and contaminated fuels are utilised. Solid residual materials accumulate in the form of ashes and slags with the accumulating quantities varying between 0.5 to 10 % depending on the kind of wood. In the context of the targeted recycling economy special attention has to be paid to the chemical composition of the residuals for application purposes. If the ashes are almost free of contamination (e. g. heavy metals), their re-circulation through fertilisation is a desirable opportunity to re-use the combustion residuals instead of disposing them without any further real net output. If a re-circulation of nutrient rich ashes can be guaranteed to the production sites this may help to minimise the nutrient export and, subsequently, the fertilisation requirements. With special regard to the decontamination of chromium VI, supposed to accumulate during the combustion process, technical solutions are already available.

The energy companies present in the forum, namely *Shell International Renewables*, *PreussenElektra* and *Sydkraft*, unanimously assume a considerably higher proportion of biomass (especially wood) for the energy supply in the future. They presented different concepts for the promotion and intensified utilisation of renewable energy sources. *PreussenElektra AG* considers the actual competitive situation for biomass as the best among the renewable energies. From the technical point of view, biomass may be integrated into existing supply-systems without greater problems. Additionally, biomass, in contrast to windpower and photovoltaic, may be stored and thus contributes to an ensured provision of capacity. To date, the energetical use is already economically viable in many cases, especially when energetical use of waste wood and organic residues takes over the task of refuse removal. From the point of view of the plant operator it is advisable to install innovative technology as simple as possible and adapted to the supply task in question. Following *PreussenElektra*, the future policy supporting renewable energies inclusive biomass has to take into consideration changed framework conditions at the energy markets. In order to avoid competition distortions in a liberalised energy market and to promote the use of biomass, it is indispensable to allot the resulting additional costs among a broad as possible public. In the opinion of the enterprise, the existing law of energy input into the national grid in Germany is not suited to sustainably support the promotion of renewable energies. Since use of biomass is mainly restricted to transformation into heat energy and power-heat combinations for power generation are actually of minor importance, the energetical use of biomass is currently only insufficiently supported by existing promotion tools (e.g. the German law).

In this context, *Shell International Renewables* predicts a considerable increase of the share of renewable energies from the years 2020 to 2030 onwards. According to *Shell International Renewables*, the future share of biomass within the renewable energies will amount for 50 to 60 % of the energy increase. Regarding Europe and the US the technical potential for meeting the energy demand using biomass will be approx. 17–25 % in the next 20 years. This points out the necessity of a structural adaptation of the agricultural and forestry sectors for developing new sustainable as well as environmentally and economically sound land use systems, which should be based on a profound scientific basis. In this context *Shell International Renewables* presented a scientifically accompanied programme to promote renewable energy sources, which is oriented at the optimisation of technologies and the avoidance of undesirable consequences for the environment and is funded by an investment volume of $ 500 million.

Already today, in Austria for example, 10–15 % of the energy is generated on the basis of biomass. But countries such as Austria, Denmark and Sweden, in which the energy supply from biofuels has already been established on the market, have created an appropriate political framework in order to increase the competitiveness of renewable energies in comparison to fossil fuels. In this context, among other things, CO_2 or energy taxes, the funding/subsidising of investment costs for plant construction, the reduction or remission of the value added tax on revenues from wood selling or a direct taxation of fossil energy sources (oil, coal, gas) should be mentioned.

Considering the existing energy-economic structures in the Federal Republic of Germany, the political framework for a more enhanced use of bioenergy are less favourable, since from a purely economic point of view the utilisation of biofuels is currently hardly competitive. Only by using a high proportion of subsidised residual and waste wood, energy prices may drop to the level of the current market price.

In summary the requirement for politics was formulated to clearly declare the support for the establishment and promotion of energy supply systems based on biofuels. Politics has to decide if and how it wants to support the utilisation of renewable energy sources in order to improve their competitiveness. Only on this basis the share of renewable energy sources regarding the total energy demand can be increased. The potentials of continuously growing fuels exist also in Germany and on international markets there is a large variety of technical implementation already available. However, economical and partly legal framework conditions are still to be developed. In this context, an extensive research and development programme for the development and optimisation of energy supply and land use systems for the production and provision of wood is required in order to be able to tackle and solve questions of economy, technology and ecology in an interdisciplinary way.

Chairman's address

Prof. Dr. R. F. Hüttl
Chair of Soil Protection and Recultivation
Technical University of Brandenburg
P.O. Box 10 13 44
D-03013 Cottbus, Germany
e-mail: huettl@tu-cottbus.de

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Grußwort des Veranstalters

Johann Schreiner

Sehr geehrte Damen und Herren,
im Namen der Veranstalter darf ich Ihnen ein herzliches Willkommen aussprechen. Ich begrüße die

- ausländischen Gäste aus 23 Staaten,
- Abgeordneten des Deutschen Bundestages und des Niedersächsischen Landtages,
- Repräsentantinnen Repräsentanten der Niedersächsischen Kommunen,
- Repräsentantin des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit, sowie den Repräsentanten des Niedersächsischen Ministeriums für Ernährung, Landwirtschaft und Forsten,
- Vertreterinnen und Vertreter der Energiewirtschaft, der Forst- und Holzwirtschaft, sowie der Umweltverbände,
- Redner der Eröffnungsvorträge, die Leiter der Workshops, die Statementgeber der Workshops, die Redner der Heid' Park Corner, wie wir unseren aktuellen Informationsmarkt genannt haben, die Aussteller aus Industrie und Wissenschaft,
- Vertreterinnen und Vertreter von Presse und Rundfunk,
- Förderer dieser Tagung, die deren Durchführung in diesem Umfang erst möglich gemacht haben.

Nicht zuletzt gilt mein Gruß Ihnen allen, die sich für eine Teilnahme entschieden haben.

Ich bin sicher, daß wir interessante und gewinnbringende vier Tage vor uns haben. Gewinnbringend für jeden von uns persönlich, aber auch für die Wälder dieser Erde, und damit letztendlich wieder für den Menschen, der auf diese Wälder angewiesen ist.

Nicht umsonst hat sich die Konferenz für Umwelt und Entwicklung der Vereinten Nationen in Rio de Janeiro im Juni 1992 gleich in zwei Dokumenten den Wäldern dieser Erde gewidmet. Sie dokumentiert damit deren herausragende Bedeutung sowohl für die wirtschaftliche Entwicklung, als auch für alle Lebensformen.

Sie tut dies ganz besonders in der sog. Walderklärung von Rio, oder, wie sie offiziell heißt, den „Rahmenprinzipien für die Bewirtschaftung, Erhaltung und nachhaltige Entwicklung von Wäldern". Deutlichere und tiefgreifende Forderungen finden sich in der Agenda 21, dem Handlungsprogramm der Weltgemeinschaft für das 21. Jahrhundert. Sie widmet der Bekämpfung der Entwaldung ein eigenes Kapitel. Die Agenda 21 zeigt in diesem Kapitel Handlungsgrundlagen, Ziele, Maßnahmen und Instrumente für vier Programmbereiche auf:

1. Aufrechterhaltung der vielfältigen Rolle und Funktionen aller Waldarten, Waldgebiete und Gehölzflächen,
2. Verbesserung des Schutzes, der nachhaltigen Bewirtschaftung und der Erhaltung aller Wälder und Begrünung degradierter Flächen durch Wiederherstellung von Wäldern, Aufforstungs-, Wiederaufforstungs- und andere Sanierungsmaßnahmen,
3. Förderung einer effizienten Nutzung und Zustandsbewertung zur Wiederherstellung der vollen Wertschätzung der von Wäldern, Waldgebieten und Gehölzflächen erzielten Güter und Dienstleistungen,
4. Schaffung und/oder die Stärkung vorhandener Kapazitäten für die Planung, die Zustandsbewertung und systematische Beobachtung der Wälder sowie damit zusammenhängender Programme, Projekte und Aktivitäten einschließlich des gewerbsmäßigen Handels der Weiterverarbeitung.

Diese Vielfalt an gesellschaftlicher Verflechtung der Wälder aufzuzeigen, wissenschaftlich zu durchdringen und daraus Handlungsanleitungen zu entwickeln, ist das vornehmste Ziel der FachForen Wald. Die FachForen Wald sind als internationale und interdisziplinäre Tagungsreihe von der EXPO 2000 Hannover als dezentrales Projekt registriert. Sie konkretisieren das Motto der EXPO 2000 Hannover „Mensch – Natur – Technik" für den Wald. Ein Motto, das den Grundprinzipien der Agenda 21 entspricht, nämlich aufzubauen auf

- sozialer Gerechtigkeit,
- dauerhafter Umweltverträglichkeit
- wirtschaftlicher Tragfähigkeit

und der Beteiligung der wichtigen gesellschaftlichen Gruppen an Entscheidungsprozessen.

Die FachForen Wald sollen durch ihren operationalen Ansatz die laufenden internationalen, politischen und wissenschaftlichen Tagungen im Waldbereich ergänzen und unterstützen. Sie sollen auch die Brücke schlagen zur breiten Öffentlichkeit und zur Umsetzung auf lokaler Ebene. Wir, d.h. die Veranstalter, haben sechs Themen als besonders brisant und dringlich identifiziert, Themen, denen bis zum Jahr 2000 sechs Veranstaltungen gewidmet werden sollen:

1. „Energiepotential Wald", das den Beitrag der Wälder zur zukünftigen Energieversorgung untersuchen soll,
2. „Biodiversität – Schätze in den Wäldern der Erde", das sich der Waldentwicklung im Zusammenhang mit biologischer Vielfalt widmen wird (Juli 1998),
3. „Rohstoffquelle Wald", das die verschiedensten Facetten nachhaltiger Waldnutzung behandeln soll (Mai 1999),
4. „Wald und Atmosphäre, Wasser, Boden", das die Einflüsse der Waldbehandlung auf Klimaänderung, Bodendegradation und Trinkwasserverknappung aufdecken soll (Juli 1999),
5. „Wald und Gesellschaft", das in einer Art Zusammenschau der in den vorigen FachForen erzielten Ergebnisse diskutieren soll, wie die Gesellschaft ihre Verantwortung für die Wälder in Zukunft wahrnehmen können (November 1999),
6. „Nachhaltigkeit in Zeit und Raum" in Kooperation mit ProSilva, Stichwort Waldbewirtschaftung (Juni 2000)

Die Ergebnisse dieser FachForen sollen dann im Jahr 2000 im Rahmen der EXPO zusammengefügt werden.

Heute haben wir zusammengefunden zum FachForum „Energiepotential Wald". Hintergrund ist dabei die zunehmend drängender werdende Forderung nach einem vermehrten Einsatz regenerativer Energiequellen. In Bezug auf Holz als CO_2-neutraler Energiequelle müssen dazu Fragen beantwortet werden wie:

- Wie groß ist überhaupt der potentielle Beitrag, den Wälder (in den verschiedenen Regionen dieser Erde) zur zukünftigen Energieversorgung leisten können?
- Welches sind die ökologischen, sozioökonomischen, sozio-kulturellen und technischen Bedingungen, die den Ein-

satz von Holz zur energetischen Nutzung beeinflussen?

Wir werden dazu heute vier Übersichtsreferate zur Energieversorgung im 21. Jahrhundert hören. Ich begrüße dazu Herrn van Oorsouw, Shell International Renewables, London, Herrn Dr. Trossero, FAO, Rom, Herrn Bourdaire, Internationale Energieagentur, Paris, und Herrn Hatje, PreussenElektra AG, Hannover. Morgen und übermorgen werden wir uns in zwei Workshops aufteilen, in denen die genannten Fragen von Vertreterinnen und Vertretern einerseits aus den Entwicklungsländern, andererseits aus Industriestaaten diskutiert und beantwortet werden sollen. Die Workshops werden geleitet von Herrn Ramani, Malaysia, und Herrn Professor Hüttl, Cottbus. In der sog. Heid' Park Corner werden ergänzend Praxisbeispiele und aktuelle Forschungsergebnisse präsentiert.

Der Austausch der Zwischenergebnisse aus den Workshops erfolgt in Plenarsitzungen, die von Frau Barsk-Rundquist, Vereinte Nationen, New York, geleitet werden.

Ich wünsche uns allen nochmals interessante, gewinnbringende Tage und einen angenehmen Aufenthalt in Schneverdingen.

Author's address

Johann Schreiner
Direktor und Professor
Alfred-Toepfer-Akademie für Naturschutz
Hof Möhr
D-29640 Schneverdingen
e-mail: nna@nna.de

WeltForum Wald – Eröffnung

Klaus Dieter Forstmann

Die Veranstalter dieses Fachforums – das sind, neben dem Partner Alfred Toepfer Akademie für Naturschutz, die Niedersächsische Forstwirtschaft, die Schutzgemeinschaft Deutscher Wald und der Landkreis Soltau-Fallingbostel mit seinem EXPO-Förderverein „Waldforum 2000", als dessen Vorsitzender ich zu Ihnen spreche – diese Veranstalter also freuen sich sehr, daß nach monatelangen, intensiven Vorbereitungsarbeiten soeben der Startschuß für die erste Veranstaltung in unserer Fachforen-Reihe zum Thema Wald gefallen ist.

Ich will gar nicht verhehlen, daß ich diese Feststellung nicht ohne ein Quentchen Stolz treffe. Wir haben es immerhin geschafft, weitgehend in privater, ehrenamtlicher Initiative, eine Vielzahl hochrangiger Persönlichkeiten für das Projekt zu begeistern und eine lange Reihe von angesehenen Wissenschaftlern an einem Ort zusammenzuführen, den wahrscheinlich kaum einer von ihnen kannte und der im wesentlichen Arbeit und keine kulturellen oder politischen Höhepunkte verspricht.

Für uns, die Veranstalter, ist es deshalb ein herzliches Bedürfnis, Ihnen, meine Damen und Herren, gleich zu Anfang sehr herzlich dafür zu danken, daß Sie unser Vorhaben so aufgeschlossen und engagiert begleiten. Sie haben es vielleicht bereits bemerkt und werden es hoffentlich während der ganzen Veranstaltung spüren: dieser Dank ist keine Routine, wir wollen für Sie da sein, vielleicht nicht immer höchsten Ansprüchen genügend, aber dafür desto engagierter.

Ich darf Sie zugleich im Auftrag des Landrats sehr herzlich im Landkreis Soltau-Fallingbostel begrüßen. Der Landkreis stellt den Wald in den Mittelpunkt seines Projekts, das er für die Weltausstellung im Jahre 2000 in Hannover vorbereitet. Der Name „Weltforum Wald", unter dem unsere EXPO-Aktivitäten als eines der ersten dezentralen Projekte dieser Weltausstellung offiziell registriert ist, ist also Programm. Wir ordnen uns sehr bewußt ein in das Motto der Weltausstellung „Mensch, Natur, Technik" und wollen zugleich einen Beitrag leisten zur Umsetzung der Klimakonvention von Rio, indem wir für den Besucher der Weltausstellung Beispiele vorbereiten für eine sinnvolle Nutzung und für den Agenda-konformen Schutz von Wald und Atmosphäre.

Entsprechend werden Sie im Jahr 2000, neben anderen, Beispiele vorfinden für

- richtungsweisendes Bauen mit Holz in einer mit neuen Techniken errichteten, ausschließlich aus Holz erstellten Kirche hier in Schneverdingen;
- für die Dekontaminierung militärisch verseuchter Böden und deren anschließende Aufforstung in der Nähe der Stadt Munster etwa 25 km östlich von hier;
- für den artgerechten Schutz von tropischen Vögeln in ihrer vertrauten Tropenwaldumgebung im größten Vogelpark der Welt etwas südlich von hier im Landkreis. Natürlich wollen wir dabei auch in geeigneter Form auf den Schutz der Wälder hinweisen;
- für eine Symbiose von Kunst und Landschaft;
- für die Nutzung der Waldressourcen durch naturnahe Waldwirtschaft;
- in einem Wald-Erlebniszentrum, und vielem anderen mehr.

Schwerpunktthema unseres EXPO-Projekts sind die „FachForen Wald", mit denen wir heute beginnen. Über die verschiedenen Themen und Ziele hat Sie Herr Prof. Schreiner soeben informiert.

Ich will nur einige grundsätzliche Bemerkungen anfügen: es geht uns nicht darum, der Vielzahl internationaler Kongresse einen weiteren hinzuzufügen. Wir wollen vor allem keine weiteren Deklamationen zum Schutz der Wälder. Wir wollen Fachforen, in denen wissenschaftlich gearbeitet wird, die eine Plattform für den Erfahrungsaustausch bilden, wo Gegenpositionen angenähert, wo zwischen Wissenschaft und praktischer Erfahrung hart gerungen wird. Wir wollen praktikable Lösungen erarbeiten, und das heißt aus unserer Sicht: nicht nur die ohne Zweifel vorhandenen Probleme des Waldes diskutieren, sondern nach Wegen suchen, wie diese Probleme Stück für Stück in Chancen verwandelt werden können. Und für solche Problemlösungen wollen wir mit Ihrer Unterstützung, meine Damen und Herren, Beispiele errichten, die die Besucher der Weltausstellung im Jahre 2000 im Landkreis Soltau-Fallingbostel besichtigen können, und mit deren Hilfe für die Öffentlichkeit Beispiele dafür angeboten werden, daß der Wald doch Zukunft hat.

Ich habe in diesem Zusammenhang einen Traum, meine Damen und Herren. Ich würde mir wünschen, daß wir mit Ihrer Hilfe in die Lage versetzt werden, die ganze Kette der Nutzung von Schwachholz oder Biomasse zur Energieerzeugung anhand von Beispielen nachweisen zu können; das heißt nicht nur die ökologisch einwandfreie und betriebswirtschaftlich erfolgreich umsetzbare Verbrennungstechnik, sondern auch die Logistik zur Sammlung und Vermarktung des Holzes, und vielleicht noch die notwendigen Hinweise auf Mischtechniken. Und das ganze so vertrauenswürdig und einleuchtend dargestellt, daß wir damit „Beispiele zum Anfassen" für die Besucher der EXPO und für die Bevölkerung in dieser Region erhalten, die zu überzeugen wissen – natürlich nicht als singuläre Lösung aller energetischen Zukunftsfragen, aber immerhin vielleicht als Beitrag zu einer ökologisch sinnvollen und wirtschaftlich vertretbaren Teillösung. Nur mit „Beispielen zum Anfassen", die notabene auch zum Photographieren und Filmen geeignet sind, werden wir im übrigen auch die Nachricht über die Medien transportieren können. Das ist mein Traum, wie gesagt. Es ist meine große Hoffnung, meine Damen und Herren, daß Sie uns helfen, diesen Traum zu verwirklichen.

Wir wissen, daß wir uns mit dieser Zielsetzung einiges vorgenommen haben. Andererseits ist gerade die Lüneburger Heide und damit dieser Landkreis prädestiniert durch seine Geschichte, Beispiele im Sinne der Klimakonvention zu liefern. Es ist heute kaum noch bekannt und noch weniger sichtbar, daß die Lüneburger Heide noch vor 100 Jahren als Folge der Plünderung der Natur während des Mittelalters und durch exzessive Salzgewinnung bedingt arides Land war, praktisch unbewaldet, mit Sandstürmen und ohne Fauna – ein Landstrich also ähnlich denen, die in der Klimakonvention als bedauerliche Entwicklungsbeispiele angeführt werden. Hier in der Lüneburger Heide ist in sinnvoller Kombination von staatlichen und privaten Initiativen ab Mitte des vorigen Jahrhunderts gegengesteuert worden – ich denke mit einigem Erfolg. Diese Region ist also bereits aus ihrer Geschichte heraus Beispiel für das, auf was wir uns heute wieder besinnen. Um so mehr kann diese Region sich berufen fühlen, für die Weltausstellung am Anfang des nächsten Jahrtausends Beispiele dafür zu liefern, was wir in Zukunft für den Wald tun sollten. Helfen Sie uns dabei, meine Damen und Herren, diesen Plan so gut es geht in die Tat umzusetzen.

Warum engagiert sich der Landkreis Soltau-Fallingbostel so intensiv für den Wald und seine sinnvolle Nutzung? Ich will hier gerne zugestehen, daß es nicht ausschließlich altruistische Gründe sind. Zum einen ist die Land- und Forstwirtschaft ein wichtiger Erwerbszweig. Zum anderen muß der Landkreis strukturpolitisch daran interessiert sein, seine wichtigste Ressource, die Schönheit und weitgehende Unberührtheit seiner Natur, als Standortfaktor stärker zu nutzen. Denn andere traditionell starke Erwerbszweige nehmen an Bedeutung eher ab. Und für die stärkere Betonung des Fremdenverkehrs oder des Wohnstandorts Soltau-Fallingbostel zwischen den Ballungsgebieten Hamburg, Bremen und Hannover spielt eine intakte Natur nun einmal eine überragende Rolle.

Hinzu kommt, daß die Entwicklung der Kommunikationstechnik dafür sorgen kann, daß sich auch Arbeitsplätze aus den Ballungsgebieten eher aufs Land orientieren. Auch dafür spielt das Naturambiente eine wichtige Rolle.

Und natürlich sind Tagungsstätten in reizvoller Landschaft, außerhalb des Lärms der Großstädte, gut geeignet gerade für wissenschaftlich orientierte Tagungen und Kongresse. Wir hoffen deshalb, daß Sie sich bei uns im Landkreis Soltau-Fallingbostel sehr wohl fühlen, und daß Sie für das nächste Fachforum Anfang Juli wieder zu uns kommen, vielleicht sogar damit einige Tage Sommerurlaub verbinden.

Die Veranstalter dieses Fachforums und der Landkreis Soltau-Fallingbostel danken Ihnen, meine Damen und Herren, noch einmal sehr herzlich, daß Sie nach hier gekommen sind. Ich wünsche der Tagung und dem Fachforum einen erfolgreichen Verlauf, mit umsetzbaren Ergebnissen für die Zukunft des Waldes und damit vielleicht auch der Erfüllung meines Traums im Vorfeld der Weltausstellung.

Anschrift des Verfassers

Klaus-D. Forstmann
Vorsitzender „Waldforum 2000 e.V."
Poststraße 14
D-29699 Bomlitz

Grußwort

Frau Ministerialdirigentin Dr. Barbara Schuster

Ich darf Ihnen die herzlichen Grüße von Frau Bundesumweltministerin Merkel übermitteln, die heute leider wegen anderer Verpflichtungen verhindert ist. Sie hat, wie Sie wissen, die Schirmherrschaft über diese Veranstaltung übernommen und damit ihr besonderes Interesse an der Thematik deutlich gemacht.

Hat doch das Thema Wald für die Umweltpolitik vielfältige interessante Aspekte und Anknüpfungspunkte. Ich nenne nur die Stichworte Naturschutz, biologische Vielfalt, nachhaltige Nutzung, Rekultivierung, Energieversorgung, CO_2-Senken. Das Thema Wald – wir wissen das besonders gut aus der internationalen und weltweiten Diskussion – steht damit auch mitten im Spannungsfeld umweltpolitischer, forstpolitischer, energiepolitischer und entwicklungspolitischer Interessen.
Ich möchte heute – wie es das Thema Ihrer Veranstaltung nahelegt – zunächst zu einigen aktuellen Fragen der Energiepolitik in Deutschland Stellung nehmen.

Sowohl für den Wirtschaftsstandort als auch für den Umweltstandort Deutschland brauchen wir eine Energieversorgung, die sicher, preiswert und umweltverträglich ist. Mit dem neuen Energiewirtschaftsrecht, das sich in der abschließenden parlamentarischen Beratung befindet, werden wichtige Weichenstellungen für die Energiepolitik des nächsten Jahrhunderts, zumindest der nächsten Jahrzehnte vorgenommen. Der bislang weitgehend abgeschottete Energiemarkt wird künftig dem Wettbewerb zugänglich gemacht. Verkrustete Monopolstrukturen wird es in diesem Bereich nicht mehr geben. Wettbewerb wird insbesondere über Durchleitung, in Ausnahmefällen auch über direkten Leitungsbau stattfinden. Unter dem Strich wird dies zum Vorteil aller Beteiligten sein, insbesondere dem der Kunden.

Zum Stand der Energierechtsreform ist folgendes zu sagen: Ende November hat der Deutsche Bundestag mit der Mehrheit der Koalitionsfraktionen das Gesetz zur Reform des Energiewirtschaftsrechts beschlossen. Erwartungsgemäß hat der Bundesrat im Dezember den Vermittlungsausschuß angerufen. Dieser berät zur Zeit das Gesetzesvorhaben. In seiner derzeitigen Fassung ist es nicht zustimmungsbedürftig. Ein möglicher Einspruch des Bundesrates könnte also im Bundestag mit Kanzlermehrheit zurückgewiesen werden. Das Gesetz kann daher noch im Frühjahr 1998 in Kraft treten.

Mit der Energierechtsnovelle wird auch das Stromeinspeisungsgesetz geändert, das in Deutschland seit dem Jahr 1990 in Kraft ist. Es regelt die Abnahme erneuerbarer Energien durch die Energieversorger. In der vorgesehenen Neufassung werden Verbesserungen für die Nutzung erneuerbarer Energien erreicht. So ist eine Einbeziehung der gesamten Biomasse in den Geltungsbereich des Gesetzes vorgesehen. Dies ist ein Schritt zur besseren Erschließung dieses vielversprechenden Potentials erneuerbarer Energien. Es entfallen die oft langwierigen und komplizierten Fragen insbesondere bei der Kofermentation. Die energetische Nutzung von Holz wird attraktiv. Ich rechne damit, daß gerade der Bereich der Biomasse eine ähnlich positive Entwicklung einsetzt, wie wir sie in den letzten Jahren bei der Windenergie zu verzeichnen hatten. Das ist auch von der Bundesregierung gewünscht: Schließlich ist die Nutzung von Biomasse witterungsunabhängig. Sie kann zu jeder gewünschten Tages- und Nachtzeit erfolgen. Dies ist ein entscheidender Vorteil verglichen mit der Windkraft und der Photovoltaik.

Im Zusammenhang mit den Änderungen im Stromeinspeisungsgesetz wird auch eindeutig klargestellt, daß der Netzbetreiber der Verpflichtete nach dem Gesetz ist. Damit sind die Regelungen des Stromeinspeisungsgesetzes mit denen der übrigen Energiewirtschaftsreform kompatibel.

Der Energiesektor ist aus zwei Gründen für die Umweltpolitik ein ganz zentrales Politikfeld: Zum ersten werden zur Enegiegewinnung große Mengen endlicher Vorräte an Rohstoffen verbraucht. Auf die Endlichkeit dieser Ressourcen muß eine zukunftsorientierte Energiepolitik Rücksicht nehmen. Zum zweiten trägt die Energieversorgung weltweit durch Verbrennung fossiler Energieträger zu mehr als 50 % zum globalen Treibhauseffekt bei.

Gerade Deutschland als führender Industrienation kommt eine besondere Verantwortung zu. Die deutsche Energiepolitik muß darauf ausgerichtet sein, dauerhaft umweltverträglich zu sein. Dann können wir auch glaubhaft auf europäischer und internationaler Ebene verstärkte Bemühungen um den Schutz des globalen Klimas einfordern.

Wie schwierig dies ist, hat die 3. Vertragsstaatenkonferenz der Klimarahmenkonvention in Kyoto im letzten Monat gezeigt. Die Interessen der einzelnen Staaten sind sehr verschieden. Trotzdem konnte ein Klimaprotokoll verabschiedet werden. Dies ist ein großer Fortschritt. Denn erstmalig ist eine Reduktion von Treibhausgasen völkerrechtlich festgeschrieben worden. Zwischen 2008 und 2012 werden die Industriestaaten ihre Emissionen um mindestens 5 % reduzieren (bezogen auf 1990).

Dies ist zugegebenermaßen weniger, als wir gemeinsam mit unseren Partnern in der Europäischen Union gefordert haben. Aber auch Kyoto ist nur eine Zwischenstation für den globalen Klimaschutz. Die Bemühungen um verstärkte weltweite Anstrengungen gehen weiter.

In Kyoto wurde auch die Bedeutung der Wälder als CO_2-Senken hervorgehoben. Wälder bieten die Möglichkeit, CO_2 zu speichern. Inwiefern diese Senken bei den Verpflichtungen zur Reduktion einbezogen werden, ist noch umstritten. Die Klärung dieser Frage einschließlich der zahlreichen methodischen Probleme wird eine der Hauptaufgaben sein, die bis zur nächsten Klimakonferenz im November 1998 in Buenos Aires zu erledigen ist.

Deutschland hat das ehrgeizige Ziel, bis zum Jahr 2005 die CO_2-Emissionen um 25 % gegenüber 1990 zu senken. Dazu hat die Bundesregierung ein umfassendes Klimaschutzprogramm auf den Weg gebracht, das – im internationalen Maßstab betrachtet – das ehrgeizigste seiner Art ist. Es enthält über 150 Einzelmaßnahmen, von ordnungsrechtlichen Anforderungen über wirtschaftliche Anreize bis hin zu flankierenden Maßnahmen. Erfolge sind sichtbar: Eine Entkopplung von Wirtschaftswachstum und CO_2-Ausstoß ist erfolgt. So sind die CO_2-Emissionen bezogen auf das Bruttoinlandprodukt seit 1990 um 19 % gesunken. Absolut sind die CO_2-Emissionen seit 1990 um über 10 % zurückgegangen. Um das CO_2-Ziel zu erreichen, hat die Bundesregierung im November 1997 weitere Maßnahmen beschlossen. Dazu zählt auch die verstärkte Förderung erneuerbarer Energien wie der Biomasse. Die Beibehaltung und Verbesserung des Stromeinspeisungsgesetzes, die ich bereits erwähnt habe, ist hierfür eine wichtige Maßnahme.

Das Jahr 1998 ist in Deutschland gekennzeichnet durch eine Bundestagswahl und mehrere Landtagswahlen (in den Bundesländern Niedersachsen, Sachsen-Anhalt, Bayern und Mecklenburg-Vorpommern). Es ist nicht verwunderlich, daß die politische Diskussion in diesen Monaten sich ganz wesentlich auf solche Themen richtet, die unmittelbar und kurzfristig die Menschen beschäftigen und zum Teil auch ängstigen. Das Thema Umweltschutz – lieber spreche ich von nachhaltiger, umweltgerechter Entwicklung – hat dabei einen schweren Stand: Die drängenden Probleme, die auf dem Arbeitsmarkt, in den Sozialversicherungssystemen oder auch im Bereich der öffentlichen Finanzen gelöst werden müssen, sind für die Menschen greifbarer als das Ozonloch, das Artensterben oder die Gefahr einer sich über Jahrzehnte hinziehenden, allmählichen Erderwärmung.

Um so wichtiger und verantwortungsvoller ist die Aufgabe, den Menschen die existentielle Bedeutung dieser Fragen für ihre Zukunft und die ihrer Kinder deutlich zu machen, nicht zuletzt auch für ihre wirtschaftliche Zukunft.

Das Leitbild der nachhaltigen Entwicklung, zu dem sich auf der Konferenz der Vereinten Nationen für Umwelt und Entwicklung in Rio im Jahr 1992 die Staaten der Welt auf höchster Ebene bekannt haben, trägt der Erkenntnis Rechnung, daß eine langfristig tragfähige Entwicklung auf der Erde nur möglich ist, wenn die ökologischen Rahmenbedingungen und Begrenzungen eingehalten werden.

Wir sind in Deutschland in den letzten Jahren und Jahrzehnten auf diesem Feld ein gutes Stück vorangekommen. Aber wir haben gerade in den letzten Jahrzehnten auch gelernt, daß es einen globalen Zusammenhang gibt, daß die brennenden Umweltprobleme zumeist weltweite sind und nur in weltweiter Anstrengung zu lösen sind.

Das wissen alle Experten und mit Umweltpolitik Befaßten. Ich halte es für eine ganz wichtige Aufgabe, diese Erkenntnis den Bürgern zu vermitteln – konkret und verständlich zu vermitteln; denn nur so können wir erreichen, daß das Thema nachhaltige Entwicklung in den Mittelpunkt auch der aktuellen und persönlichen Interessen der Menschen rückt. Das darf nicht nur in Form von Horrorszenarien geschehen. Es müssen ganz sicher auch erreichte Erfolge gezeigt werden, und es müssen erreichbare Erfolge aufgezeigt werden. Man muß den Menschen auch Mut machen, sich an die Lösung der Probleme zu begeben. Dazu gehört, daß man Chancen, Lösungswege, neue Ansätze vorstellt. Ich denke, Ihre Veranstaltung kann das tun – auf einem ganz wichtigen Feld der nachhaltigen Entwicklung, nämlich der Energieversorgung. Hier kann man exemplarisch deutlich machen, wie der Mensch mit Natur und Technik umgehen kann und umgehen sollte, um Zukunft zu gestalten. Damit wird das Motto der EXPO 2000, so meine ich, besonders treffend illustriert.

In diesem Sinne wünsche ich Ihrer Veranstaltung herzlich einen interessanten Verlauf und gute Ergebnisse.

Anschrift der Verfasserin

Dr. Barbara Schuster
Bundesministerium f. Umwelt,
Naturschutz und Reaktorsicherheit
Bernkasteler Straße 8
D-53175 Bonn

Grußwort des Herrn Ministers Karl-Heinz Funke

übermittelt von Axel Delorme

Meine Damen und Herren Abgeordnete,
meine Damen und Herren,

das Weltforum Wald als von der EXPO-Gesellschaft registriertes dezentrales Projekt vereint zahlreiche Einzelprojekte in der Region. Die Spannweite der Projekte reicht vom Bau einer Holzkirche bis zu wissenschaftlichen FachForen. Das Weltforum Wald macht ernst mit dem Motto der EXPO: Mensch – Natur – Technik.

Dieses Projekt rückt den Wald und seine Bedeutung für das zukunftsfähige Miteinander von Mensch, Natur und Technik in das Licht der Öffentlichkeit. Die FachForen Wald unterstützen diesen Prozeß in besonderem Maße. Als mehrteilige Veranstaltungsreihe focussieren die FachForen jeweils den Blick einer weltweiten Öffentlichkeit auf ein Fachthema. Hier sollten konsensfähige und praxisorientierte Handlungsempfehlungen für den Erhalt sowie die umweltgerechte und nachhaltige Nutzung der Wälder erarbeitet werden.

Den Auftakt einer Reihe von FachForen, die bis ins Jahr 2000 veranstaltet werden, bildet das FachForum „Energiepotential Wald". Ich habe die Ehre, mit meiner Kollegin, der Bundesministerin für Umwelt, Naturschutz und Reaktorsicherheit – Frau Dr. Angela Merkel – als Schirmherr diese Veranstaltung eröffnen und die Grüße des Gastgeberlandes Niedersachsen überbringen zu dürfen.

Das Thema „Energiepotential Wald" ist für mich ein besonderes Anliegen. Ich bin überzeugt von den **ökologischen Vorteilen** des Rohstoffes Holz und seiner Zukunftsfähigkeit als **idealer Rohstoff für die oft geforderte Kreislaufwirtschaft**. Als für die Forstwirtschaft zuständiger Landesminister bin ich natürlich um jeden Festmeter Holz froh, der einen zukunftsfähigen Markt findet.

Ich sehe, wenn ich die derzeitige Konkurrenzfähigkeit des Rohstoffes Holz als *Energieträger* betrachte, allerdings erheblichen Handlungsbedarf, um noch bestehende rechtliche und ökonomische Barrieren aus dem Weg zu räumen.

Doch zunächst zur positiven Seite: Holz ist ein idealer regenerativer Energieträger. Lassen Sie mich Eigenschaften herausstellen, die Holz für die Energiepolitik besonders interessant machen.

Beginnen wir mit dem großen Vorrat der regenerativen Energiequelle Holz in unserem Land. Das Land Niedersachsen hat nach der Bundeswaldinventur 1990 einen Gesamtholzvorrat von ca. 147 Millionen Kubikmeter. Auf Grund der überwiegend jungen Bestände sind ca. 61 Millionen Kubikmeter schwaches Holz (Mittendurchmesser 10 bis 25 cm). Der Privatwald hat daran einen großen Anteil.

Die jungen Waldbestände, in denen dieses schwache Holz steht, müssen gepflegt werden, damit sie als stabilere und strukturreichere Bestände auch zukünftig ein sicherer Bestandteil des Waldökosystems bleiben. Das anfallende Holz wäre sicherlich zu einem erheblichen Anteil für eine energetische Nutzung geeignet und könnte somit einen Beitrag zur Entlastung unserer Umwelt von den Folgen der Verbrennung fossiler Rohstoffe leisten.

Leider müssen wir dennoch feststellen, daß derzeit nur rund 2 % des deutschen Primärenergieverbrauches aus regenerativen Energieträgern, also Wasser, Sonne, Wind und Biomasse gewonnen werden.

Andere Länder sind uns da deutlich voraus. Innerhalb der aufgeführten regenerativen Energieträger hat Holz einen Anteil von 14 % und steht damit hinter Wasserkraft und Klärschlamm auf Platz 3.

Die auf der Hand liegenden Vorteile des Rohstoffes Holz sind:

- Holz ist der bedeutendste erneuerbare Rohstoff.
- Holz hat als Brennstoff unbestritten ökologische Vorteile.
- Es ist ein anerkannt CO_2-*neutraler* Brennstoff.

Vergleichen wir Holz mit Heizöl, so hat 1 Tonne Holz (absolut trocken) den gleichen Heizwert wie eine halbe Tonne Heizöl. Bei Heizöl müssen wir allerdings gegenüber Holz ca. die 12fache Menge an CO_2-Emission in Kauf nehmen.

Holz hat einen extrem *niedrigen Energieaufwand für die Bereitstellung*. Nur 3% des Heizwertes von Holz werden als Energie für die Bereitstellung aufgewandt. Den größten Anteil hat dabei der Transport des Holzes mit ca. zwei Drittel des gesamten Energieaufwandes.

Auf das *geringe Transportrisiko* möchte ich nur nebenbei hinweisen, beim Holztransport sind weder Tankerunglücke noch sonstige Umweltkatastrophen zu befürchten.

Durch das stetig nachwachsende Holzpotential in unseren Wäldern erzeugen wir nachhaltig und naturnah den Energieträger Holz. Wenn Sie so wollen, ist unser Wald die umweltfreundlichste Energiequelle überhaupt. Und was diesen Punkt noch interessanter macht: *Holz steht bereits hier und jetzt zur Verfügung* – wir brauchen keine neuen Anbaumethoden zu entwickeln, um diesen Rohstoff bereitzustellen.

Für die **Kreislaufwirtschaft** hat Holz geradezu Vorzeigecharakter. Bei der Holzverbrennung freigesetzte Emissionen werden von den nachwachsenden Wäldern als Bausteine für die Photosynthese oder als Nährstoffe weitgehend wiederverwertet. Nahezu sämtliche Glieder der Wirtschaftskette kommen aus der Region, ideale Voraussetzungen, um Arbeitsplätze und kleine Unternehmen vor Ort entstehen zu lassen.

Meine Damen und Herren,
in der Praxis haben wir mit größeren Holzheiz- und -energieprojekten in unserem Land bereits erste Erfahrungen sammeln können. Lassen sie mich nur drei Beispiele vorstellen:

Beispiel 1: Holzverbrennung im Braunkohlekraftwerk Buschhaus

Braunkohlekraftwerke sind wegen der Ähnlichkeit der Brennstoffe am ehesten für eine Mitverbrennung von Holz geeignet. Wir haben ein solches Kraftwerk im Lande, auf technisch hohem Niveau wird es in Buschhaus betrieben.

Eine Studie der „PreussenElektra" ergab aus Sicht der Technik, daß jährlich 50000 Tonnen Holz nach entsprechender Aufbereitung und Zerkleinerung mit in die energetische Nutzung gehen könnten. Der dafür erforderliche zusätzliche Aufwand hätte es aber nicht möglich gemacht, für das angelieferte Holz einen auskömmlichen Preis zu zahlen. Das ist der Grund, weshalb PreussenElektra dieses Projekt zunächst nicht umsetzt. Eine Umbewertung der verschiedenen Energieträger, also volkswirtschaftliche oder ökologische Bewertungen, könnten das Projekt aber realisierbar werden lassen.

Beispiel 2: Holzkraftwerk Fallingbostel

Hier war auf Initiative privater Waldbesitzer ein Heizkraftwerk mit einer Kapazität von 25 bis 30 Megawatt geplant worden. Als Abnehmer der Energie stand ein größerer Industriebetrieb bereit. 7,1 Millionen DM standen aus öffentlichen Kassen als Anschubfinanzierung zur Verfügung. Alle zogen an einem Strang – nur im Wettbewerb mit Gas war das Projekt am Ende um 30% teurer.

Beispiel 3: Holzhackschnitzelheizwerk im Emsland, Gemeinde Vrees

Erst im November haben wir dieses Holzheizwerk in Vrees eingeweiht. Wir konnten ein technisch ausgereiftes Demonstrationsprojekt in Betrieb nehmen und werden immerhin 85 Wohneinheiten mit dem nachwachsenden Rohstoff Holz beheizen. Dabei wird Schwachholz aus den umliegenden Wäldern, Recyclingholz aus der Altholzaufbereitung und bei Bedarf auch Restholz aus der Sägeindustrie zum Einsatz kommen.

Das Werk in Vrees ist mit Förderung vom Land Niedersachsen und der Bundesstiftung Umwelt entstanden. Die Hälfte der Investitionskosten in Höhe von 1,4 Millionen DM hat das Land und die Bundesstiftung Umwelt übernommen.

Das Hauptproblem in Sachen Holzheizung – das machen die aufgeführten Beispiele sehr deutlich – sind die Rahmenbedingungen, die dem Holz in Deutschland derzeit kaum Wettbewerbschancen bieten. Würde unsere Marktwirtschaft konsequent die externen Kosten mit Holz konkurrierender Energieträger in die Preisfindung einbeziehen, unser Holz würde mit einem Schlag wettbewerbsfähig. Nicht ohne Grund sind ja Länder in der energetischen Nutzung von Holz führend, die fossile Energieträger mit einer Sondersteuer belegt haben.

Meine Damen und Herren,
wir sollten diese unbequeme Wahrheit zur Kenntnis nehmen und unsere Wirtschaft gemeinsam mit den Wirtschaftsunternehmen ökologisch umbauen. Daß dieser Schritt notwendig ist, davon bin ich überzeugt. Daß es eine der schwierigsten Bewährungsproben für unsere Marktwirtschaft ist, die wir nur im Miteinander von Wirtschaft und Umweltpolitik bestehen können – das glaube ich ebenso. Doch der Druck zur Lösung dieses Kernproblems wird weiter zunehmen.

Ein Zitat des Münchner Physikers Hans Peter Dürr soll diese Einschätzung untermauern:

„Nachdem wir uns nicht mehr primär mit dem Ost-West-Konflikt auseinandersetzen müssen, kommen nun die eigentlichen Probleme zum Vorschein. Da ist die Frage, wie der Mensch mit seiner Ökosphäre langfristig zurecht kommt. Er muß einen Lebensstil entwickeln, der diese Lebensgrundlage nicht zerstört. Wenn die ganze Welt unseren Lebensstil imitierte, würde die Erde mehrfach zusammenbrechen. Das sind viel schwierigere Probleme als die Abrüstung, weil wir der Feind jetzt selber sind, in gewisser Weise auch die Verführten."

Prägnanter und dramatischer als mit diesen Worten von Hans Peter Dürr läßt sich die Kernfrage unserer Zukunft nicht formulieren.

Doch mit diesen Worten möchte ich mich nicht von Ihnen verabschieden – dazu bin ich ein zu optimistisch eingestellter Mensch.

Jede Reise beginnt mit einem ersten Schritt. Lassen Sie uns also in der Frage der energetischen Nutzung von Holz einmal die Problemanalyse unserer Fachleute anschauen.

Meine Damen und Herren,
die Niedersächsische Energieagentur stellt in ihrem Gutachten zur energetischen Nutzung von Holz einige Grundprobleme heraus. Sie betont dabei in ihrem Resümee – ich zitiere jetzt:

„Die Forstwirtschaft verfügt kaum über Kenntnisse im Energieversorgungsbereich und den damit zusammenhängenden Schwierigkeiten bei der Versorgung von Industrie und Kommunen mit Energie."

Wenn ich mir die Struktur dieses Fachforums anschaue, so möchte ich heute sagen: ein Problem weniger! Die Steuerungsgruppe des Fachforums und seine Organisatoren haben bei der Betrachtung des Energiepotentials Holz die Sicht der potentiellen Kunden eingenommen – Ihr Ausgangspunkt ist der Energiemarkt!

Forstleute und Waldbesitzer treten hier in den Dialog mit den Energieversorgern – einen Dialog, der zum Verständnis statt zum Ausgrenzen führen soll, einen Dialog, der uns die Auffassungen, die Probleme und Möglichkeiten beider Seiten vor Augen führen soll. Ich darf mich daher an dieser Stelle ganz besonders bei denjenigen Energieversorgungsunternehmen bedanken, die dieses Fachforum großzügig finanziell unterstützt haben, und ebenso bei der Bundesstiftung Umwelt als wichtigem Sponsor.

Meine Damen und Herren,
damit wünsche ich dieser Tagung im Namen des Landes Niedersachsen viel Erfolg.

Anschrift des Verfassers

Karl-Heinz Funke
Nds. Ministerium für Ernährung, Landwirtschaft und Forsten
Calenberger Straße 2
30002 Hannover

Key-notes

The International Dialogue on Forests and Energy

Elisabeth Barsk-Rundquist

It is an honor for me to have been asked to chair the Plenary sessions of this Forum on Forests and Energy. My work at the UN has over the years been dominated by the complex and interesting problems of energy and now more recently forests. To be presented with this opportunity to explore together with you the areas at which these two issues intersect will be challenging but hopefully illuminating for all of us.

The negotiations on forests that have taken place over the past eight years

Since three years back governments have been involved in intense negotiations aimed at reaching an agreement on an array of issues affecting forests.

In 1992 governments met at the United Nations Conference on Environment and Development, the so called RIO CONFERENCE. At the eleventh, if not to say the twelfth hour, governments, in spite of an often infected debate, hammered out two agreements which deal with forests: Chapter 11 of the Agenda 21 and the Forest Principles, for which the UN's Food and Agricultural Organization, the FAO became the task manager within the UN system.

After Rio the United Nations established the Commission on Sustainable Development (the CSD). In 1995 the Commission felt that the time was ripe to initiate international negotiations on forests once again. They decided to establish the Intergovernmental Panel on Forests (the IPF) which discussed, over two years, 11 issues divided into five categories. The discussions covered such issues like: national forest programmes, underlying causes of deforestation, indigenous knowledge, reforestation, finance, trade, institutional issues as well as legal mechanisms.

In February last year the Panel concluded its work. Governments came to a common understanding on almost all the technical issues that they discussed, and put forward a report with over one hundred proposals for action. There was one issue on which the Panel did not reach an agreement. They could not agree on if they were going to start negotiations on a convention on forests or not. Finally the General Assembly's Special Session, held in June last year, decided to continue the high level policy debate on forests through a three year process with the name the Intergovernmental Forum on Forests.

The current three year process, namely the Intergovernmental Forum on Forest (the IFF) and how the issue of Forest and Energy fits into that process

At the Forum's first and organizational session, held late last year, governments agreed on a work programme divided into three categories:

1. The forum will under the first category consider how international organizations, countries and others such as non-governmental organizations and the private sector can implement the IPF's proposals for action.
2. The second category consists of an array of other substantive matters which were either left pending by the IPF or that had not been given enough time to discuss in depth.
   The major issues here are finance, trade and technology transfer. It is within the last topic that the Forum decided that they would discuss wood as an energy source. The reason that this item will be considered within the issue of technology transfer is because of the need for increased use of efficient technologies by industry and households, so as not to deplete the resources base unnecessarily. *This would be particularly important for energy technologies in view of that 60 % of the global annual wood harvest enters the energy stream today, 50 % through fuelwood use in mostly developing coun-*

tries and 15 % through the waste recycling to energy generation mostly by the forest industry in developed countries. This issue will be taken up at the Forum's next meeting in August.

3. The last and third category is the most politically sensitive one, namely the issue if to have a convention on forest or not having one and if there was to be a convention on forest, what would it contain, and what would it do. As the say the devil is in the details.

In the year 2000 the Forum will report back to the Commission on Sustainable Development.

The results of the recently concluded debate on Forests and some of the implication for the discussions that will take place here in the next few days

1. National Forest Programmes

The Panel stressed the value of developing national forest programmes within the overall context of integrated land use with the participation of all stake holders with an interest in forests, that is, forest owners, forest products industry, the people who live in the forest and those that are dependent on them. This meeting could address how the use of wood and biomass for energy should be incorporated into national forest programmes and how land use and energy plans be implemented in such a fashion that they are not detrimental to forest programme objectives.

2. Research and Technology, Information and Assessment, Capacity Building, Financing, International Trade

This meeting could address the very different research and technological needs of for example a power utility company located in a forest rich country with high GNP, in contrast to those of a forest poor country with almost negligible GNP where the burning of wood corresponds to 80 % of their energy use while also being in the unenviable position of having the most acute shortages of supply.

We could also address the problem of lack of reliable data on exactly how much wood is used for energy purposes and what proportion of deforestation is due to the removal of wood for energy.

The issue of financing is a thorny one and in the case of wood for energy use closely linked to price of oil and that of alternative high value uses of wood and fibre.

This meeting could also explore some of the consequences and desirability of wood entering the international trade as an energy source.

3. Institutions, Instruments and Coordination

One of the notable successes of the IPF process was the establishment of the informal, high level inter agency task force on forests (the ITFF). This group is chaired by the FAO as the task manager for chapter 11 of Agenda 21 and the Forest Principles, the other members are United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), the International Tropical Timber Organization (ITTO), the World Bank, the Secretariat of the Convention on Biological Diversity, and the Centre for International Forest Research (CIFOR). Immediately after the conclusion of the Panel the task force developed an action plan outlining in which areas these organisations could contribute to the implementation of the Panel's proposals for action through a coordinated system wide effort.

4. High-Level Policy Making and International Priority Setting

Apart from national regulatory frameworks, there are several international legal instruments that affect forests. For example the Convention on Biological Diversity, CITES, which deals with endangered flora and fauna, the Framework Convention on Climate Change, and the ITTA, dealing with tropical timber trade etc. The largest significance of the establishment of the Forum is that it showed that an integrated policy debate focused on forests, in themselves, had been very useful and should be maintained.

Forests provide as diverse products and services as there are demands on them, energy being one of the major ones.

Experience has shown that when local populations derive benefits from managing and planting forests, trees are planted and forests thrive. A forest that has no value to the people who are in a position to do it harm, will soon degrade and maybe even disappear. One might then ask the question why is it that those countries which rely the most heavily on wood for their energy consumption have the most acute shortages of supply? The need for wood is certainly there and often they do not have the means to purchase alternative fuels. One would think that there should be every incentive to nurture trees which could not only provide energy but also other service such as wind breaks, protect water sheds and timber for shelter etc. So why has it not happened? There are obviously other forces at play here, some of them are socio-cultural, such as: the low status of women in the household and her lack of control over the allocation of the family investments both in time and money. Some are economic and legal such as involving land and resource user rights: in many countries user or ownership rights can only be claimed when cattle or crops are present on the land not if you plant and/or manage trees (a goat is an asset a tree is not).

This switch to modern technologies for converting wood to power and heat is happening in the developed world mainly in the forest products industry which generates energy through converting wood waste. This recycling makes economic sense: there is no need for transportation as the energy is generally produced where the waste is generated and the energy is needed on site. The greatest benefit of using wood and wastes in this case is the fossil fuel NOT used.

In the future, there is no doubt that with better policies, the use of wood as an energy source could be a positive factor in many countries, rather than an yoke around their necks like it is today. This could be achieved through policies which increases locally available supply and with a switch to modern and efficient technologies rather than a switch in the fuel itself.

I would like to mention the role of forests in the dichotomy of energy use and mitigation of climate change. Forest store carbon and they can also act as carbon sinks. Deforestation contributes about one fourth to annual carbon emissions today, most of it from land use conversions in developing countries. One thing must be assured and that is that increased use of wood as an energy source should not add to deforestation, it has to increase the value of the forests, especially in the eyes of the local population, so as to ensure sustainable management.

The discussions on energy that will take place in the UN's Commission on Sustainable Development (the CSD) in the year 2001

I will conclude by very briefly inform you about the future debate that will take place within the CSD on Energy. The Special Session of the General Assembly also had a difficult and protracted discussion on energy and its future work programme in this area. It was decided that the CSD session in the year 2001 would be dedicated to a discussion on sustainable energy with a two year preparatory process leading up to it. An inter agency coordination group within the UN system is starting to plan for the two year preparatory process. There is of course several initiatives already being undertaken on sustainable energy like for example this meeting and it is hoped that the results you achieve will also feed into the energy process.

Author's address

Elisabeth Barsk-Rundquist
Sustainable Development Officer
Secretariat of the Intergovernmental Forum on Forests
Two United Nations Plaza, DC2-1264
New York, NY 10017, USA
e-mail: barsk-rundquist@un.org
http://www.un.org/esa/sustdev/iff.htm

Renewable Energy in the 21st Century from a Global Energy Perspective

Frank van Oorsouw

Abstract

Over the last hundred years, energy demand per capita has more than trebled, from 18 to 78 GJ/year, spurred by economic growth. However, major parts of the world's population have still little or no access to the comfort provided by electricity nor to the wider range of choices and opportunities linked to mobility. Meeting these needs, for today and tomorrow, will require growing and sustainable energy supplies.

Building on historical patterns which have shaped economic development – inventiveness, competition, productivity, converging developments – two contrasted energy visions are explored for the future, "Sustained Growth" and "Dematerialisation".

- In "Sustained Growth", abundant energy supply is provided at competitive prices, as productivity in supply keeps improving in an open market context. The growth pattern in supply of the last century continues, with energy consumption per capita reaching 150 GJ/year by 2060, today's Japanese level.
- In "Dematerialisation", human needs are met through technologies and systems requiring a much lower energy input. A different pattern emerges, leading to an energy use per capita of 90 GJ/year by 2060.

For both scenarios, fossil fuels contribute to most of the growth over the next few decades, but renewable energy sources gradually take an increasing market share and their contribution becomes significant by 2020–2030. A more detailed description of these scenarios is published in the brochure "The Evolution of the World's Energy Systems", which is available from Shell.

In these scenarios, the penetration of renewable energy is essentially driven by economic growth providing sustainable development for a world of 8 billion people, expected by 2030. Although fossil fuel resources are abundant, they eventually reach their maximum potential. Their rate of commercialisation is slowed by increased distance from market and/or lower quality of resources, while renewable energy sources, available close to local usage, become more competitive through a "learning process". As a result the world energy systems become more diversified and hence more robust.

Over the last eighty years, since oil has become a significant energy source, real term oil price has seldom moved away from an average of $ 15/bbl, for a long period of time. Making heat and power from wood requires more capital investment than when using oil products or gas, or high quality coal, as traded internationally. In this world, biomass or energy forestry must be profitably delivered at about $ 1.5–2.5/GJ, as a fuel, to a point of use to provide genuine economic value. This price target could be relaxed by $ 0.5–1.0/GJ, for a world in which oil prices would consistently remain at $ 20–25/bbl.

When moving away from a coastal location, the logistics of transporting internationally traded fossil fuels gradually adds to the cost. Similarly, the production of wood for pulp becomes less attractive because increased distance from coast leads to higher transport costs to a harbour for export. As a result, commercial niche markets appear for heat and power generation from sustainable energy forestry. The size of these markets depend essentially on land price, sustainable wood production yields and costs, and the capital intensity and flexibility of conversion technologies into heat and power.

Competition for land with agriculture is not an issue when market mechanisms are not distorted: food products command a higher value, leading to a land price premium which makes energy forestry unattractive. As energy production yields improve, partly switching land use back to agriculture, if economically sound, is also conceivable over a period of time.

Shell companies are currently under

taking a number of projects, focused on testing the commercial potential of various biomass (energy forestry) and photovoltaic concepts. Over the last 15–20 years, the Group has built competences in both areas. Shell Uruguay has started plantation trials of fast growing tree species, to demonstrate high sustainable yields and lower costs. These trials will provide information to identify commercial energy forestry projects in Latin America which would generate heat and power.

The success of these projects is linked to the emergence of a new industry, which will involve major equipment and technology suppliers and engineering firms. This requires a long term commitment of financial and human resources which can only be justified by sound economic fundamentals, for instance when supplying heat and power from wood in certain remote areas, rather than by distorting energy markets through taxation.

Whereas the emergence of an energy industry based on biomass and photovoltaics has a significant potential also for the European environment, several initiatives in Europe focus on equipment and technology development, whilst others aim at testing key commercial concepts. In our views the last category is of particular interest for the development of biomass based industry.

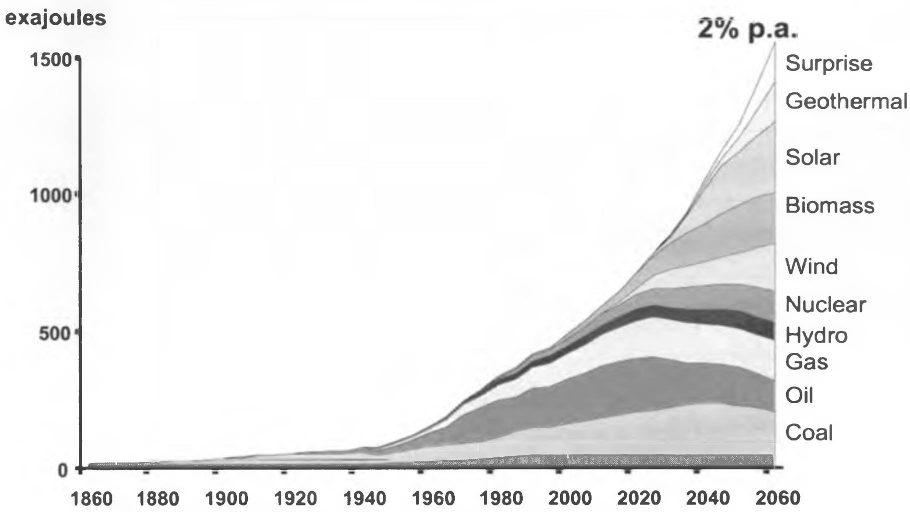

Fig. 1: Shell International long-term szenario "Sustained Growth".

Transcript of the presentation by F. van Oorsouw based on tapes including clarifications and additional information discussed after the presentation

Responsible editor: Jutta Poker

I am grateful to have been invited to share a view of an oil company on the future, particularly on the future of renewable energies. We are certainly not at the level of policy makers or international priority setters. We are as Shell just an energy company, we have a view on renewable energy and that is precisely what I would like to introduce to you.

The long term energy supply from the point of Shell

Looking at possible scenarios for future energy supply was a work which was done a couple of years ago. You cannot reasonably expect that we change our views on the long term future, particularly if it concerns 50 to 60 years into the future, every other year. These views still represent the internal views of Shell and we in the meantime did not come up with something which is much different from that.

There are basically two scenarios which stretch over a period of 50–60 years (which is definitely longer than our normal long term scenarios). These two scenarios give an indication of the future energy supply world-wide based on a summary of a number of regional studies. A lower scenario, "Dematerialisation", presumes a much higher energy efficiency than right now and a lower population growth than is foreseen.

The higher scenario, to which we lend slightly higher credibility than to the lower one, is the "Sustained Growth" (Fig. 1). We see this continuing growth based firstly on the population growth itself, and secondly based on the fact that there is already a large part of the world population with hardly any access to the benefits of energy. It is clear that when the lesser developed countries start using more and more energy that there will be a tremendous growth in energy consumption.

There might be some aspects of doing things in a fundamental different way than we do them today. Some of the signs are there. To give an example: the phone. People are replacing contact by phone calls. At any time of the day they call their relatives, business partners or whoever instead of visiting them eye to eye. In a way, this could reduce travel. Another effect: distributed offices where people would work from their homes with all the new information highways which might become available. So we will do things more efficiently; thus, we still expect a very significant growth in energy consumption.

How could this increased amount of energy be supplied? Over the next 70 years we still do see an increase in the traditional fossil fuels, in coal, oil and gas. But already within a period of ten years other forms, which one would label "renewable energy supplies", are coming into the picture. We expect them to grow continuously and to become a very significant element by about 2020. Particularly significant contributions will be made by wind, biomass, solar, geothermal and something that our learned friends still keep in disguise for us but I am sure they will come up with something exciting.

In the scenario with less energy growth, labelled dematerialisation, with a focused attention on obtaining higher energy efficiencies in what we are doing as nations and communities, the energy level by the midst of the next century will reach nearly 1000 EJ which is about two third of what we calculate for the other scenario, the one with "Sustained Growth".

Overall, this analysis has given rise to what we call in our company the "fifty/fifty vision", which means that by the year 2050 we expect 50 % of the total energy consumption in the world to come from renewable energy. That is an enormous task ahead of us to prepare for and to manage that half of the total energy will be supplied by renewable energy.

This will of course have all kind of effects. One effect is the impact on CO_2 emissions. From the baseline given by the Intergovernmental Panel on Climate Change in 1992 we derived our estimate. In the perspective of the enormous increase in energy consumption which we expect and see especially in the developing countries, global CO_2 emissions will still increase for some time until about 2020, then emissions will start to tail off and come down sharply by the early midst of the next century. This view is based on a free development of the industry under market forces which are not influenced by governments and other international and non-governmental bodies. The alternative would be an accelerated policy where the energy efficiency would already result in a decrease at an earlier stage.

Shell's reaction to that view: Launching of Shell International Renewables

Shell believes that this is the development for the future, that renewable energies will play an important role. Thus, we have looked at where we have something to add to the development and the introduction of renewable energy. If one cannot contribute to anything, to a new development, then there is no point in participating and it is better left to other people who do know about it.

We thought that we could contribute in a number of areas and that belief was strong enough to create a new core business. The basic structure of the Royal Dutch Shell Group includes now 5 businesses:

1. exploration and production of oil and gas,
2. refining and marketing of oil products,
3. chemicals,
4. gas and, as from mid October 1997,
5. renewables has been added as a core business.

The addition as a core business is intended to be a strong signal, because as a company like Shell you do not start a new business and drop it the next year or so. It means a long term commitment, with allocating significant funds and man power pursuing that business. We emphasise the word business. It is not intended as a public relation's movement, it is not intended to polish up our image a bit. If we would try to do so, the public at large and the press would very rapidly recognise that, and we would be in a lot worse shape than we have ever been before. So, we are in there because we see significant business opportunities in renewables. That is the main, and I must emphasise, the only reason why we are in there: for the business opportunities, just indeed to make a profit also.

The renewables sectors in which we would involve ourselves are selected on the basis of actually possible contributions, starting from the bottom for a change. In forestry we have operational experience for almost 20 years. In the early 80s we moved into forestry for pulpwood and saw timber production. Of course, if we talk about forestry what we actually mean is wood plantations. The exploitation of natural or indigenous forests will not be touched by Shell for understandable reasons.

Existing forest operations are located in South America (Uruguay, Chile, Paraguay), New Zealand and the Republic of Congo. The plantations are reforestations of abandoned agricultural land. The size of these plantations is about 120000 ha, which is still fairly modest compared to the plantations of the very big players in that industry. It is not big but it is enough to have a solid basis to work from.

In photovoltaics we have an experience of 25 years. We have been in photovoltaics in the States, we have left it there. We still are in photovoltaics manufacturing in Japan, the Netherlands and until recently in France.

The biomass is seen as having an upstream part (growing the feedstock) which is related to forestry and a downstream part (the conversion of biomass to liquid and gaseous fuels, electricity and process heat).

The wind sector is currently under study to explore the way in which we can best contribute to that. We believe we could indeed make a contribution in the off-shore wind sector. Off-shore operations are very well understood by Shell from the off-shore oil production and exploration activities. Thus, we feel really at home in that environment.

We see renewables as significant solution for the future and we feel, Shell's business is to energise a sustainable world. We intend to be a key-player in this renewable's industry hence we have allocated an amount of half a billion dollars for the coming five years. Half a billion is much and is little, we need to leave it to the future to decide whether the amount is high or low. We are in the early stage of development of renewable energy, so the number of opportunities available to us and to the industry in general will be limited. If we would say we want to invest 5 billion dollars, we would be very unrealistic. It could not be done, in no way one could economically invest that amount of money in this new industry. It has to grow from an almost zero base. At a certain stage, what we call the take-off stage, it will start growing much more rapidly and that's where the larger investments can be made. In our view that would be between 2010 and 2020.

Shell's views about the future shaping of energy markets

In order to illustrate the implications of the different energy forms, let us compare the amounts of energy required to generate 50 MW of electric power (Fig. 2).

It would require

- 1 km^2 of solar cells,
- 2500 barrels of oil,
- 100 wind turbines with the current size of turbines available,
- 150 km^2 of forest.

As we see, the land occupation of biomass production is very significant.

What size could the business grow to by 2020? Being a business company, we have expressed it in billion dollars:

Energy industry	billion $ per year
wind	130
biomass	90
photovoltaic	25

These indeed are very impressive markets. Whether the markets will materialise in the range of our estimate remains to be seen. We might be off by 25 % easily, but that they will be significant is without any doubt. Certainly significant enough for us to be interested in them.

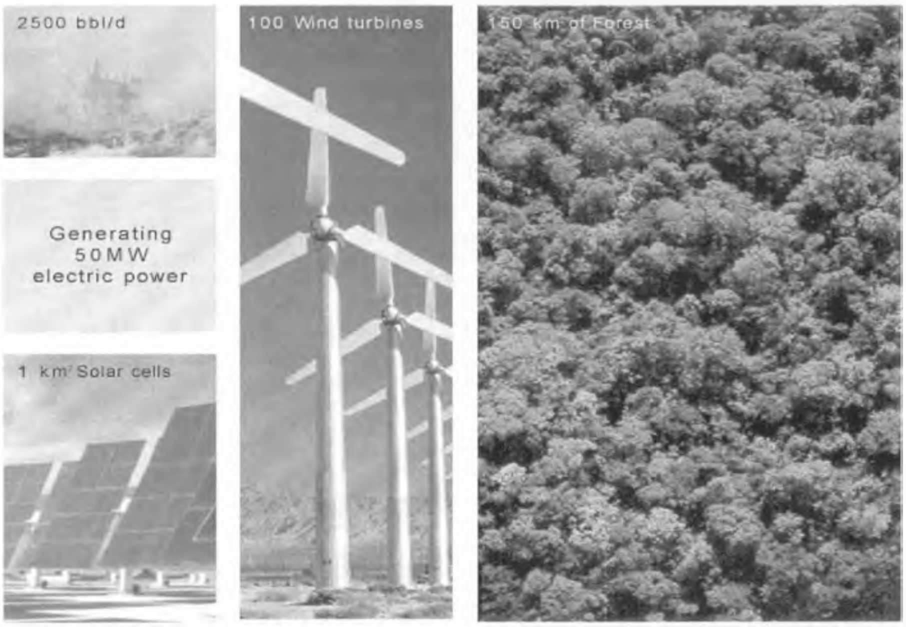

Fig. 2: Energy sources required to generate 50 MW of electric power.

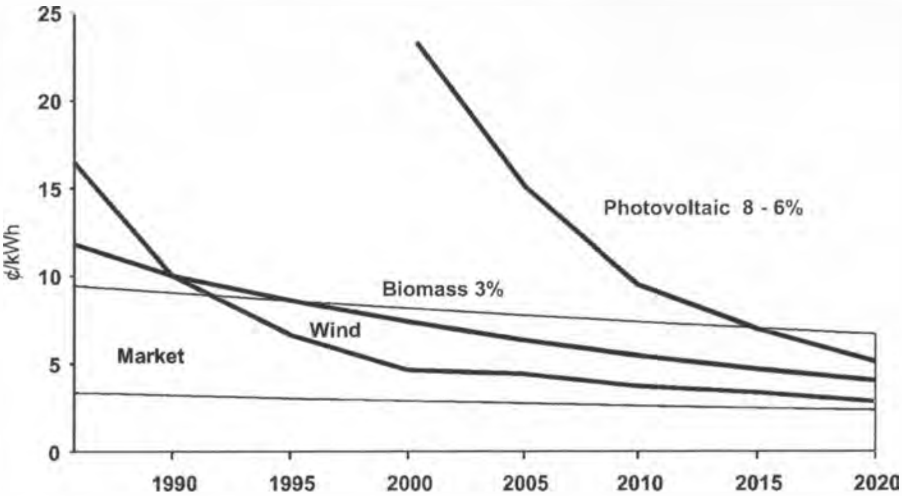

Fig. 3: Costs of electricity from various sources compared to market prices.

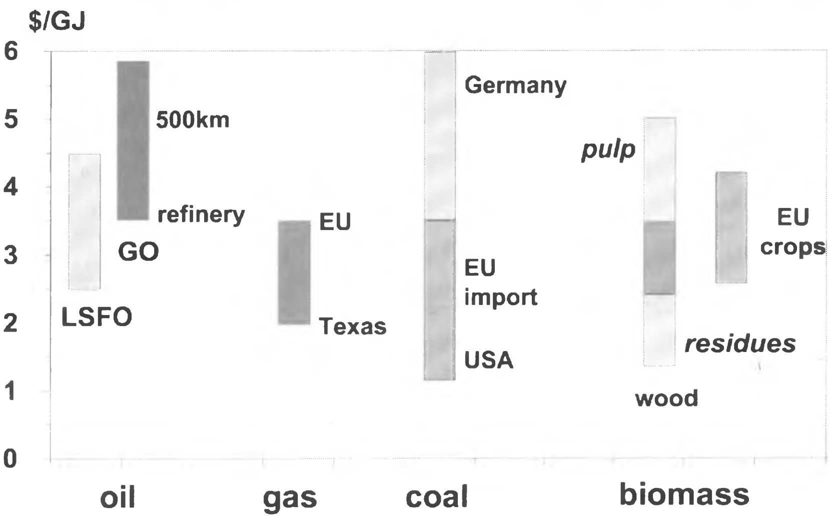

Fig. 4: Price ranges of various energy forms for industrial consumption.

Before it will get that far, however, the renewable energy will have to be competitive. Competitiveness will be governed by the market. We work on the premise that the market will be determined by economic choice. There may be other ways to shape that market. We will accept it as it will be and we will look at our possibilities to compete with alternative forms of energy.

There will be development with decreasing energy costs for the various forms of energy (Fig. 3). Photovoltaics is still very expensive, biomass, depending on the actual situation, has already entered the range of market prices charged for electricity. Wind has already come down steeply and we feel the onshore option is already an economically viable alternative. There are some complications, as we are all aware of. People do not really like to see wind turbines close to where they live. Also, the older wind turbine types make some noise. It will need to be balanced carefully.

For biomass an important factor will be the price at which the energy in form of biomass will become available (Fig. 4). Since biomass is a fuel with a slightly lower efficiency in electricity generation compared to fossil fuels, a price on the upper end of the range will probably add another limit towards its introduction.

The residues from forest thinnings and also the harvest residues are a very interesting resource. We feel it is a sustainable energy supply and could play an important role, in particular during the initial introduction stage of biomass to electricity conversion. In the long term, however, there has to be additional production of energy wood.

Some notes on biomass to electricity products

Let us move to some of the products and the markets. Biomass to electricity, which is the main line of development we are pursuing at this point in time, will play a significant role. Size and conditions in the various electricity markets will be different.

Starting from the largest scale, let us look at the national grids. These well developed strong high voltage grids are in operation in most countries in Europe, North America, in a number of countries in South America, etc. We could see electricity production from biomass in the scale of about 30–100 MW for such a grid as an independent power producer or as sales in a deregulated market where electricity can be sold after the transmission. We believe, 100 MW is about the ceiling for a biomass to electricity scheme in view of the sheer size of plantations needed for that. 100 MW would require a plantation of about 30000 ha, that is 300 km^2. The typical distance for transportation of biomass would already get in the order of about 15–30 km and that is an important cost element. The logistic costs are enormous for a fuel like biomass. So there will be a ceiling there.

Currently, yields average 21t dry matter/ha+yr. In view of ongoing research results we are expecting significant increases in yields of fast growing tree species and energy crops. In order to reduce transport costs tests are being carried out if the conversion of wood into solid fuels is a viable option. However, non-existing markets for charcoal are a restriction to this option.

There are many situations, particularly in developing countries, where grids are smaller, operating on a regional level. They are medium high voltage, within the range of 1–10 MW and they cover a distance of typically 100 km in length. That is where distributed power production could be a solution. Pyrolysis is a technological option in this context because this is the technology to produce liquids which can easily be transported. For a grid it is essential to have a number of electricity supply points. A grid can never be reliable if it is based on one supply point only. These grids are generally linked to small industrial electricity generation in areas of rural development or linked to power generation within agricultural activities in many countries of the world. For example, rice drying processes produce rice husks, which could be considered as source for electricity generation.

The smallest application, the smallest product we see in this market is village electrification where we are starting virtually from a zero base with no electricity supply at all. There are large parts of many countries where extension of electrical grids are not really considered because they are deemed to be too expensive. A product designed for this situation which we call a Shell Sun Station is based on a fairly small 50–400 kW gasifier engine combination. A sustainably managed forest would supply fuel for an efficient wood gasifier engine feeding a local grid. Some photovoltaic capabilities are incorporated to generate further electricity since a hybrid solution is generally seen as adding value and increasing the reliability of the system. Another option to ensure reliability is the combination of several gasifier engines.

This is a fairly new product and its introduction will not be one without challenges particularly due to the absence of economic activities on a level which could sustain electricity production. That has to be taken into account.

A study calculation for a 50 MW power plant and dedicated plantations resulted in an electricity price of 5 to 6 cents/kWh, taking into consideration as most important factors: land prices, plantation costs, resulting feedstock costs, capital costs for the installation. A price of 5–6 cents/kWh might in a number of situations already be economic but we expect it would have to be reduced a bit further to become economic on a greater scale.

How do we think as Shell to fit into this? We see basically two segments:

- an upstream sustainable biomass production dedicated to energy. This includes not only forestry but also the production of energy crops like *Miscanthus*, bamboo, or whatever we feel is a biomass which is produced on a sustainable basis as part of a cycle. We expect increasing yields in all of these crops.
- a downstream conversion into marketable energy. Products could be electricity, combined heat and power, light oils or solid products. So far, methods to convert wood into gasoline are not very promising and the abundant availability of oil renders their introduction less probably in the short to medium term.

A point which is not widely understood is the significance of a biomass market developing. In no country, to our knowledge at least, there is a biomass market for forestry owners or agricultural activities, where people can invest in plantations and be sure that there is a market for selling their products. That market has to be developed and we think that is probably more important for the introduction of renewable energy than the technology which we see so often demonstrated in all kinds of demonstration projects. A commercial framework has to be established which would stimulate people to start investing by offering a reasonable certainty that they would get a reward for producing biomass, dedicated biomass in particular.

It will be clear that the forestry, we are involved in, in fact are wood plantations. In view of the dramatic global deforestation rates of natural forests, we want to underline this point. The use of natural forests is, as far as we are concerned, for us out of bounds.

Besides our activities in the biomass sector, we are also involved in photovoltaics. As stated before, photovoltaic is further away from being economic as we would expect biomass to be, hence in Renewables we like to put from time to time a little challenge in front of some of our colleagues. If we look at the two activities in Shell, solar for energy production which is photovoltaic and biomass, we have to conclude that for the time being the most economic photovoltaic cell remains the leaf of a fast growing tree. This might well be hard economic reality for the next 20 or 30 years; but do not forget, we feel that both will be important and we are active in both areas.

Author's address

Frank van Oorsouw
Director – Head Biomass and Wind Power
Shell International Renewables
Shell Centre
London SE1 7NA

Forest and Energy in the 21st Century from a Forestry Point of View

Miguel A. Trossero

Abstract

The threat of climate change, as a result of the accumulation of greenhouse gases (GHG) mostly derived from the massive utilization of fossil fuels, paradoxically opens new opportunities for the development of bioenergy, and especially forest energy, as a major mechanism for carbon sequestration and substitution. Moreover, current institutional adjustments, new energy policies and changing economic conditions, as a result of the liberalization and globalization of markets, are also contributing to make biofuels in general, and woodfuels in particular, a cost-effective alternative to meet the growing need for energy, diversify forest activities, accomplish new environmental conditions and improve socio-economic prospects for those living in rural areas.

The possibilities of forests, woodlands and trees to combat climate change are great, using the biomass available and, where possible and feasible, establishing energy plantations. Technical options are many: some can be implemented immediately using existing mature technologies, while others still require the transfer of technology to the places where they should be applied. In all cases, however, support of R & D of technologies is urgently needed to improve existing solutions and to generate new ones in order to produce more energy with less fuel at lower cost.

However, old and new emerging problems affect the development of the full potential of forest energy; for example, institutional weakness, insufficient properly-trained human resources, lack of information and data, land use changes, deforestation, lack of technologies, etc. International co-operation is urgently required to mobilize funds and supply technical assistance to tackle major problems and build the necessary institutional framework and infrastructures, as well as to establish sound forest, energy and environmental policies.

This paper presents an overview of the past and present contribution of forests, woodlands and trees to meet the energy need of both developing and developed countries, analyzes the most relevant characteristics of existing wood energy systems, and highlights the major elements required to enhance the contribution of woodfuels to the energy sector, taking into consideration the current circumstances of countries, as well as factors derived from the recent meeting in Kyoto and other relevant events.

Transcript of the presentation by M. Trossero based on slides presented and tapes including additional information discussed after the presentation

Responsible editor: Jutta Poker

First of all I wish to express my sincere gratitude to the Alfred Toepfer Academy for Nature Conservation for inviting me to address this important and crucial topic. I must say that it is not easy to present this complex subject in a comprehensive manner because there are many important aspects and issues involved which cannot be highlighted with the time available.

PRESENT AND FUTURE CONTRIBUTION OF FORESTS TO MEET ENERGY NEEDS

Present woodfuel consumption

Based on currently available information, collected mainly during the last two years, forests and trees contribute 23000 PJ of the world's total primary energy consumption (Table 1). In forestry terms, the equivalent is 2.3 billion m^3 of wood. The share of wood energy represents only 7 % of the world's total energy consumption of which a meagre 2 % is used in developed countries. Most of the wood energy is consumed in developing countries where mainly fuelwood and charcoal provide 35 % of the energy needs in Africa and 12 % in Asia, Latin American and the Caribbean countries. In Oceania this share even runs up to 52 %.

In terms of quantity also forests and trees contribute significantly to the energy sector. Though the ratio compared to total energy may be low like in the developed countries, the amount of wood in terms of m^3 and the amounts of energy in terms of PJ are impressive (Fig. 1). Divided by regions, the greatest quantities are consumed in Asia. In Latin

Table 1: Woodfuel consumpting by regions.

Region	WOOD FOR ENERGY "Best estimate"		Ratio (wood/all energy)
	1000 CUM	PJ	%
Developing Countries	1 763 262	17 633	15
Africa	486 248	4 862	35
Asia	1 002 846	10 028	12
Oceania	5 804	58	52
Latin American Countries	268 364	2 684	12
Developed Countries	536 754	5 368	2
Grand total	**2 300 016**	**23 000**	7

Table 2: Regional woodfuel consumption.

Region	%
Africa	21.1
Asia	43.6
Developed Oceania	1.2
Developing Oceania	0.3
Latin America + Carib.	11.7
Europe	8.5
Former USSR	1.9
North America	11.8
World total	**100.0**

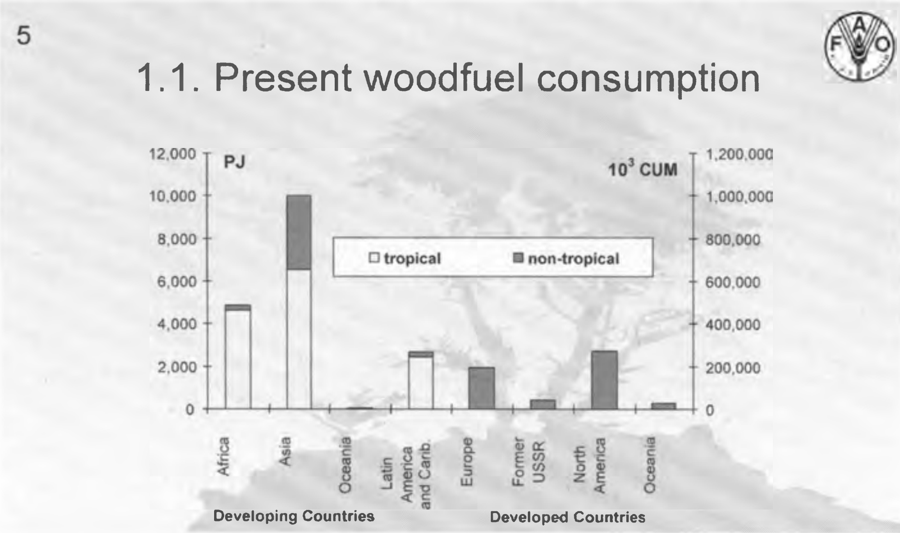

Fig. 1: Amount of woodfuels consumed by regions.

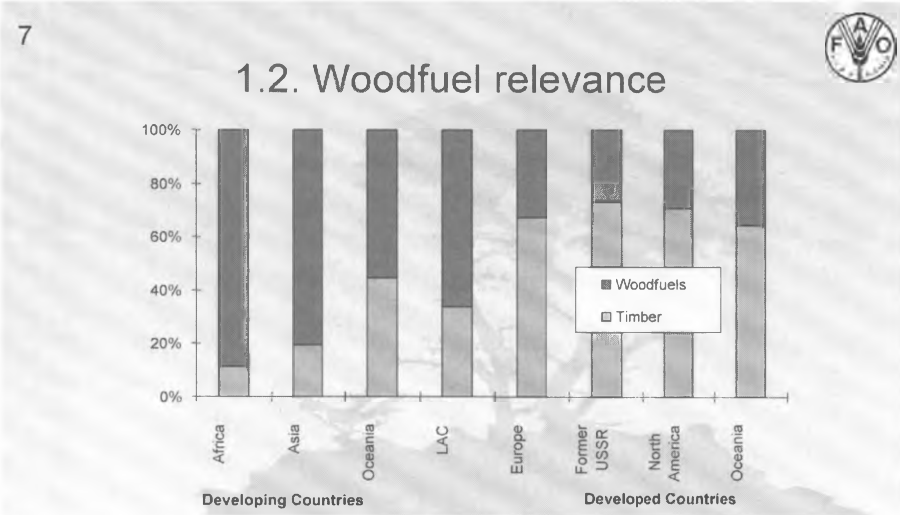

Fig. 2: Woodfuels vs. timber consumption by regions.

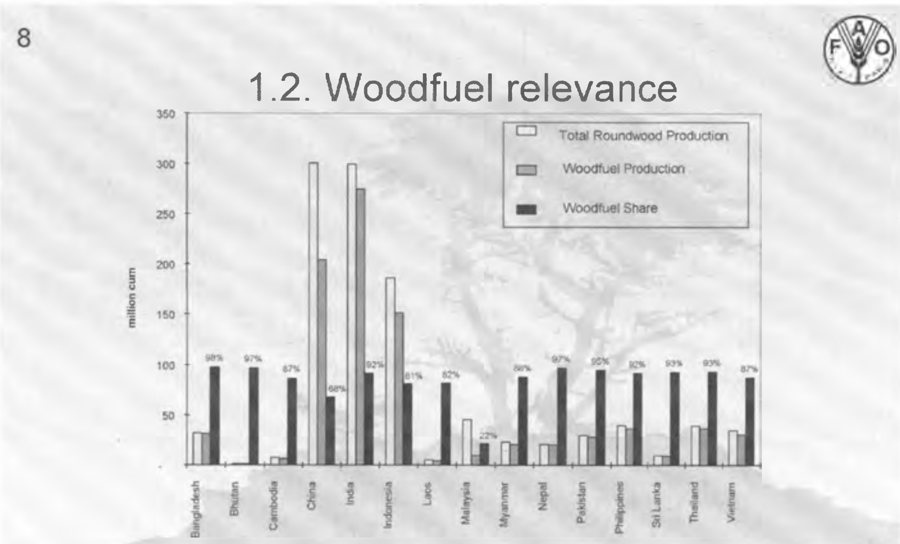

Fig. 3: Woodfuels vs. timber in Asia.

America and Caribbean, in North America and also in Europe the contribution of woodfuel is quite important.

The share of total woodfuel used is again greatest in Asia (Table 2). But also North America and even Europe consume a considerable amount of all woodfuels.

Woodfuel relevance

As a result of a combination of factors, among them the lack of accurate and reliable data and information, most countries have not properly recognized the role and relevance of wood energy in their forestry and energy policies and programmes.

Since large quantities of woodfuels are moved in informal markets, the relevance of wood energy is not easy to demonstrate. Figure 2 shows a comparative magnitude of the share of woodfuels in total round wood consumption by region. It is worth to note that there is an extremely high use of woodfuels in Africa with approximately 90 %, followed by Asia (80 %) and Latin American countries (about 70 %). The developed countries consume 30 to 40 % of their wood consumption for energy purposes which is still an impressive amount in absolute values.

The same analysis in 15 Asian countries (Fig. 3) demonstrates again the extremely high proportion of woodfuels in total round wood production. The total production of these forests reached in 1995 1075 million m^3, of these 865 million m^3 or approximately 80 % accounted for woodfuels.

Apart of Malaysia which is one of the most developed countries in the region and where fuelwood consumption is modest (22 %), the share of woodfuels in total round wood production runs from 68 % for China up to 97 % in Bangladesh, Cambodia, Nepal and Pakistan.

In the European countries woodfuels on an average have a share of 3 % in total energy supply (Fig. 4). Woodfuels play a more important role in Austria (12 %), Sweden (>16 %) and Finland (18 %). In terms of wood removals dedicated to fuelwood, France is the leading European country although woodfuels contribute only 4 % to total energy supply.

Woodfuel categories, supply, sources and users

Woodfuels consist of very different types and qualities and their regional usages vary considerably (Fig. 5).

In most developing countries woodfuels are mainly composed of fuelwood directly derived from forest and non-forest land, especially in the case of Africa and Asia. In developed countries great proportions of energy are obtained from black liquor and residues. The share of black liquor in total woodfuel consumption is greatest in mainly Australia and New Zealand (Fig. 6). In the case of the Latin American and Caribbean countries, the high share of charcoal is due to Brazil's great charcoal production for the iron and steel industry.

Forest energy systems

Based on many field studies and woodfuel analyses, a general picture of the highly complex and very site specific forest energy systems was developed (Fig. 7). Woodfuels not only are derived from different sources such as native forests, woodlands, reforested and afforested land and trees planted under agroforestry and community forestry schemes but also from forest by-products from silvicultural activities, logging operations and timber processing industries (sawmills, particle board plants, etc.). On the demand side, the users are a divergent group of customers such as households and industries in rural as well as in urban areas and commercial activities.

This scheme of interrelationships within the forest energy systems also explains why the predicted fuelwood crisis of the end of the 70's never happened. It shows that fuelwood and charcoal use do not necessarily lead to deforestation but, in the contrary, lead to planting of more trees as in the case of agroforestry systems.

Forests provide multiple product functions and services which are again interrelated (Fig. 8). Many of these interrelations are not always properly recognized and valued.

Moreover, Fig. 8 on forest fuels and products highlights the intrinsic complexity of the multiple contributions of forests and their multidisciplinary inter-

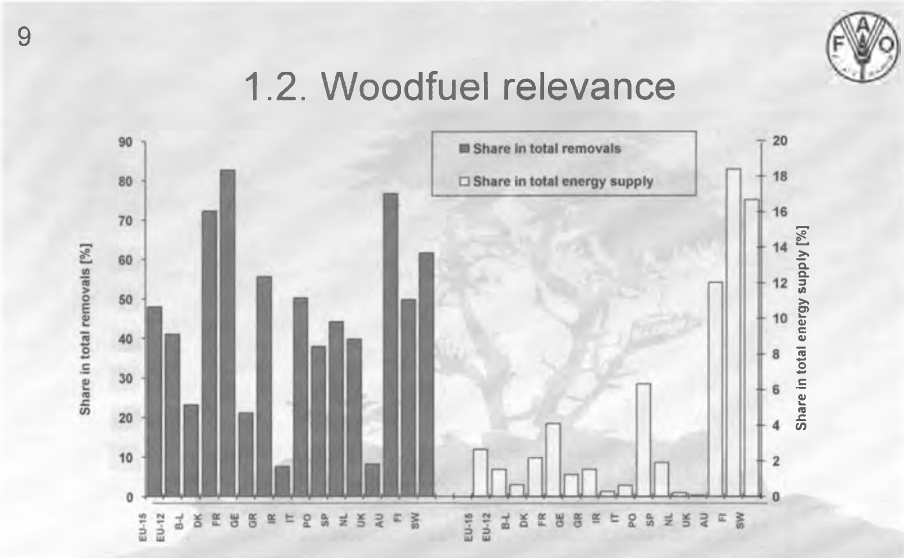

Fig. 4: Woodfuels vs. timber and energy in EU Countries.

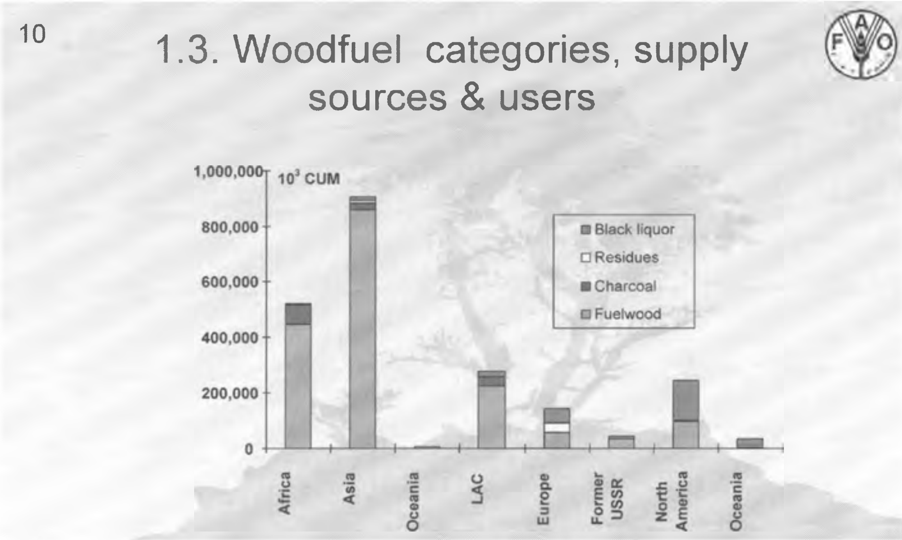

Fig. 5: Amount of woodfuels used by category.

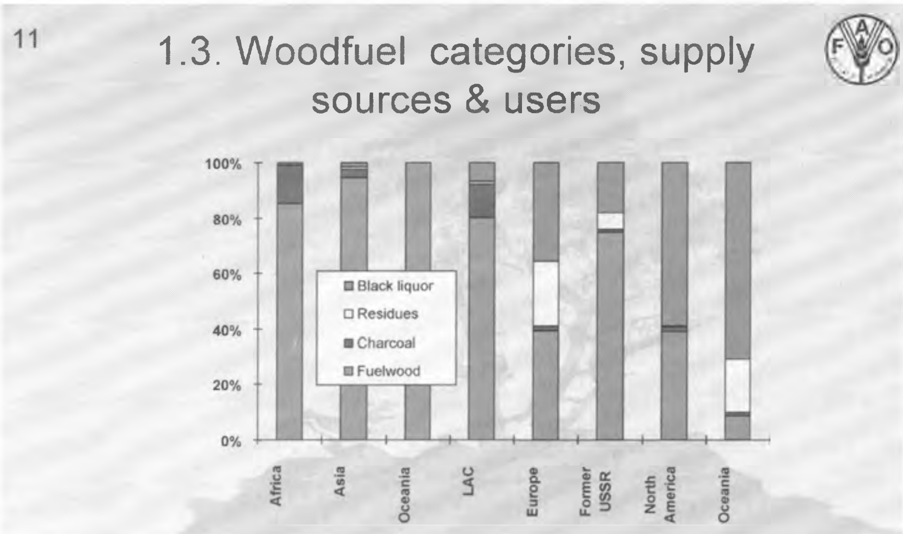

Fig. 6: Share of woodfuels categories.

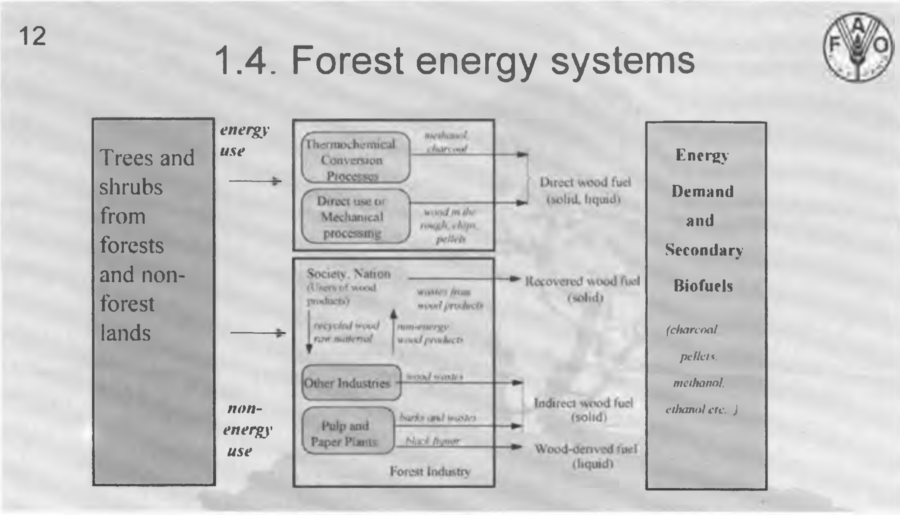

Fig. 7: Forest energy systems: Woodfuel categories, sources and users.

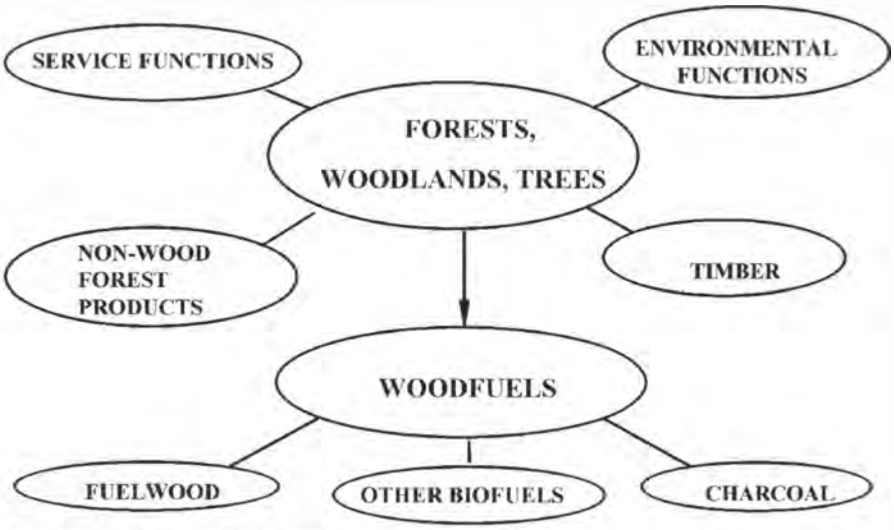

Fig. 8: Forests fuels and forest products.

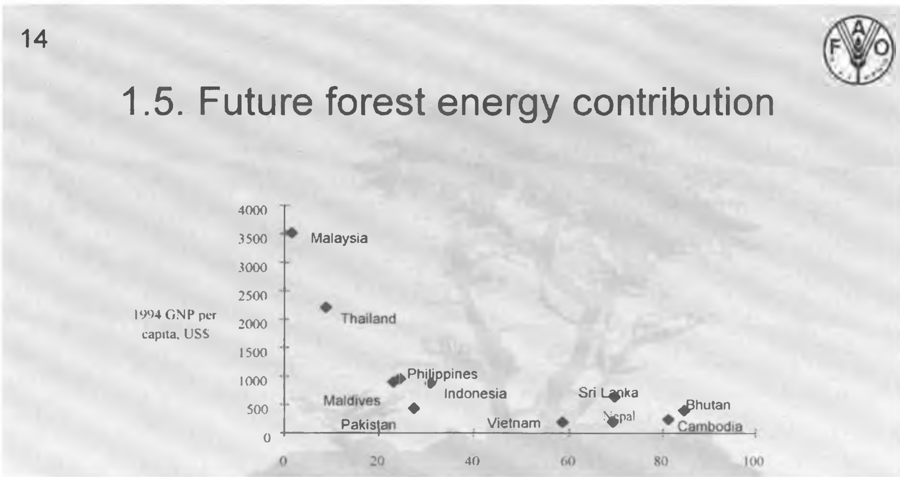

Fig. 9: Share of woodfuels in total energy consumption in Asia (%).

relations with different sectors implies many categories of actors from different economic levels and sectors. These actors and sectors have to be properly considered when wood-based energy plants are analyzed, planned and implemented. We have to avoid the risk to continue to look at forests as merely a supplier of timber, parks for hunting, etc.

Future forest energy contribution

The level and structure of energy demand is affected by the economic performance. High energy consumption is associated with higher income. High income countries consume more modern than traditional fuels. In these countries, households take a smaller portion of total energy consumed in comparison to transport, industries, and services. In contrast, households take a substantial portion of the total final energy consumed in low income developing countries. Moreover, these countries rely on traditional fuels, woodfuels playing a more prominent role.

Therefore, wood energy consumption is related to economic performance. The share of fuelwood in total final energy consumption tends to be higher in low income countries which is exemplified in a study in Asia (Fig. 9) by Cambodia, Bhutan, Lao, Myanmar, Nepal, and Vietnam.

Likewise, the correlations also indicate that dependence on wood energy tends to decrease with higher levels of economic development. The economies of Malaysia and Thailand illustrate this point in the above example.

In general terms, the contribution of wood energy to the national energy mix are decreasing for all Asian countries (Fig. 10) indicating that total energy consumption is normally growing faster than fuelwood consumption. A gradual shift to alternative fuels is happening, especially as the result of ongoing economic development and industrialization processes in most countries. Similar trends can be observed in other regions, too.

A combination of factors such as current economic development, modernization of industrial sectors and urbanization processes are the major causes of the progressive reduction of woodfuel use in most of the developing countries. However, in absolute terms, the amount of woodfuel consumption at national, regional and global level is progressively increasing (Fig. 11). During the last 15 years, world-wide woodfuel consumption increased by about 15 %.

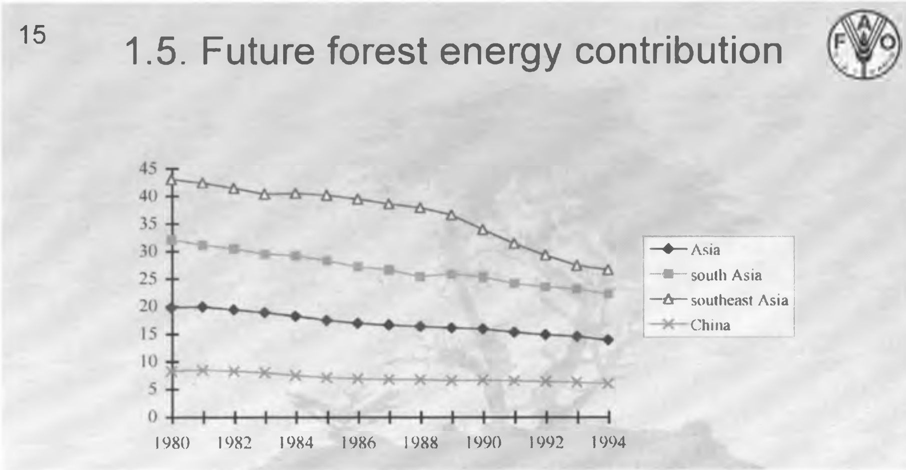

Fig. 10: Woodfuel consumption in Asia 1980-94 (%).

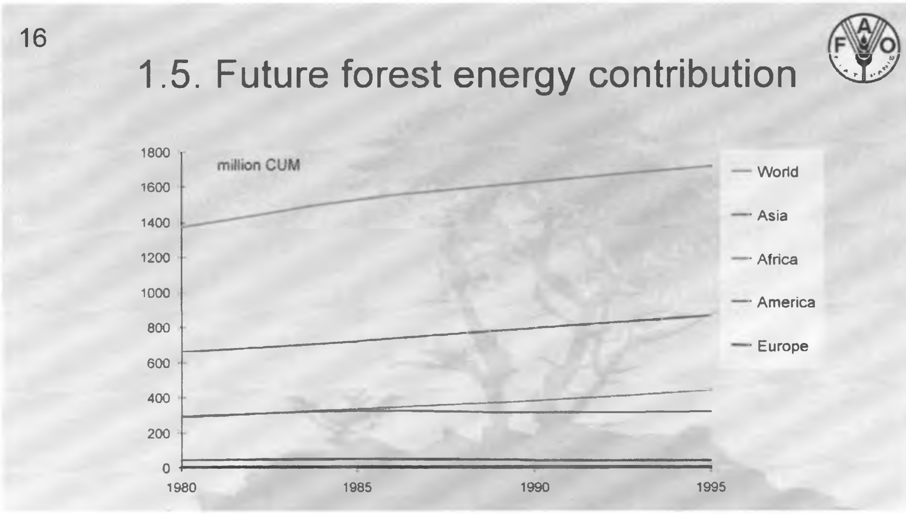

Fig. 11: Woodfuel consumption history.

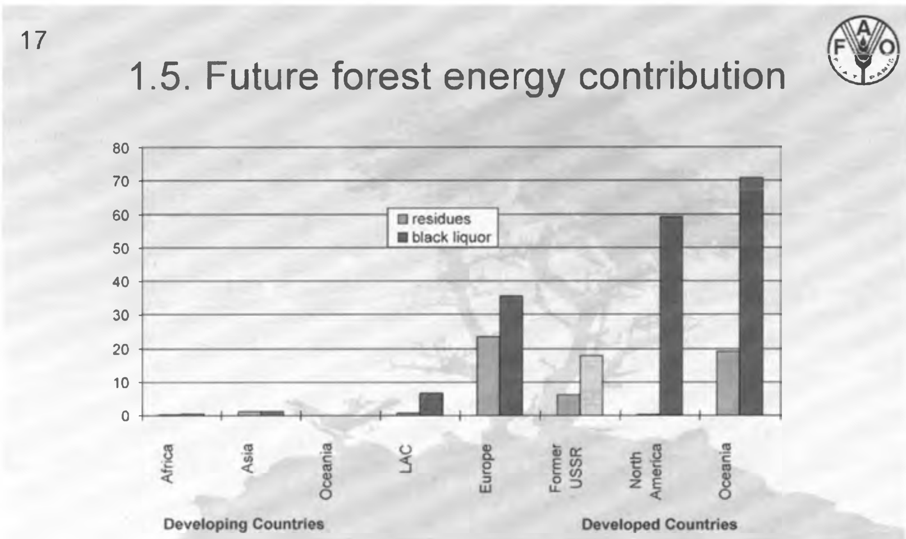

Fig. 12: Forest by-products used for woodfuels (%).

The reasons for this development are manifold such as population growth, poverty or current economic reforms enacted in many countries. The situation is not expected to change dramatically. Fuelwood and charcoal will remain to be an important source of energy. However, as a result of the Kyoto Protocol, it is expected that much more of the woodfuels currently used become more sustainably produced and the use of forest and agricultural by-products derived from the production and processing of different end products such as logging residues, slabs, sawdust, black liquor, bagasse, rice husks, etc. could gain progressively more importance as sources of energy following the trends already adopted in most developed countries (Fig. 12). Especially in developing countries, the by-products form a great potential to be developed.

Forest by-products can become major future sources of energy. One area which still bears a lot of potential is the forest industry, where the equivalent of 4 m^3 residues are left along the processing of 1 m^3 kiln dried timber (Tab. 3).

Table 3: Products and by-products during the first processing of a tree.

Forest by-products	Share of wood harvest (%)
Logging residues	40.0
Kiln dried sawn wood	20.4
Bark	7.2
Slabs, etc.	20.4
Planer shavings	3.6
Trimmings	1.2
Sawdust	7.2

Product diversification is also an interesting future option in agricultural production. A study in Latin American countries provides an historical analysis of the ratio of prices for energy/major agricultural commodities on base of the year 1975 (Fig. 13).

With international energy prices continuously growing or approximately constant over the years and prices of major agricultural commodities remaining constant or decreasing as result of increased global competition and market liberalization, the gap between energy price and commodity prices widened during the past decades. In Latin America, agricultural production had to be constantly increased to receive the same amount of dollars. In the case of electricity, the price more or less stabilized which means that for many industries in forestry and agricultural production the best solution is to diversify their production and to become energy producers/ suppliers in order to face increased competition and to enhance their productivity.

In some agro-industries, this process already started. For example: electricity generation in some sugar mills in Nicaragua and Honduras are already initiated and now they are seeking the association with neighbor forest industries for their supply of woody residues as extra fuel to produce more electricity when bagasse is not available. Another example are pulp and paper mills especially those of developed countries. These now are often increasing their efficiency and productivity as well as profitability by getting surplus of energy which is sold to other users.

FOREST ENERGY CONTRIBUTION TO CARBON SEQUESTRATION AND SUBSTITUTION

Economic aspects

The use of forests and trees for energy has several economic and socio-economic dimensions as well as environmental implications. Generally, it is said that fuelwood has no value. The Regional Wood Energy Development Programme (RWEDP) by FAO in Asia analyzed the economic relevance of woodfuel use at national level based on existing consumption data and using average calorific values and market prices for fuelwood and charcoal (Table 4).

The equivalent value of domestic as well as industrial fuelwood and charcoal totals 29 billion US dollars per year. These figures demonstrate the significance of wood energy for countries' economies. In the case of Thailand, for example, wood energy represents more than 50 % of the total import. If this amount of fuelwood, mainly for heating and cooking, would have to be substituted by gas, LPG or kerosene, one can imagine how much Thailand would have to spend to import this amount of energy.

Another example is the use of fuelwood in electricity generation which is already happening not only in Latin America, Africa and Asia, but also in Europe. The implication of the use of these fuels in biowatt generation for the macroeconomy is exemplified by a case study of sugar mills in Nicaragua conduced by FAO in collaboration with the University of Utrecht (The Netherlands). Fuel costs and energy costs of two sugar mills fuelled by fuelwood, bagasse and fueloil are compared in a macroeconomic analysis (Fig. 14).

When using imported fossil fuels, fueloil to be exact, only 5 % of the costs are locally expended while the production of fuelwood in Eucalyptus plantations results in local expenditure of 67 % of the costs. Nearly the same ratio results when comparing costs for electricity generation. Only 14 % of the money expended by the company remains in the country in the case of fueloil, but 73 % add to the local economy in the case of woody fuels.

The sugar mills in this case study do not only produce sugar and alcohol during the usual six months production period, they also produce electricity all year round thus serving as power plant for the surrounding areas. Fuelwood is delivered from a Eucalyptus plantation in the marginal land which was established about 16 years ago. The prices for the electricity generated by different kind of fuel mixes vary from 4.3 ct/kWh based on wood and bagasse at zero costs up to 5.7 ct/kWh based on wood

Table 4: Values of fuelwood (FW) and charcoal (Char) in households (Dom.) and industries (Ind.) in Asia (million US$).

Country	Fuelwood	Charcoal	Dom. FW	Dom.Char	Ind. FW	Ind. Char	Total
Bangladesh	306	-	255	-	50	-	306
Bhutan	37	3	33	-	3	3	40
China	9 320	-	9 320	-	-	-	9 320
India	9 080	-	8 440	-	640	-	9 080
Indonesia	2 317	-	2 317	-	-	-	2 317
Laos	88	-	88	-	-	-	88
Malaysia	31	49	31	49	-	-	80
Maldives	3	-	3	-	-	-	3
Myanmar	914	213	914	213	-	-	1 127
Nepal	469	-	451	-	17	-	469
Pakistan	1 318	-	1 317	-	-	-	1 318
Philippines	618	491	618	491	-	-	1 109
Sri Lanka	463	5	363	-	-	-	440
Thailand	432	1 595	432	1 595	-	-	2 027
Vietnam	1 139	139	1 055	133	-	1	1 278
RWEDP	**26 506**	**2 494**	**25 637**	**2 481**	**710**	**4**	**29 000**

and bagasse at the same price. Based on oil, costs rise up to 6.8 ct/kWh which makes biowatts considerably cheaper. Similar findings are reported from other studies, e.g. the EC-ASEAN COGEN Programme which is besides others working with rice mills.

Socio-economic aspects

The different energy options of fuelling the sugar mills were also analyzed in terms of employment (Fig. 15).

In the Nicaraguan example, the generation of employment of high cost is approximately the same for all the options. Similar impacts are observed when analyzing investment and maintenance costs for the power plants. However, the socio-economic impact of operating power plants with different fuel options shows that the use of woodfuels (fuelwood combined with bagasse) provides nearly 30 times more employment at low cost than burning fueloil.

A study in Sweden analyzed the manpower needed (number of persons per year) in different energy generating systems connected to forestry activities to produce the same amount of energy per year (Table 5). Compared with coal, the wood energy system offers about 8 times more employment.

These topics are of special interest for rural areas of developing countries where most people are affected, among other aspects, by poverty, lack of investments and land degradation which oblige them to migrate towards urban areas where they find other conflicts derived from lack of employment opportunities due to economic reforms enacted, the modernization of the industrial sector, etc.

Another study of employment opportunities provided by the energy sector also reveals the options offered by bioenergy (Table 6). The fuelwood system employs about 10 times greater manpower than the kerosene system, in the case of charcoal production employment opportunities are even up to nearly 20 times greater.

Therefore, forest energy has to be analyzed, planned and implemented not only from an environmental point of view but also as a mechanism to channel investments into rural areas and to redistribute national incomes by creating new jobs in poor areas.

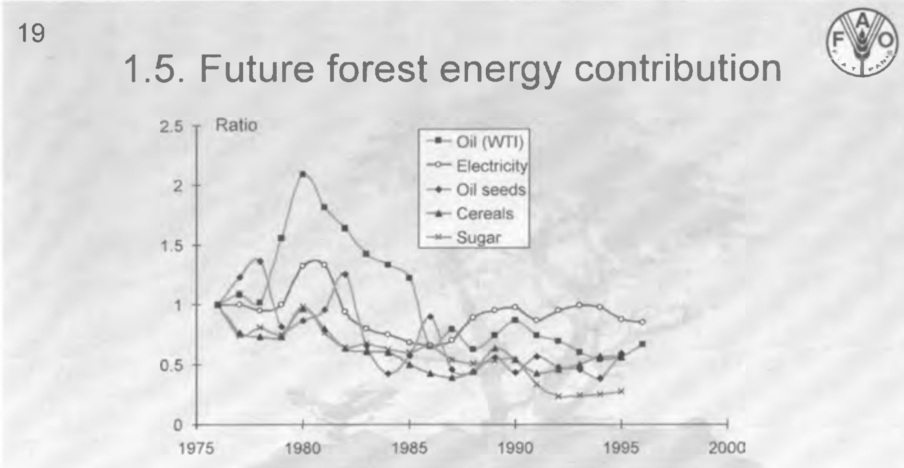

Fig. 13: Energy vs. agricultural commodity prices (Latin America, inflation considered).

Table 5: Employment required in different energy systems to produce the same amount of energy.

Production system	Manpower per year
Sawmills	8
Recycled use	13
Logging residues	32
Residues pulp and paper industry	34
Direct harvesting of fuelwood, manual	73
Direct harvesting of fuelwood, mechanical	35
Woodfuel for small scale household use	63
Willow short rotation coppice, manual harvesting	113
Willow short rotation coppice, mechanical harvesting	25
Canary Reed	26
Straw	23
Coal	8

Table 6: Employment generated by bioenergy options.

Fuel type	Quantities of fuel per Tera Joule (TJ)	Estimated employment per TJ consumed in persons/day
Kerosene	29 000 litres	10
LPG	22 tons	10-20
Coal	43 tons	20-40
Electricity	228 MWh	80-110
Fuelwood	62 tons	110-170
Charcoal	33 tons	200-350

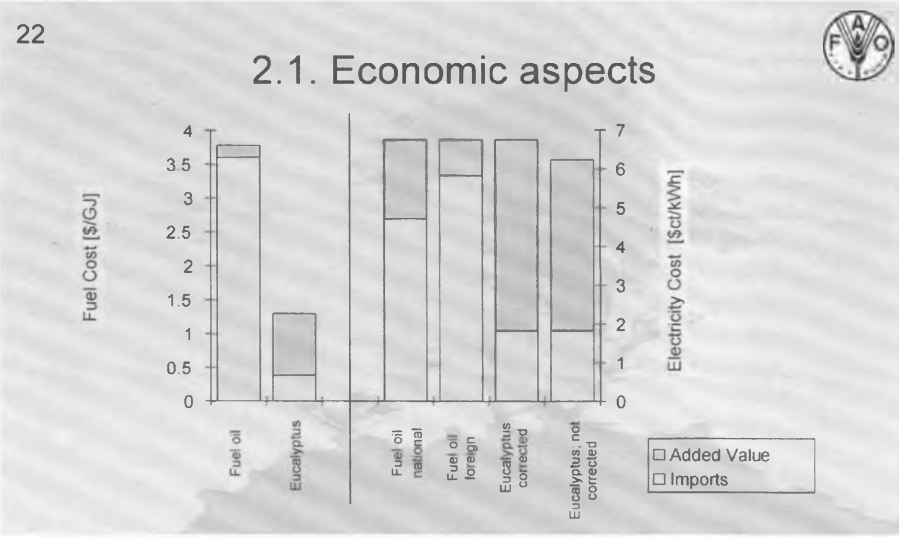

Fig. 14: Macroeconomic analysis of biowatt generation.

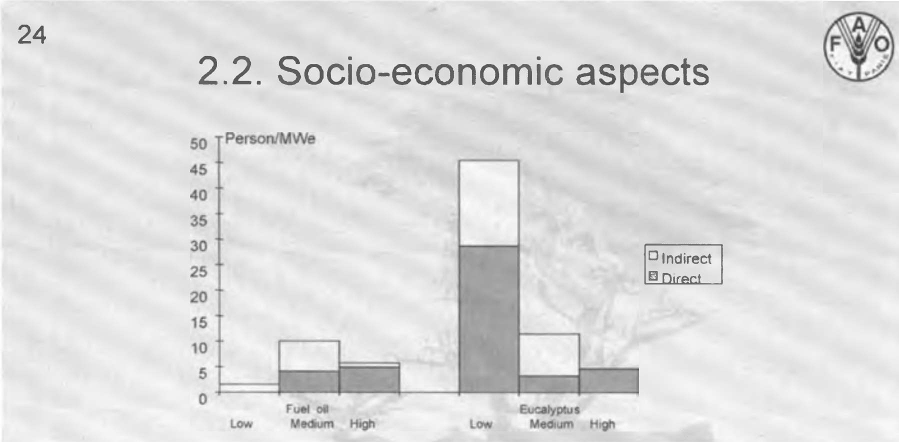

Fig. 15: Employment generated in biowatt plants in Nicaragua.

Environmental aspects

One of the main topics of discussion with regards to forests during the meeting in Kyoto was the role of the forest as a mechanism for carbon sequestration. This offers the opportunity for reafforestation of great areas. But, will this be enough? Who is going to provide the land? In our view, forest energy may play in even larger role in future, not only for storage of carbon but also for substitution of carbon. It is urgently needed to make this carbon sequestration/carbon substitution start to work in this process.

The study on the Nicaraguan sugar mills also included investigations on CO_2 emissions of different type of fuels. The comparison of emissions of burning fueloil and of Eucalyptus reveals (Fig. 16) that CO_2 emissions derived from the utilization of fueloil are about 30 times higher than those derived from the woody fuels. Additionally, it has to be considered that woody fuels release the carbon which they sequestered during their life span, thus the overall effect is even greater.

A lot of research is concentrated on emissions from wood burning. Also the Kyoto meeting concentrated on woodfuel utilization in terms of producing pollution. The other aspect, avoiding of emissions of fossil fuels through the use of woodfuels is unfortunately often neglected.

The implications of woodfuel utilization for traditional energy (mainly heat production) for the global environment was investigated by the FAO-RWEDP project for 16 Asian countries. Greenhouse gas emissions derived from different fuel options to meet the energy needs of the household sector were calculated considering the various energy mixes in the different countries. The calculation in Table 7 is focused on CO_2 emissions assuming that

- most woodfuels used in the 16 Asian countries under study are produced on a sustainable basis, particularly those woodfuels originating from agroforestry and community forestry schemes on farming land,
- most of forest-by-products derived from logging activities and forests industries are used as fuels instead of being left in the field and emitting CO_2 as result of decomposition.

The results show that woodfuel use in 1994 avoided the accumulation of 278000 ktons of CO_2 hypothetically produced by use of LPG which produces the least emissions of the fossil fuels. This amount represents approximately 6 % of the total CO_2 emissions in these countries. By the year 2010, this amount could grow to 349999 ktons representing about 35 % of total emissions. The monetary benefit derived from the current use of woodfuels represents

Table 7: Implication of woodfuel use on CO_2 emissions in 16 Asian countries.

Environmental effects	**1994**	**2010**
CO_2 emissions from fossil fuels (1000 tons)	4 317 000	10 602 000
CO_2 emissions avoided through woodfuel use (1000 tons)		
as compared to LPG	278 000	349 000
as compared to kerosene	334 000	420 000
as compared to coal	560 000	703 000
CO_2 costs avoided, as compared to LPG (million US$)	**14 000**	**17 500**

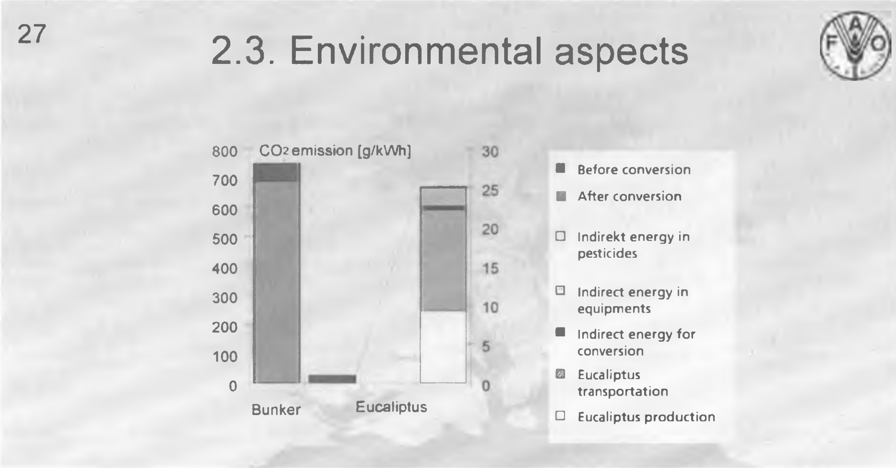

Fig. 16: Bunker vs. biofuel emissions from a power plant.

US $ 14 billion on the basis of current costs for CO_2 absorption in 1994.

In view of these figures, the Kyoto follow up actions focused on planting forests and trees for carbon sequestration are good, but not enough. Existing forests and trees and new plantations can play a greater role if they are planned not only for carbon sequestration but also for carbon substitution. Additionally, the impacts in terms of employment and income generation leading to a real process of the promotion of sustainable development have to be taken into consideration.

INSTITUTIONAL ISSUES

Institutional barriers

In the area of institutional aspects, barriers prevail. The most crucial ones are the lack of:

- political and public awareness of the role of forest energy to combat climate change;
- national capabilities to develop forest energy programmes;
- interrelations among different public and private organizations involved in wood energy issues, in particular among forestry, energy, environmental and rural development agencies;
- information and data crucial for sustainable forest energy and forest management; and
- Research & Development of new technologies to produce more bioenergy with less fuels at lower costs.

The real role which woodfuels and energy generated by woodfuels play as well as their value are still not properly recognized by the major actors of the forestry, energy, environmental and rural development sectors of both public and private agencies. This is in particular true for the role of forest energy in combating climate change. The biomass sector has not yet been able to mobilize investments into a business.

The greater part of the human resources available particularly in the developing countries are not properly trained for monitoring, planning and developing sustainable wood energy systems. The few existing systems are very weak. Communication among forestry, energy, environmental and rural development agencies is practically not existing, consequently, market structures for bioenergy are lacking and human resources are not prepared to manage a business of growing fuelwood up to running a power plant.

Wood energy systems are site specific and relatively complex systems. Data and information about use, trade, markets and supply sources are relatively scarce, out of date and unreliable. Moreover, available data banks on wood energy on national, regional and international level are plagued by different terminology, definitions, units and conversion factors.

Research and development of technologies offer a wide range of opportunities for improvement, e.g. in the case study of the Nicaraguan sugar mills, the efficiency of electricity production ranges between 18 and 22%. Especially in developing countries process oriented new technologies are needed in order to improve the efficiency of woodfuel use, enhance the productivity of forest plantations for energy purposes and reduce its production costs, identify opportunities for wood energy and mechanisms for the financial support of wood energy programmes. In a lot of cases, this is just a question of transfer.

The Kyoto Protocol might be a key mechanisms to change this situation. In Kyoto, countries have agreed to achieve quantified emissions by 2010 through:

- the implementation of policies and measures for carbon sequestration (protection and enhancement of carbon sinks) and carbon substitution (using wastes, environmentally sound technologies and renewable sources of energy); and
- the formulation and implementation of regional and national programmes to mitigate climate change.

However, the rules governing greenhouse gas emissions and removals do not yet include the role of forests and trees for carbon sequestration and substitution. Other factors such as deforestation, use of different forestry and acricultural by-products, land use changes as well as food production have to be re-examined in the light of different environmental conditions.

Many countries are still uncertain about the position to be adopted and action to be taken for the development of Joint Implementation projects. FAO, jointly with other international organizations, can play an active role to assist these countries.

CONCLUSION

Forests and trees

- are a cost-effective source of fuels to combat climate change through carbon sequestration and carbon substitution;
- in traditional and modern energy systems can be integrated with conventional forest and agricultural activities;
- used for energy can channel funds to rural areas thus generating new jobs and incomes;
- can provide biofuels in a sustainable manner using existing mature technologies; and
- used for energy have not yet received the attention they deserve by public and private organizations; consequently, political and public awareness needs to be raised and national capabilities enhanced.

RECOMMENDATION

Mobilization of funds and assistance to develop forest energy through

- raising of political and public awareness about the role forests and trees play and have to play in future in combating climate change. Moreover, forestry policy and decision makers play a crucial role for the development of concrete actions in the field with respect to the enforcement of sustainable forest management
- creation and enhancement of national capabilities
  - information and data systems
  - human resources development
  - development of policies, programmes and projects for forest development and tree plantations for carbon sequestration and substitution.

In particular, strengthen forest services which are in most of the countries extremely weak and understaffed with regard to their responsibilities and functions

- improved partnerships among forest, energy, environmental and rural development agencies
- Research & Development, as well as transfer of technologies
- improvement of existing technologies not only for more efficiency of woodfuels but also for the development of sustainable systems.

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Author's address

Dr. Miguel A. Trossero
Forest Energy Initiatives
FAO-Forest Products Division
Viale delle Terme di Caracalla
00100 Rome, Italy
e-mail: miguel.trossero@fao.org

Energy-Related Services and Global Environmental Concerns – What Possible Strategies for Forestry?

Jean-Marie Bourdaire and Jane Ellis

Introduction

Biomass is used for energy purposes both in industrialised and in developing countries. The importance of biomass energy use is generally higher in developing countries, due to its ready availability and cost compared to other energy sources. However, the focus on issues surrounding biomass energy use is very different in industrialised (OECD) and in industrialising (mainly non-OECD) countries. This paper outlines the biomass energy situation at a global level, while also distinguishing between the differences in biomass uses, outlooks and policies at an OECD and non-OEDC level.

Economic development strongly influences energy demand patterns. When purchasing power grows, consumption shifts to more practical and efficient energy sources, from non-marketed to marketed energy further followed by a transfer from fossil fuels towards electricity. In mature countries, energy intensity decreases over time, with a move towards "noble" energy forms. Thus, in OECD countries consumption patterns have successively changed; first from wood to fossil fuels and then to electricity. This is also seen in some non-OECD countries. This move reflects the convenience of such fuels in terms of transportation and flexibility of end use. It should be noted that these rates of change slow over time.

Even in developing countries, where biomass may account for a majority of energy consumption, there is a noticeable move from non-marketed to marketed energy. The transfer to marketed energy is made through fossil fuels. To date, there have been no examples of direct transfers to electricity. At the same time, in rural regions, biomass maintains an advantage thanks to its widespread, cheap availability.

The use of biomass for energy supply has many associated environmental externalities. Negative environmental externalities of biomass energy use include deforestation, and associated problems such as decreased biodiversity, erosion, changes in sedimentation patterns and changes in soil moisture. It is difficult to evaluate total environmental effects due to large knowledge gaps in data. Many countries do not have an accurate picture of biomass energy supply, potential demand or deforestation (often

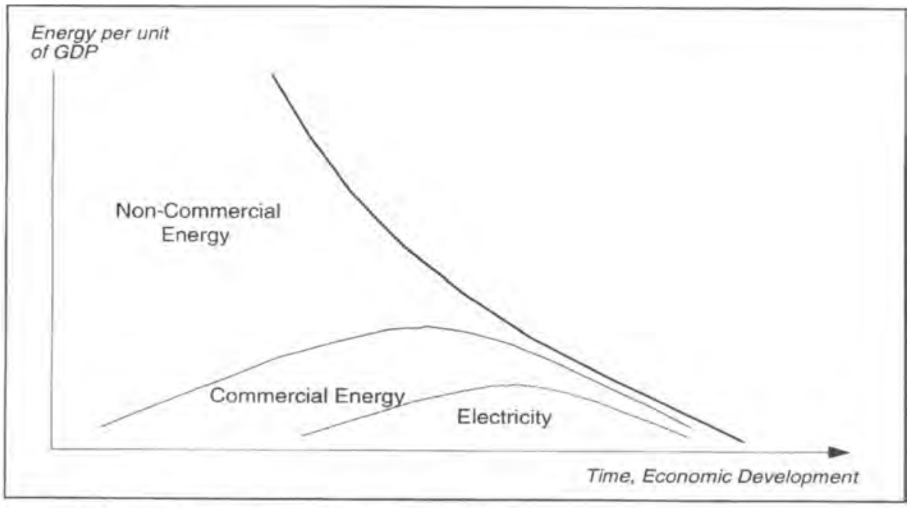


Fig. 1: Evolution of Energy Intensity: An Illustration.

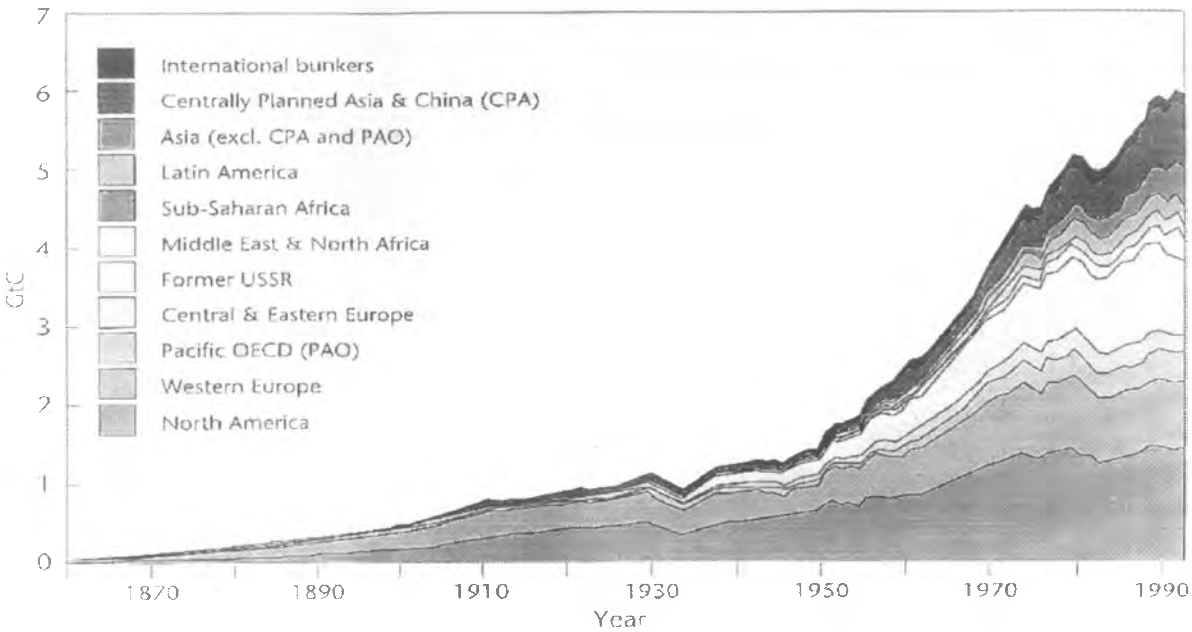


Fig. 2: Global energy-related emissions of CO_2 (billion tons carbon per year). Source, IPCC 1996.

due to non-energy uses of biomass such as agricultural clearing).

On the positive side, the sustainable use of biomass energy can enable countries to slow the growth in emissions of anthropogenic CO_2, and can also decrease the level of certain industrial agricultural waste streams. The potential for biomass energy to contribute towards sustainable energy use, and in particular the role of biomass energy in helping Annex I countries (essentially the OECD and Central and Eastern Europe) to meet their commitments under the UNFCCC is one of the driving forces in the increased biomass energy use in many of these countries. Let me say a few words about the Framework Convention on Climate Change, and the commitments from the Convention for Annex I countries (All IEA countries are included in Annex I).

Emissions Commitments of Annex I Countries

In 1992 in Rio, the World's nations, recognising the threat of climate change, launched a process aimed at stabilising concentrations of greenhouse gases at a level that would prevent 'dangerous anthropogenic interference with the climate system.'

The industrialised nations, that is the OECD countries and mature countries with economies in transition[1], are responsible for the greater part, by far, of the build-up of greenhouse gases in the atmosphere. They have therefore accepted the responsibility to take the lead in addressing this issue. I propose to concentrate, in this paper, on the energy implications of that commitment and on the role of biomass energy.

The initial aim, adopted in Rio, was to bring Annex I countries' greenhouse gas emissions in the year 2000 back to 1990 levels. Subsequently, in Berlin in 1995, the Annex I Parties agreed to strengthen their commitments. They undertook to negotiate towards a protocol, adopted last December 1997 which relates to the period after 2000 and sets quantified emission limitation and reduction objectives for the period 2008–2012. Consistent with the Geneva Declaration of 1996 (at the second Conference of the Parties) the emission limitation and reduction objectives are legally binding.

This protocol agreed upon in Kyoto at the end of 1997 (which will be legally binding after ratification) calls for a cut in greenhouse gas emissions[2] from Annex I countries to approximately 5 % below their 1990 levels by approximately 2010. The negotiations were, generally, conducted by Environment Ministries and Foreign Ministries. But energy ministers, recognising the major contribution to CO_2 emissions made by energy production and use, have, over several years, agreed that energy must be a major part of an "achievable, realistic and cost-effective" solution to the climate change problem. That is why I should now like to focus on the energy implications of these existing and prospective commitments.

Given that is the industrialised nations who have so far made the most explicit commitments, and the place which energy is bound to play in discharging those commitments (since energy-related CO_2 accounts for more than two-thirds of anthropogenic greenhouse gas emissions), it will be no surprise to you that the International Energy Agency (IEA), which brings together the energy interests of the major mature countries, has been deeply involved, from the outset, in the processes associated with the UN Framework Convention on Climate Change. On the basis of the analytical work carried out between the member nations and within the secretariat we have:

- contributed to the formulation of the standards applied by UNFCCC nations in reporting their greenhouse gas emissions, and helped to evaluate countries' National Communications;
- brought our unique expertise in energy statistics for both IEA and non-IEA countries, and helped to evaluate those national returns;
- with the OECD, provided analysis of a number of potential response options, e.g. increased use of renewables; elimi-

1 In this context, these countries are known together as the 'Annex I' countries.

2 The gases covered by the Kyoto protocol are CO_2, CH_4, N_2O, HFCs, PFCs and SF_6.

nation of subsidies; voluntary agreement with industry; tradable permits;

- at the request of the member states of the OECD and IEA, provided secretariat backing to the Climate Technology Initiative, which those states announced in Berlin.

There have been many other aspects to our involvement, including one of our most recent contributions to the process, which will be my cue to go more specifically into the energy aspects of these questions.

In March 1997, the IEA countries released to the climate change negotiators, a statement on the Energy Dimension of Climate Change (EDCC) which was further endorsed by the IEA Energy Ministers at their June 1997 Ministerial meeting. The purpose of this was to provide an authoritative, constructive, and realistic input to negotiations. This statement is the only document, apart from national governmental submissions, to form part of the negotiating texts underlying the present phase of the negotiations.

This EDCC Statement presents past trends in energy consumption, related CO_2 emissions, and the conclusions which can be drawn from these trends. It does so by analysing three main energy-related services (rather than the conventional analysis by fuel or by consuming sector as a function of time): electricity (demand and generation), mobility and heat (i.e. fossil fuel end use) as a function of GDP. The objective is to improve understanding of the challenges ahead under the Climate Convention, to try to ensure that decisions bearing on the energy sector are realistically based, and to identify priority areas for action.

Biomass Energy Use in Context

Four broad categories of biomass use can be distinguished:

a) basic needs e.g. food, fibre, etc.;
b) energy e.g. domestic and industrial;
c) materials e.g. construction; and
d) environmental and cultural e.g. the use of fire.

Biomass use through the course of history has varied considerably, greatly influenced by two main factors: population size and resource availability.

Since the annual photosynthetic production of biomass is about eight times the world's total energy-use, and this energy can be produced and used in an environmentally sustainable manner, while emitting no net CO_2, there can be little doubt that this potential source of stored energy must be carefully considered in any discussion of present and future energy supplies. The fact that nearly 90 % of the world's population will reside in developing countries by about 2050 probably implies that biomass energy will be with us forever unless there are drastic changes in the world energy trading patterns.

Biomass use varies widely from country to country. It is the 4th largest energy source world-wide, accounting for approximately 15 % of total energy supply. It is also the predominant renewable energy source. However, data and statistics are difficult to collect. Unlike many fuels (i.e. fossil fuels or electricity), biomass fuels are often gathered by individuals for individual use. Therefore, much of this use is "non-marketed", which prohibits accurate monitoring.

Information on biomass production and use patterns is grossly inadequate even as a basis for informed guesses, let alone the making of policy and the implementation of plans. In the 1980s there were extensive debates as to whether a number of countries had a 'woodfuel gap' between fuelwood supplies from forests and woodlands and the use of fuelwood. Estimates of biomass energy use are consequently only approximations and reliability of data varies significantly according to the methodology used (i.e.: questionnaires or selected measurements on a sample population) and the type of information gathered. The balance between marketed and non-marketed energy can also influence results (i.e.: is wood use for charcoal production correctly reported? The primary fuel, wood, is often harvested on non-commercial grounds whereas charcoal is commercially marketed).

However, good statistics are vital to understanding the changing nature of energy supply/demand. Biomass is such an important energy source that analysis will be biased if it is missing from a country's energy balance. Knowledge of current biomass use is important to determine common indicators such as energy intensity and energy consumption per capita. We also need to be able to project future changes in biomass energy use, since they have far-reaching consequences on a country's future energy situation due to the diversity of potential biomass use together with the growth of population and the shift from non-marketed to marketed energy. While the use of biomass could continue to grow to unsustainable levels, the move to marketed energy may result in higher demand for petroleum products and other fossil fuels.

Current Levels of Biomass Energy Use

Wood and charcoal fuelled industrial development until well into the 19th century in Europe and it was not before the second half of the 19th century that, in a country like France, forest acreage ended its continuous historical decline and started to extend again (and is still growing today). This trend is explained by the growth of fossil energy which has marked the beginning of the industrial era. Fossil energy has fuelled economic growth in industrialising countries, leading to a sharp increase in greenhouse gas emission levels and their build-up in the atmosphere. But throughout history and even nowadays, the link between energy use and economic activity is by no means "one for one". On the contrary, our experience is that the amount of energy (taking together use of commercial and non-commercial energy, e.g. fuel-wood) required to produce a unit of output tends to decrease over time in parallel with the growth of economic productivity and economic output. In short, energy intensity decreases over time according to the three following stages:

- a shift from non-commercial to commercial energy (for heating and transportation) which is more efficiently used because of the technology/economic drive;
- an increase in efficiency in commercial energy end-use and moves towards less energy-intensive industrial activities; and
- the penetration of electricity which substitutes for direct fossil fuel uses for energy services, including maybe one day oil-driven mobility.

Non-OECD countries account for the majority of world biomass use. In OECD countries, the proportion of biomass in total energy supply is relatively low (around 3 % of TPES), whereas it averages approximately 30 % in non-OECD countries. In mature countries, it is mainly used to provide heat in the residential sector, or as a fuel in the industrial sector or for power generation. In some non-OECD countries, it is the most important energy source and is generally used for cooking or heating. Biomass energy supplies more than 90 % of the energy needs of some countries (e.g.: Nepal, Tanzania and Uganda).

Types of use vary significantly between countries depending on many factors including fuelwood availability and weather patterns, population growth and rural/urban population split, energy demand and technological advances, demand for food and other goods, changes in the supply pattern of other fuels, infrastructure developments, etc.

One can expect demand for biomass to rise, maybe considerably, in the future because of first, population growth, particularly in developing countries; second, greater use in the industrial countries due partly to environmental considerations (in particular, OECD countries are trying to increase their use of modern biomass to mitigate CO_2 emissions); and, third, technologies presently being developed will allow either the production of new or improved biomass fuels, or the improved conversion of biofuels into more efficient energy carriers and thus stimulate demand for feed-stock. In the OECD, biomass energy consumption is projected to grow faster than the projected growth rate of total energy supply, increasing its relative share in this world regions.

Recognising the growing weight of developing countries in the world energy scene and the importance of biomass energy within those markets, the IEA has increased its work on biomass energy use in non-OECD countries. The project "Assessing Biomass Energy Use in Non-OECD Countries" comprises two interrelated initiatives. The first one is the compilation and publication by the Energy Statistics Division of reference biomass energy data. The latest edition of the *Energy Statistics and Balances of Non-OECD Countries* includes the latest available biomass energy statistics for all non-OECD countries and regions, disaggregated, as far as possible, into subproducts and end-use sectors. The next step is to compile and/or estimate biomass energy historical series for the period 1971–1996.

The second part of the project is carried out by the Economic Analysis Division which is responsible for producing long-term analyses of energy demand that underpin different work such as climate change policies, energy efficiency indicators, pricing policies, etc. carried out by the IEA. It is developing a new version of its well recognised World Energy Model (WEM) in order to produce a new "World Energy Outlook" which will set out the IEA long-term projections of energy supply and demand.

Neglecting biomass has been identified as one of the major weaknesses of the past analytical framework of the WEM. Work is underway to integrate biomass energy in the WEM and to produce long-term biomass projections for the main non-OECD regions for inclusion in the forthcoming *World Energy Outlook 1998*.

Current Reality of the Energy Scene

The analysis in the Energy Dimension of Climate Change starts from the obvious point that energy is an essential factor of economic activity which is consumed not for its own sake, but for the services it provides. The three principal energy services are:

- mobility,
- electricity, and
- heat, or stationary fossil fuel and biomass end-uses (other than electricity).

We can identify certain similarities, across countries in the evolution of the three services (mobility, electricity and stationary fossil-fuel end-uses) over the last three decades, when observed against the evolution of gross domestic product. But there are also differences, which stem from different energy endowments, climate, geographical situation, population dynamics and end-use prices.

Norway, for example, relies almost exclusively on hydro power for electricity production, while producing growing volumes of oil and gas for export. Countries with large domestic resources have tended to attract energy-intensive industry; others may have relatively high energy prices, reflecting the internalisation of security concerns. Is either category more virtuous than the others in terms of CO_2 emission controls?

Returning to the three basic energy services, and looking at experiences across the IEA countries as a whole, the links with GDP have been as follows:

- there appears to be a linear trend between GDP growth and electricity demand, which goes unaffected through the oil shocks, but with significant differences in terms of fuel inputs across countries and hence differences in CO_2 emissions;
- there is an almost linear link between energy use in transport and GDP, with the exception of North America, where a high starting point and the implementation of *corporate average fuel economy standards* resulted in a downward shift at the time of the second oil shock (1979–1982);
- there is a broken trend in the use of energy for heat, with adjustment of the trend and of its slope downwards after each oil shock.

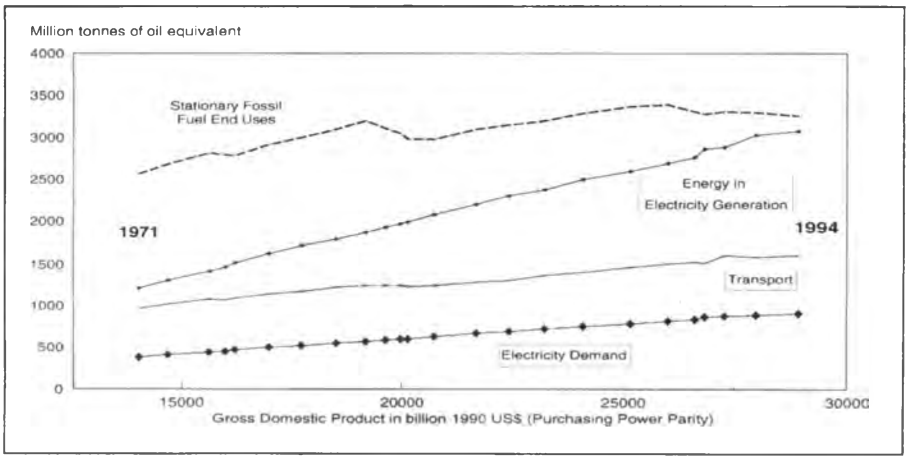


Fig. 3: World Energy Demand: a Sectoral View 1971–1994.

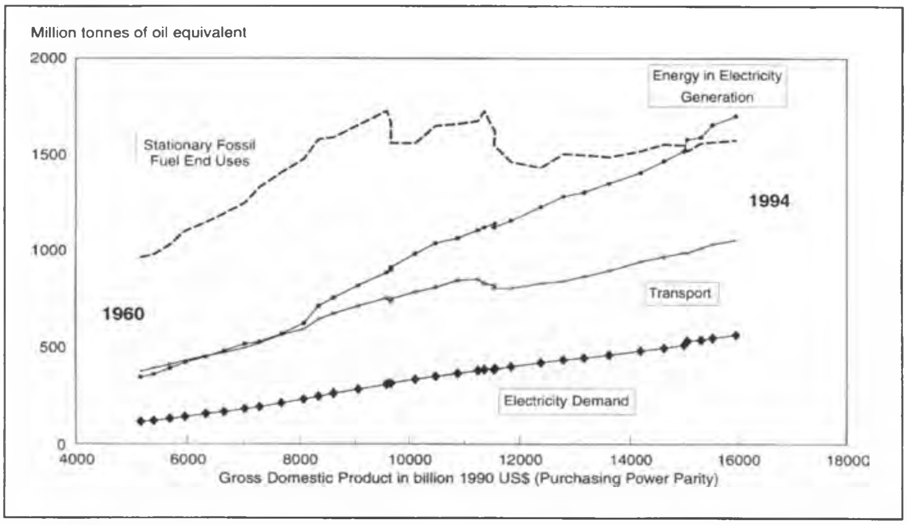


Fig. 4: Energy Demand in IEA Countries: a Sectoral View 1960–1994.

With the exception of the power sector, where significant decarbonisation was achieved through fuel switching (mainly to nuclear power), similar trends can be observed for energy-related CO_2 emissions. With stationary fossil fuel use representing a barely growing (yet large) element of overall emissions, and emissions from the two other services rising alongside GDP, clearly reducing overall CO_2 emissions in the energy sector from current levels presents no easy option.

Trends and Policies in Energy Services: Lessons from Past Trends

What should these trends suggest to policy makers? Elaborating successful strategies for sustainable climate-friendly energy systems obviously requires an understanding of these historical trends and how past policies and measures have influenced energy consumption in the three sectors: mobility, electricity and heat.

I will look at each of these three services separately, but let me say first -- in case we get too depressed at the evidence of the trends – that most programmes to reduce energy consumption among IEA countries have in the past been limited, either in their scope or over time, since they were primarily driven by the two oil shocks. For more than ten years now, IEA countries have enjoyed stable or declining energy prices in real terms, which has reduced incentives to save energy. Lessons need to be drawn from the sectoral approach I am using here, but we should not preclude the possibility of a sustained departure from past trends stemming from the sort of basic revaluation of social and economic priorities which one might read into the evident political priority of environmental concerns today in some North European countries; and there is always room for, and a need for, a more thorough analysis, at the sub-sectoral level, of the dynamics of energy uses and their associated CO_2 emissions. In fact such detailed analysis has started since 1995 in the IEA with major works on "energy indicators".

So, let us consider each of the three service sectors in turn.

Electricity: offsetting trends, the apparent role of prices and technological change

First, improvements in the energy efficiency of individual electricity-using appliances have to some extent been offset by the development of new uses of electricity. Electricity demand, in total, is very closely linked to the level of total economic activity. That link seems to be a particularly tough one to break. Yet at the same time, the electricity intensity of GDP varies a lot across countries. The IEA view is that one should not let up on efforts to improve efficiency in the end-use of electricity, even though increased efficiency may result in new demand for electricity services.

Second, the different levels of total electricity needs relative to GDP across IEA countries are apparently mostly explained by the price environment in the various countries. Price levels are normally linked to the availability of resources domestically and, to a lesser extent, to the conversion technologies used.

Third, significant changes have occurred in the fuel mix of power generation either because of changes in relative fuels pricing at the oil shocks or country shocks because of the CCGT technological breakthroughs. The penetration of non-fossil fuels has resulted in lower CO_2 emissions per unit of electricity produced. The thermal efficiency of fossil based power plants is improving, though the improvement overall is only gradual, as old thermal plants are replaced by more efficient technologies. Since the IEA countries as a whole are in a situation of overcapacity (30 % overall), the pace of change for them is slow. How deregulation in the electricity market might affect this process is uncertain. It should lead to lower prices (which do not favour investments in new capacity) but it may also lead to earlier retirement of older, less efficient plants. Furthermore, because of the economic turmoil of the economies in transition, they too suffer from large electricity power overcapacities.

The lessons one would draw, in terms of the way forward in reducing CO_2 emissions from electricity are these:

- capture every opportunity for improvement as capital stock is retired. Since most of the new capacity is being installed outside the member countries of the IEA, great importance attaches to the development of a full co-operation either through the new mechanism set out in the Kyoto Protocol, the "clean development mechanism", or the further development of trading with Annex I countries;
- wherever possible, increase the share of non-greenhouse gas emitting generation systems, such as large-scale hydro (though there is limited potential for expansion in IEA countries) and other renewables, including biomass-based systems. Biomass energy systems can be competitive in certain situations (such as electricity generation from bagasse), may benefit from economic and fiscal incentives (e.g. in Sweden, Austria and Denmark) and may also have potential niche markets for such systems. In many countries biomass energy systems are

not exploited to their full potential. Expanding nuclear power as a means of lowering the CO_2 intensity of electricity production may also be feasible in some countries, where public acceptance exists;

- increase the thermal efficiency of fossil power generation, through the penetration of combined cycle gas turbines, combined heat-and-power technologies and coal gasification; and
- remove subsidies favouring fossil fuels for power generation.

This brings me to my first conclusion for biomass: *there is significant potential for biomass-based electricity generation in the longer term. However, despite biomass playing an important role in the electricity generation of some individual countries, it is unlikely that, on a regional scale, biomass electricity will be a major player in short-term total electricity generation in either industrialised or developing countries.*

Another possible marriage of biomass and electricity exists for those countries where electrical home heating is commonly used. Peak demand for electricity can be switched to biomass if one accepts to use a fireplace at such times.

Demand for mobility: the overwhelming contribution of oil, the achievement of past policies and the role of prices

Turning now to the service I have described as mobility, I want to draw out three features from the observed trends:

First, oil is overwhelmingly dominant in the transport sector (about 98 %). Its share of the sector has increased over the last 35 years, gaining over natural gas and electricity. In IEA countries as a whole, this reflects a decline in the share of public transportation and rail, and a raise in the share of private cars and road freight.

Second, it appears that the policies that most significantly altered the trend of oil demand from transportation did so by addressing the average efficiency of the whole fleet of new cars, or by discouraging the purchase of energy-intensive cars through the imposition on them of high sales taxes.

Third, among other factors such as geography, population density and urbanisation, the price of transportation fuels has been a major determinant of the intensity of transportation in any given country. This operates through influence on car design, on car usage and on the split between road and rail usage.

Although some countries have introduced policies designed to promote via subsidies the increased use of biofuels (derived from agricultural crops) in transport, their present contribution to transport fuels is tiny, and such fuels are unlikely to economically satisfy a significant proportion of transport fuel demand in the foreseeable future. Biofuels are therefore unlikely to have significant impact on the levels and nature of biomass cover within a country. I will therefore not go into details about the challenge of this sector, which is to find ways of improving energy efficiency so as to provide the same service with less greenhouse gas emissions.

Energy fuel demand for heat purposes: responsive to price changes, now roughly stable in IEA Countries, but still representing an important share of CO_2 emissions

I turn now to the stationary end-use of fuels. The breaks in the trend lines in this sector in 1973–1975 and 1979–1982 demonstrate that substantial energy savings did take place as a result of the two oil shocks and the associated macroeconomic recessions. These were due both to the discarding of old, less-efficient plants and to energy savings (e.g. improved insulation and new heat exchangers) in retained industrial plants and shells. Continued application of efficiency programmes designed at the time of the oil shocks, including energy efficiency audits, building codes, and other efficiency standards, has been more successful in commercial and industrial buildings. Yet it seems that additional efficiency policies have had very little effect (trends are quite unaffected since 1982). And of course, we have been experiencing structural change in IEA economies, with some industrial relocation outside the region as the service sector grows in importance.

While mobility and electricity demand are growing consistently in all countries, the trends of commercial fossil fuel and biomass for stationary end-uses, mostly heat-raising, have been very different in IEA and developing countries. While the use of fuels in stationary end-uses have mainly stabilised in the former group of countries, it is still growing at a fast pace in the latter, even though there is evidence that trends in these countries are also bending downwards. This raises a fundamental question: why? What is the contribution of the progressive substitution of non-commercial biomass by fossil fuels, and what is the role of industrial delocation from the IEA to developing countries?

In IEA countries, there is a clear inverse correlation between fossil fuel prices and demand for fossil fuel-based heat, with a lasting impact on the fossil fuel use for heat across IEA countries. Industrial companies generally have become much more conscious of the place of fuel costs in their product cost structure and the scope which exists to contain that element of cost, for example by switching (where possible) in the Scandinavian pulp and paper industries, depending on the spot price of electricity. However, short-term fuel switching is not available as an option in many sectors, and moreover there is a lack of market for biomass in some countries and sectors (e.g. government buildings).

The last lesson to draw out is the striking evolution of the fuel mix in IEA countries:

- coal use has either stabilised or is declining (the slightly rising trend in industry, mostly steel, being offset by the decline in other sectors, particularly households);
- the share of natural gas is steadily increasing;
- oil has been relegated to a marginal fuel;
- biomass energy use is marginal except in selected industries, such as pulp and paper, and in residential use in some countries.

For policy makers, these trends suggest the following approaches:

- increase the share of gas, which is a less GHG-intensive fuel;
- remove unjustified subsidies and introduce a permanent signal through prices (reflecting the environmental externalities associated with each fossil fuel), while recognising that, for industry, there are difficult issues of international competitiveness at stake. In such a context of international industrial competitiveness, tradable permits are to be preferred to taxes;

- deeper further tools which have demonstrated their effectiveness: audits and standards, such as building codes for insulation; and better assess the potential of promising new policy options, such as voluntary agreements, of which many IEA countries have some experience; favour CHP systems, either in city networks for households (seasonal load) or in industry (baseload);
- improve energy efficiency in non-IEA countries, where the sector is growing proportionately more than in IEA countries. Because of rapidly growing associated needs for heat and electricity in developing countries, there is a large potential for combined heat-and power. Programmes of co-operation could help finance the diffusion of these efficient and climate-friendly technologies in developing countries.

This brings me to another conclusion: *the use of biomass is therefore likely to grow in both industrialised and developing countries, although data unavailability makes any analysis of trends difficult. However, its importance is likely to increase in mature countries (due to the promotion of low or no-carbon energy sources, for environmental reasons) and to decrease in developing countries (where its current importance is high and that of conventional fuels is low).*

Economic Barriers

One of the most significant barriers inhibiting "modern" biomass energy use (as distinct from the traditional direct use of biomass for fuel) is the often higher cost of biomass energy systems when compared to other energy systems within a country. These relative economics are, at least partly, explained by a lack of a level playing field either due to subsidies (either direct subsidies or cross-subsidies) to other fuels and not to biomass, or a lower level of biomass-energy related subsidies than subsidies for other energy types/systems. These subsidies can be either at a national level or directed at certain types of consumers, e.g. farmers. Another, more indirect economic barrier to the uptake of biomass energy systems is the non-incorporation and non-monetisation of the positive externalities associated with biomass energy use. These externalities are environmental (such as potentially mitigating effects on CO_2 emissions), social (such as the effect on poverty alleviation/development) and energy-related (no negative externality associated with the security of supply as for imported oil, gas or coal).

The lack of explicit valuation of forest resources often because of ownership/management may also inhibit their use in the most efficient manner.

Lack of available finance because of the lack of an appropriate institutional frame may also reduce a population's access to biomass energy technologies, and therefore the availability of such technologies. This is particularly the case in developing countries in which insufficient micro financing and credit also inhibits the penetration of even low-capital cost technologies if these are replacing no-cost systems. The lack of micro financing may not be due solely to lack of available capital, but to the high administrative burden that would be entailed by financing many small projects. This burden is difficult to overcome, although the administrative burden could be lessened for lending organisations via the establishment of, for example, regional biomass centres or a national biomass user group which could be used to channel any financing to a more distributed group.

Technological Barriers

Beyond the often high cost of logistics in efficiently transporting and storing biomass, one major technological limitation concerning biomass energy systems is related to the efficiency of such systems: many technologies, especially cook-stoves and charcoal production, actually have a low conversion efficiency. This results in a highly inefficient use of initial fuel. Cook-stove efficiency improvements have been the focus of some biomass energy policies, especially in India and China and have resulted in an improved efficiency of biomass use. However, efficiencies in the field are often lower than hoped for.

Limited technology transfer and/or co-operation between developed and developing countries may also inhibit biomass energy developments in developing countries. However, such transfer may be limited by the applicability of different technologies in different regions. For this reason, increased South-South technology development is desirable.

Policy Conclusions

I should like to sum up the overall conclusions, both for the role of biomass in energy, and of energy in climate change.

Firstly, the issues surrounding biomass energy use and development are completely different between industrial and developing countries. Many mature countries are trying to reduce their fossil fuel dependency for strategic as well as environmental reasons. And biomass can help to achieve these goals mostly for household heating and also for some specific industries, notably pulp and paper, and to a lesser extent for power generation. This is why the share of biomass is expected to grow, slowly. Conversely, in developing countries, the emphasis is more on increasing the availability and supply of energy, and particularly high-dense commercial energy forms such as electricity, to the population at large. While biomass can be used to such ends (e.g. by using vegetal waste streams to generate electricity/heat), and may be increasingly done so in the longer term, and while the absolute use of biomass could increase, the proportion of "traditional" biomass use in the total energy supply of developing countries is likely to decline.

Biomass energy use has important ramifications in the non-energy sector, such as agriculture, forestry, agro-industries (and other often small scale industries). Such ramifications may cause conflicting demands, as biomass could therefore be used as either food, fuels, industrial feedstock or construction materials. Any biomass energy "solutions" must fit within a very broad range of socio-economic context, concerns, priorities and opportunities for positive change.

This is why biomass use should be integrated at a national level into energy/agriculture/forestry policy making and planning, i.e. forestry and energy ministries should co-operate to develop a consistent and coherent biomass energy policy. Such planning would also need to incorporate issues relating to land degradation, food production, biodiversity, etc. and would ensure that efforts by different departments did not duplicate or contradict one another. This explicit recognition of biomass energy use, and the better co-ordination between different government departments or organisations involved in different aspects of biomass energy use should not only help to raise the political profile of biomass (including its use as an energy source) but help to minimise any potential conflict arising from its multiple uses. The integrated planning for biomass should also encompass the different needs that have to be addressed within biomass energy development: i.e. short-term vs long-term and global vs local (or national).

The link between biomass energy use and deforestation is far from clear. While it is well known that deforestation can occur in the early stages of economic development (although only a small number of countries can quantify their current deforestation rate with any degree of accuracy), the cause of such deforestation is not known. Is the "desertification" seen around many cities in the developing world due to an increased urban demand for woodfuels or to a higher value of land when used for agricultural crops?

Regarding the broader energy picture, the IEA messages from our statement on the Energy Dimension of Climate Change are about achievable actions now which are realistic and cost-effective – and the form those actions can best take – including starting action for the longer term and using the global opportunities for progress.

Realism and cost-effectiveness are closely linked. Realism means understanding the established relationships between economic development and energy use. It means active acceptance that there are two parts to sustainable development: sensitivity to environmental damage, certainly, but also a commitment to economic development as the means to a better life, especially for those in the developing world. And economic development necessarily means the provision of energy services at a price reflecting all the costs, including the associated externalities.

We have seen how close a relationship there is between growth in GDP and, especially, mobility and the use of electricity. Realism means not expecting to find sudden new means to break that relationship. In the medium term, most emission reductions will have to be achieved with currently available technologies and within the limits of the existing economic infrastructure. The current rate of economic growth in IEA countries and the overcapacity which exists in the power sector suggest a slow rate of capital stock turnover, and hence limited short-term margins for energy-related emission reductions. Cost-effectiveness means, in particular, recognising the scale of past capital and social commitment to creating our pattern of social development, before awareness grew of the threat to greenhouse gases.

To illustrate these long-term opportunities let me quote, for a final conclusion, General Lyautey, who in the 1930's at a time when Morocco was still under French rule, was asking the troops to plant cedar trees in the Atlas mountains.

"My general, these trees will take a very long time to grow", said his aside de camp.

"Reason more to start early", answered Lyautey.

Authors' address

J.-M. Bourdaire, Director, Office of Long-term Co-operation and Policy Analysis
Jane Ellis, Administrator, Energy and Environment Division
International Energy Agency
IEA Secretariat
9 rue de la Fédération
F-75739 Paris Cedex 15, France

Use of Biomass for Power- and Heat-Generation – Possibilities and Limits

Wolf Hatje and Matthias Ruhl

Abstract

Although biomass covers about 10 % of the World's energy consumption, its share in industrialised countries represents only niche-markets with alternating sizes. Due to its huge potential, the best cost-efficiency inside the renewables and the corresponding positive role for CO_2-reductions programs, the use of biomass for energy purposes is expected to increase. As there are substantial differences in the markets for forestry goods and energy, one of the most challenging tasks is to integrate both markets by new and innovative organisational schemes. In order to get a secure and low cost supply of fuels, it is a necessity that potential fuel suppliers take part in the equity risks of biomass-plants. Following the developments on the North American energy markets, the World's energy markets will be liberalised although there are differences as to timing and path of transformation. Competitive application of biomass will enter in energy-economic well-founded markets. Environmentally and politically stimulated markets as well as the marketing of green/biomass-energy offer additional applications for biomass. Any future support-model for renewables must have a sound market-orientation. Adapted to the scale and scope of supply, the design for biomass-projects should be as less complex as possible and as much innovative as necessary.

Introduction

The use of the forest and wood respectively for energy purposes has a long tradition. Up to the middle of the 19th century wood was the dominant fuel for energy generation when its position was taken over by fossil fuels like coal and oil.

Actually, biomass covers about 10 % of the World's energy consumption. The penetration of energy markets by biomass varies sharply from region to region and even from country to country. The use of fuel wood in developing countries contributes significantly to satisfy the daily energy needs for cooking and heating. In industrialised countries biomass only represents niche-markets with alternating sizes. Despite of this unfavourable situation, it is often discussed

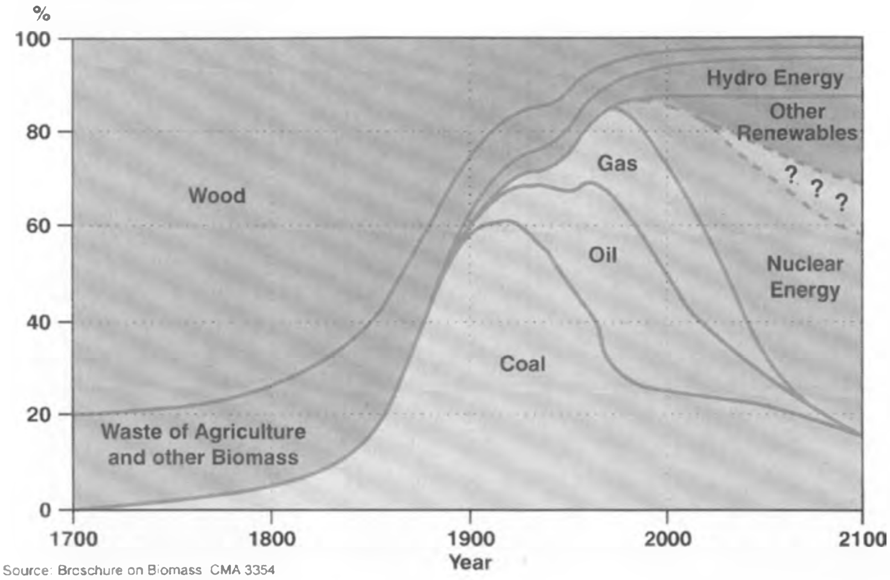


Fig. 1: Epochs of energy supply (Bohn, 1976).

how to increase the share of biomass for power and heat generation.

There is a number of actors such as political parties, environmentalists and renewable energy associations which are reclaiming a higher penetration of energy markets by biomass.

Discussion

So, what are the reasons for this wide consensus?

1. Climate protection and reduction of CO_2-emissions in particular

After a prolongation for one day the 3. Conference on the "United Nations Framework Convention on Climate Change" in Kyoto has come to a binding protocol on the reduction of greenhouse gases between 1990 and 2012. Whereas the results are being considered as "the least minimal compromise" by some groups, it is however a starting point on the long run to cut the emissions. For example, Germany's official and ambitious reduction aim was set by the federal government at 25 % between 1990 and 2005.

2. Huge annual production of biomass (approx. 100 bn t) exceeds the World's annual energy consumption (12 bn t coal equivalent) by a factor of 6–7

The existence of such a potential is *one* necessary condition for the use of biomass for energy purposes, *but not more.* Without a detailed investigation of the regional or national market in question with its specific regulatory and energy economic framework, any estimation of biomass exploitation is senseless.

3. Best cost-efficiency of biomass inside the renewables (except hydro energy) with respect to total energy cost and CO_2-reduction-cost per t

According to various analyses and to the experiences we have gained so far, biomass leads the group of renewables from the economic point of view. Unfortunately, this has not been reflected on most of the energy markets in industrialised countries. The reasons for that are market interferences and politically motivated (supporting) laws with preferences on other renewables such as wind and photovoltaics.

Compared to other renewables such as wind and photovoltaics, biomass can easily be stored and delivers secured contributions for meeting the energy load. Thereby from the technical point of view, there are no obstacles to the integration of biomass into energy-supplying systems. Due to the lower energy content of biomass in comparison with hard coal, oil and gas it requires significant higher volumes in order to reach the same net energetic value. That increases the cost for handling (transportation and other processing cost). At the final end, the *specific investment cost* of biofuel-powered plants exceeds the corresponding figures for its main competitors gas and oil by a factor of 3–4.

Another heavy burden for a larger penetration of energy markets by biomass are the substantial differences in the markets for forestry goods and energy. I am quite aware that the following comparison might be too general and easy, but please consider it as an attempt to describe shortly the principles of both markets.

Energy markets *of the past* in industrialised countries can be characterised as follows:

- long-term relations between suppliers and demanders
- limited number of actors
- well organised
- stable markets with respect to security of supply and price-stability

Forestry markets can be characterised as follows:

- short-term relations between suppliers and demanders
- high number of actors with heterogeneous supply structure
- missing transparency
- unstable markets with respect to security of supply and price-stability

The challenging task is *to integrate* both markets by creating and developing new innovative organisational schemes.

We consider it a necessity that potential fuel-suppliers take part in the equity risks of plants. This is different to that what has been practised on conventional energy markets of the past. The market for forestry goods and its corresponding prices is very volatile. The aim is to give incentives to fuel suppliers – such as *marketers of recycled/used wood* and forestry companies – to guarantee a secure and low cost supply of fuels.

These schemes have to take into account the very specific regional frame of both markets. Woodfuels must fit into the different energy systems as one potential energy carrier.

Today's energy markets are facing a deep and ongoing change. A lot of this has already been implemented, e. g. the new German Energy Law, but a great deal more change will come.

With respect to pace of growth, we can differ markets as follows:

- Stagnation markets
- Substitution markets
- Increasing markets

Unless we have different types of markets, there are more and more ongoing similarities:

■ **Tendency to more liberalisation and globalisation**

The time of protectionism of national markets is over. While the key word "globalisation" is well-known to large industrial companies, more and more small and medium sized enterprises face the international competition. Energy markets of the past with its monopolies will be liberalised and opened for competition.

■ **All over the World transformation of the energy industries; differences in the timing and path of the transformation**

Like in many other fields of cultural and economic life, the developments on the North American energy market are stimulating a drive for change on most of the World's energy markets including Europe in particular.

■ **Conversion of energy into a "normal" commodity**

Energy will not be longer a special or "extra treated" good. Buyers will become customers, that means more customer-focus inside the whole business. An impressing impact on already free markets such as Norway is for instance that petrol stations offer electricity to customers. Within the short-term future, you can probably buy electricity in supermarkets.

■ **Occurring of new and unknown risks for the energy industries, such as uncertainties in the regulatory framework and new competitors**

Thanks to well defined exemption rules electricity and gas were more or less excluded from competition. When analysing the European path for the deregulation, it was a long and hard work to define a compromise, the so-called European Directive for an Internal Electricity Market. Within its ongoing transformation into national laws, it is still open if the spirit of free competition will be implemented. The uncertainties concerning the potential new competitors are compared to the above mentioned negligible!

■ **Entrance of new actors with ample experience in commodity marketing and trading**

Although there are risks as to timing of the changes and the regulatory, liberalised energy markets are very attractive for companies being familiar in marketing and trading of a commodity. Especially banks and brokers with ample experience in the financial sector and in netting-principles in particular, are keen to enter the energy markets.

■ **Pressure to cut costs and prices**

Like a sword of Damocles the danger of loosing customers is going on within the group of the "old" actors. The first reaction of most utilities was to increase efficiency of the whole supply chain and to cut cost. And the companies that will do best are the ones that have started it as early as possible.

■ **Unknown future for all renewable energies which are not economic and thus requiring financial support**

As it was difficult for renewables to enter the energy markets in the past, the situation has not improved by the forthcoming liberalisation. It will be more and more important to answer the questions: What renewables shall be supported? When do we start (with the support)? How many funds will be available? Who will pay the extra costs?

Conclusions

At the end of the day renewable energy sources will have to find their position in a liberalised market, that means, they must be competitive. Their share of the total energy supply will be restricted as to natural potential and the cost of production. You may say that this is trivial, but its displacement produces very often disputes between political will and entrepreneurial acting. Politicians claim generally to increase the use of renewables while companies have to follow economic rules, that means restriction on the renewables which are feasible.

Actually, we can differ between two kinds of potential markets for renewables:

I. Energy economic well-founded markets (**open markets**):

■ need for new capacity

■ huge natural (technical) potential for renewables

■ high energy cost

■ no environmentally friendly generation

■ increasing energy demand

■ lack of financing

■ often limited access to new *technologies* such as biomass conversion

From the energy-economic point of view those are the most interesting markets for renewables. The combination of abundance of technical potential and such energy-economic conditions leads to increasing competitiveness of renewables. The spur is already prepared. Transfer of technology and capital and last but not least co-operation between national governments, national partners and foreign investors offers prospective business opportunities. As a windfall profit, this contributes indirectly to the further development of the whole technology of renewables.

II. Environmentally and politically stimulated markets (**protected and added value markets**):

■ no need for new capacity

■ low share of renewables at energy supply

■ high financing potential

■ political backing of renewables

■ voluntary declaration from the political side to reduce CO_2-emissions

From the energy-economic point of view, the chances for renewables on those markets are quite poor. There are other driving forces than the market which are backing the renewables. In any case, extra cost for the support will occur and have to be financed. But who will pay the bill and what is the best model for supporting the renewables' market introduction?

Government price regulation

■ Energy feed laws forcing the utilities to pay a politically set and guaranteed price per kWh (tariff as % of the average consumer-price) and no compensation of the occurred extra costs *such as the German electricity feed law*

■ Energy feed laws forcing the utilities to take over energy from renewables at a set price (see above) but with a compensation of the extra costs by a combination of state subsidies and taxes *such as the Danish windmill law*

Regulated competition

■ Tender models for renewable capacity such as the English Non Fossil Fuel Obligation (NFFO)

■ Individual renewable energy quotas for utilities combined with the option for trading in between the utilities and across country borders (tradable green power credits) under discussion in the US and in Europe

Market driven

■ Marketing of "green" electricity by the utilities as part of their generation portfolio through extra-pricing schemes ("green tariffs") to the customers such as in the US and Netherlands in particular
■ Introduction of energy/CO_2-taxes only for fossil and nuclear fuels such as already implemented in Scandinavia and the Netherlands

Facing the liberalisation of the energy markets all over the World, any future supporting model for renewables has to fit in the forthcoming regulatory framework.

The old as well as the just modified German Electricity Feed Law is neither in line with the liberalised markets nor did or does it support the use of renewables for heating-purposes such as biomass. By the way, in 1997, the extra costs by wind energy feeding in the PreussenElektra-group amount to approximately 300 million DM. This constitutes a heavy financial burden and taken into account the expected growth of installations up to the year 2000, the extra cost will almost double.

In order to stimulate further cost-reductions, any support model has to give incentive for competition inside the renewables while offering financial support, but not at all endless subsidies. By maintaining the pressure to reduce the costs of the whole systems (manufacturer, suppliers, services) the chances for exporting renewable energy technologies increase.

There is no chance of us recommending you this or that solution. A rigid, uniform approach to support renewables or biomass in particular on different markets is doomed to fail right from the start. Nevertheless, only a sound market-oriented model will find a wide acceptance across the certain lobbyists.

Biomass has the potential to increase its share of the World's energy supply significantly. The main focus will be in the heating sector and on the use of already obtained "products" such as straw and wood. Within the later, recycled or "used" wood – that already has had a material use prior to its energy use – is the most cost-efficient biomass and also "CO_2-neutral" like other biomass.

In order to realise an ambitious goal of increasing the share of biomass for energy generation up to 5 %, one has to work parallel in several fields:
■ small-scale district-heating networks for households (especially on green land)
■ process energy for industrial enterprises
■ co-combustion in power plants (mainly coal-fired)
■ fuel-wood in developing countries.

All kinds of combustion-technologies have to be taken into account. Their choice is influenced by the access to the technology and has to be adapted to the scale and scope of supply. In other words: *As less complex as possible and as much innovation as necessary.*

PreussenElektra has examined some projects, e.g. decentralised heat plants for industrial areas and the co-combustion of wood in coal-(hard coal and lignite)fired power stations. We are often asked to participate in various projects. We have learned that natural gas with its increasing competitiveness and actual abundance is the main competitor of biomass.

Expectations

What do we expect from biomass in the future and what are the conclusions for us?

1. PreussenElektra has a close eye on all the developments with respect to the use of biomass for energy generation.
2. As an energy supplier we are open to use any energy carrier provided that is economically feasible.
3. The short and medium future will show if it is possible to market "green energy" along the expected product-differentiation of the commodity energy.
4. According to our assessment, biomass leads the portfolio of renewables although it has not yet got the corresponding public attention.

Authors' address

Dipl.-Ing. Wolf Hatje
Dipl.-Kfm. Matthias Ruhl
PreussenElektra AG
Corporate Policy
Tresckowstraße 5 · D-30457 Hannover
Fax +49-511-4185

Workshop: Energy Systems in Construction

Forest and Energy in Developing Countries – Nigeria as Case Study

Balogun Ibraheem*

In most developing countries of the world, Nigeria for example, with a population of about 100 million and a forest vegetation cover of about 30000 sq.km, much is derived from the forest in providing energy for the population at least in rural areas where alternative sources of energy are relatively hard to get.

Nigeria is a typical example of a developing country, the urban areas are more densely populated than the rural areas, consequently, being an oil producing country, most of the energy consumption is being derived from petrochemicals and its allied products in particular in the urban areas.

Electrical energy also contributes immensely to the supply of the much needed energy for human consumption and has not been too low in supply (until recently). This is also true in the urban areas. The two above mentioned sources have been able to provide energy for

* Mr. Balogun was finally unfortunately unable to attend the meeting.

more than 65 % of the country's population that live in the urban areas.

Improper planning, unstable management and down trend economy in most developing countries, Nigeria for example, make the two above mentioned sources of energy not perpetual, therefore a slight break in their supplies forces the people, most particularly urban dwellers, to invade the forest for energy needs.

Taking also into consideration the rural dwellers that depend solely on the forest for their energy consumption, an average of 320000 ha of Nigeria's forest is lost annually in order to harvest 98.6 million m^3 of wood of which 90.7 million m^3 or 89.47 % is for fuel and charcoal, while the rest is consumed as industrial roundwood.

Unbelievably, reforestation is only occurring at 30000 ha per year. The reforestation, if occurring, does not involve the interest of the population that surrounds such a project. Their participation in these projects is also far from being involved.

A project is now in place that brings community participation, interest and knowledge into consideration. Such will lead to a way of establishing fuelwood plantations and making use of other forest products or by-products to generate energy for the population.

Author's address

Balogun Ibraheem
The Tropical Forest Network
Office of the Director
Dugbe G.P.O. / P.O. Box 38471
WAN-Ibadan, Oyo State, NIGERIA

Energy from Residues in the Forest Industry

Jean François van Belle and Y. Schenkel

Abstract

Technologies for energy conversion of wood residues have been developed and implemented all over the world. For forest industries which require electricity and process heat, the existence of these technologies and the huge amounts of by-products form forest and wood processing activities present a tremendous potential of energy source, which can cover their energy needs.

Wood residues may require either of the following procedures before it can be utilised for energy: collection, transport, chopping, drying, handling and storage. These procedures are highly dependent on the physical nature of these by-products.

A study on the feasibility of producing energy with wood residues in a cogeneration system in Southeast Asia show that investing in a wood-fired cogeneration plant gives a pay-back period of less than 2.5 years. This is quite attractive compared to purchasing electricity from the grid or running diesel gensets. Where there is little access to grid electricity therefore, as is the case in most wood industries in ASEAN (and where compliance with strong environmental regulations has to be realised), a wood industry would reap economically attractive returns on its investment from a wood-fired cogeneration system.

This is also what the EC-ASEAN COGEN Programme has tried to demonstrate by implementing its Full Scale Demonstration Projects in wood industries in ASEAN.

Introduction

The forest industry produces a lot of by-products or residues throughout its whole process. These can be utilised in other wood industries [pulp, boardmilling, etc.] or outside this sector [mulch, compost, etc.]. Energy [heat and for electricity] is one of them, sometimes, the only one.

This paper aims at explaining the process of using wood residues for energy purposes. This is based on the 7 year experience of the EC-ASEAN COGEN Programme which aims at accelerating the implementation of proven technologies generating heat and/or power from wood and agro-industrial residues through partnerships between European and Southeast Asian companies.

By-products and residues produced by the forest industry

Depending on the forest characteristics and on the logging system [full-tree, cut-to-length, skyline] forest harvesting can leave in the forest more than 40 % of the total volume cut. This is a waste of natural resources. Moreover these residues can be the source of wild forest fires. Therefore, it is important to collect them and use them in a way or in another.

Primary processing industry [sawmills, plymills, pulpmills, boardmills] produces between 45 and 55 % of residues. These are bark, sawdust, off-cuts, peeling core [for plymills]. All these residues are wet [around 40 % moisture content on a wet basis] and often coarse, except sawdust. All of them can be used in other industries but often transport costs make this option not viable.

Downstream industries [furniture making, etc.] are also heavy producers of residues through off-cutting, sanding, moulding, etc. This leads to 40 to 80 % of heterogeneous but dry woodwaste [10–20 % moisture content on a wet basis].

Residues preparation, handling and storage

Six preparation processes are possible before transforming wood into energy in the forest industry: comminution, drying, briquetting, pyrolysis, carbonisation and gasification. Only the first one is generally used in the forest industry. The other ones are not necessary or cost more than the benefits they can give in investment cost saving or increasing in efficiency.

Comminution is often used because it makes handling and feeding easier, it allows reduction in investment cost for combustion equipment and it gives a better combustion control and so for gas emissions.

For clean wood [off-cuts, edging, slabs, ...] its often a disc or drum chipper which is used. The disc chippers are among the most accurate comminution

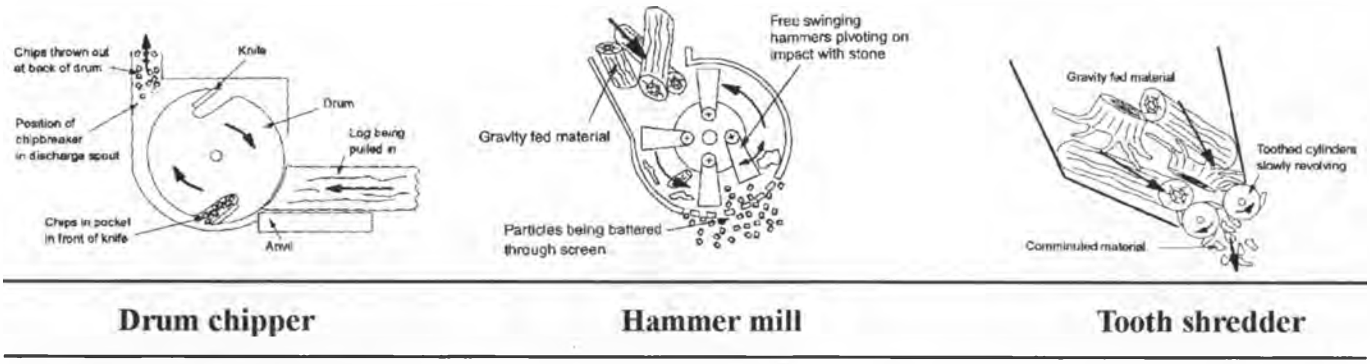


Fig. 1: Type of comminution equipment.

techniques. The cutting system is made of one large and heavy disc with 2 or 4 knives fixed on it. For dirty wood [bark] with soil or stones, it is better to use a hammer mill. Hammer hogs reduce material by impacting it to break it up by using blunt hammers.

For forest residues like large branches and tops, a disc chipper is generally used. It is mounted on a tractor or a forwarder. For grinding stumps or dirty small branches, it is better to use a hammer mill mounted on a forwarder or on a tub grinder.

In small secondary processing industries like pallet manufacturers or joineries, one can often find tooth shredders. They have one or two rows slowly rotating, with teeth mounted on cylinders at the bottom of a hopper. The material is broken up by being pressed by one set of teeth against the other set or against stationary anvils.

Equipment for storage and handling

The method used for storage and outfeeding largely depends on the particle size.

Large sized residues up to 600 mm of length [bark, off-cuts] can be stored in a concrete rectangular silo and outfed with push bottom conveyor. It consists of slide shafts with pushers which are driven in pairs by hydraulic cylinders. The changing over from forward to backward feed is done by push switches. Other feeding systems for rectangular-silos are: travelling screw conveyor for fuel which risks bridging, clamshell crane for very large silo or front-end loader.

Small sized particles [sawdust, shavings, sander dust] can be stored in metallic cylindrical silos. These are generally outfed by rotary screw conveyors. It consists of a sturdy, dust-proof casing which is screwed onto the bin-bottom above the mounting frame. Other outfeeding systems for cylindrical silos also exist like extraction screw with leaf sprong-type conveyor.

Apart from crane and loader, if wood residues are coarse they can be transported with a scraper chain conveyor. They can move wood pieces up to a size of 500 mm at a flow of 50 m³/h and a distance up to 80 m.

If residues are fine [dust, coarse grain up to 50 mm], a screw conveyor is generally used for a capacity up to 14 m³/h and distance up to 10 m per unit. If material conveyed is very fine [dust, fine grain 0–5 mm], one can use pneumatic transport with capacities up to 3 t/h and distance up to 200 m. Particles are blown into tubes by means of fans.

Furnaces

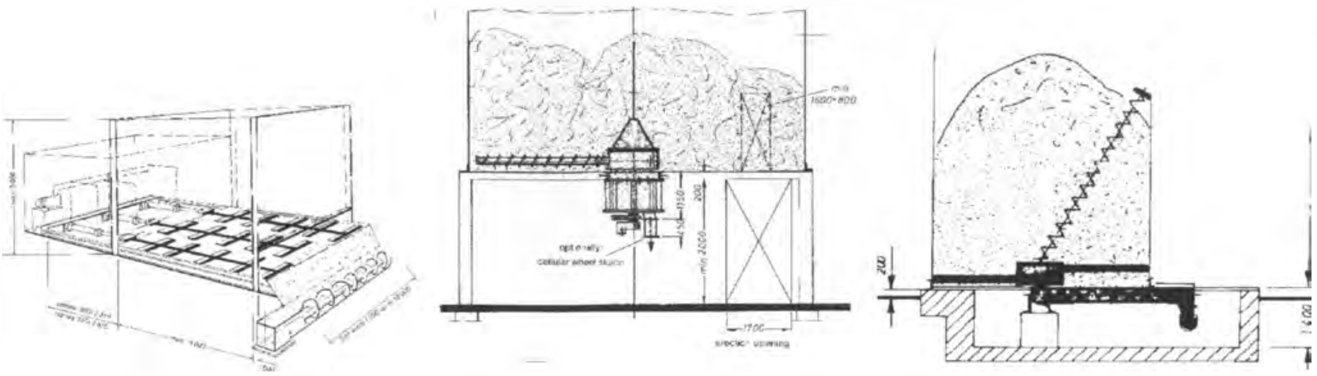
The most reliable and cheapest way of producing heat from wood at the present time is combustion in a furnace. The systems generally used in the forest industries are of four types: Dutch oven, underfeed stoker, moving grate and blowing-in furnaces.

The Dutch oven system was widely used in industrialised countries, and is still running in most parts of the world. This furnace is characterised by a combustion in two phases: firstly the fuel is fed onto a grate and forms a conical pile; underfire air is fed through the grate and overfire air is fed around the side of the pile. In this system, it is difficult to control the combustion and flue gas content. So, in the countries where the emission regulations are strict, this system is not used any more.

Except Dutch oven, one can define three main types of furnaces which are adapted to the characteristics of the

Table 1. Amount and characteristics of residues generated by forest industries.

Process	Type of residue	%	Size	Moisture
Sawmilling	Bark	7 - 15	coarse	wet
45 - 55 %	Sawdust	7 - 12	fine	wet
	Slabs and edging	25 - 40	coarse	wet
Plymilling	Off cuts	4 - 5	coarse	wet
45 - 55 %	Bark	10 - 12	coarse	wet
	Peeling core	4 -10	coarse	wet
	Wet veneer waste	22 - 25	coarse	wet
	Edging	6	coarse	dry
	Sander dust	6 - 10	extra fine	dry
	Sawdust	2 -4	fine	dry
Downstream	Coarse residues	40 - 70	coarse	dry
processing	Fine residues	30 - 60	fine	dry
20 - 60 %				



Rectangular concrete silo with push bottom outfeeder	Cylindrical silo with rotary screw outfeeder	Cylindrical silo with leaf sprong type conveyor
Max. height: 5 to 10 m Conveying capacity: 20 m³/h	Max. diam.: 4 - 10 m 150 m³/h	Max. diam: 5 m

Source: Lambion

Fig. 2: Silo and outfeeders.

residues (Source: Lambion): If the wood particles are wet and coarse [calorific values down to 8 MJ/kg and grain size up to 100 mm] like bark of small off-cuts, moving grate furnaces are used. They are fed by a scraper-chain conveyor followed by a hopper or in more recent systems, by a hydraulic cylinder pushing the fuel in the upper part of the step grate where it starts to dry. The different steps of the grate are moving in a way allowing the wood to fall down slowly, going progressively from the evaporation zone to the pyrolysis one before ending its travel in the solid charcoal burning zone. Above the grate, there is a large chamber where the wood gases are burnt by mixing them with secondary air. Primary air is fed through the grate. The hot flue gases go into the boiler where they transfer their heat to water. Capacities range from 1 MW to 50 MW.

If wood particles are small and homogeneous in size [up to 40 mm], an underfeed stoker furnace is used. In this system, wood chips are fed under the fire bed by the mean of a screw. The wetter the wood, the thicker the layer of firebricks. This is to keep a minimum temperature in the combustion chamber. Capacities rank from 500 kW to 6 MW.

When particles are very fine and dry [up to 5 mm, calorific value above 12 MJ/kg] like sander dust, they are pneumatically blown into the furnace chamber where they burn in suspension. The capacity ranges from 500 kW to 10 MW.

Boilers

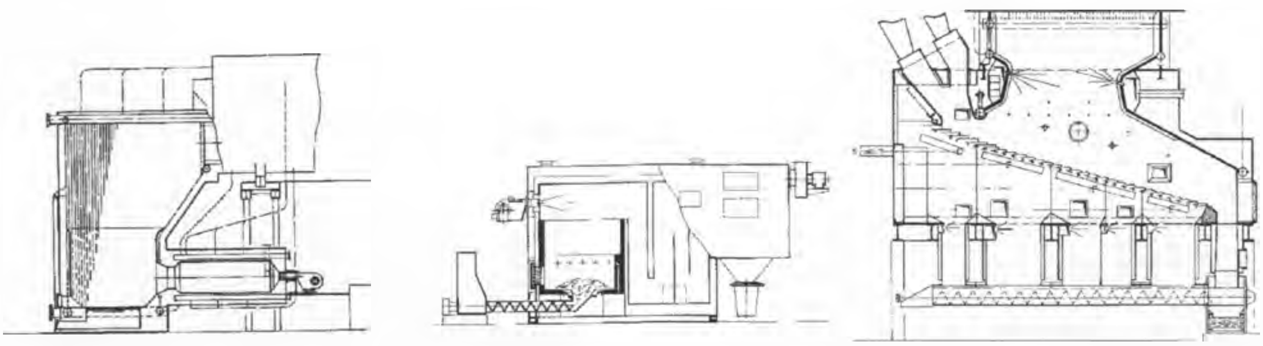
The heat produced has to be transferred to the process. Several heat carriers exist: steam, thermal oil and water. The last two carriers are very particular to certain processes such as wood drying or the production of wood panels.

For small mills which need a maximum of 20 t/h of steam at pressures below 20 bar, fire-tube boilers have the advantages of being not costly in investment and in maintenance. In this type of boiler, hot gases from the furnace pass through the boiler tubes. There can be

System	pneumatic	screw	scraper chain
Max. flow	3 t/h	14 m³/h	50 m³/h
Max. size of particles	< 5 mm	< 50 mm	< 500 mm
Distance	< 200 m	< 10 m/unit	< 80 m for vast height differences

Source: Kara

Fig. 3: Transporting systems.



	Blowing in	Underfeed stoker	Moving grate
Particles:	< 5 mm	< 40 mm	
Cal. Value:	12 - 20 MJ/kg	8 - 28 MJ/kg	4 -33 MJ/kg
Power:	0.5 - 10 MW	0.5 - 6 MW	1 - 50 MW

Source: Lambion

Fig. 4: Main types of furnaces used in the forest industry.

from one-pass boilers up to four-pass boilers, according to the number of times that the flue gases flow through the boiler before leaving it. This is done to increase the rate of heat transferred to the water.

When higher steam output and/or higher temperature and pressure are required, water-tube boilers are usually used. The concept is exactly the reverse of the fire-tube boiler: water circulates inside the tubes which are surrounded by the combustion gases. This type of boiler is generally equipped with one, two and even sometimes three drums. The water flows through the tubes from the upper drum to a lower drum or header. During this process, the heat produced in the furnace is transferred to the water. The heated water turns into a water-steam mixture which flows upwards. The water is then separated from steam and recirculated or is sent to the cleaning unit.

Hot water is commonly used at mills with low temperature requirements, between 100 °C and 150 °C. A typical application is wood drying kilns in sawmills. As the boiling temperature of water at atmosphere pressure is 100 °C, hot water boilers have to be pressurised. The pressure increases with the increase of required temperature.

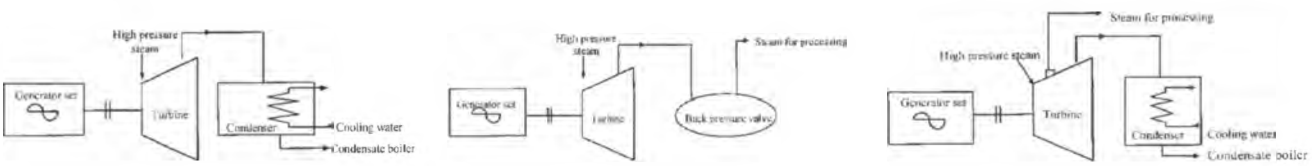
Thermal oil boilers can reach a temperature above 300°C without pressurisation. This technology can be economical when temperatures higher than 200 °C are needed. The main applications of thermal oil boilers are in the wood panel industry.

Turbo-generators

Electricity is produced by the means of a steam turbo-generators converting thermal energy into mechanical energy. Thermal energy is converted into kinetic energy by expansion of the steam through suitable nozzles. In impulse turbines, the jet of high velocity steam impinges on blades set on a wheel, causing the rotation of the wheel due to the impulse force on the steam jet. In reaction turbines, the steam enters the wheel under pressure and flows over the blades. The steam propels the blades by the reactive forces of the blades. Fixed blades give a good direction to the steam as it leaves the rotating blades and send it again to a following set of blades. The turbine shaft in rotation is connected to a generating set which transforms mechanical energy into electricity. Power capacity ranges from 300 kW up to hundreds of MW.

From a end-user point of view, turbo-generators can be classified in three types: condensing, back pressure and extraction condensing turbines.

If no steam is needed for a process in the mill, one uses condensing turbines. Exhaust steam is condensed under vac-



Condensing **Back-pressure** **Extraction-Condensing**

Source: Mohanty, 1996

Fig. 5: Type of turbo-generator sets.

uum. If steam is required for a process, back pressure turbine are used. In these turbines, exhaust steam is at atmospheric pressure or higher. This steam is then used for the process.

To combine the benefits of condensing and back pressure turbines, one can use extraction condensing turbines. Steam can be extracted directly from the turbine, and not after it. The main advantage is that the extraction pressure can be regulated, which is very useful in the case of cogeneration operation.

Energy requirements in the forest industry

Forest industries need energy for drying the wood, for heating the glue for panels, etc. They also need electricity for running their equipment. Table 2 shows typical ranges of value for different types of wood industries. Sawmills are low level consumers but paper mills are heavy consumers.

In Table 3, there are some indications on how the amount of produced residues matches the energy needs. If the production is not integrated like a sawmill and a plymill, there's an excess of by-products that can be sold or used to produce electricity for the grid.

If the complex is well integrated with furniture, moulding and a board factory and if the whole needed power is generated from biomass equipment, extra wood residues have to be bought or collected from other wood industries or logging operations.

Table 2: Energy requirements for different operations in the forest industry.

	Heat	Electricity
Sawmilling	150 - 200 kWh/m_ (when drying)	25 - 40 kWh/m_
Plymilling	350 - 500 kWh / m_	150 - 165 kWh/m_
Papermilling		
Mechanical	13.6 - 17.7 GJ/t of dry pulp	1700 - 2000 kWh/t
Semi-mechanical	16.1 - 22.4 GJ/t of dry pulp	550 - 715 kWh/t
Chemical	19.3 - 27.3 GJ/t of dry pulp	880 - 1210 kWh/t
Board manufacturing		
Particle board	700 kWh/m_	130 kWh/m_
HDF	1390 kWh/m_	350 kWh/m_
MDF	1150 kWh/m_	325 kWh/m_
OSB	850 kWh/m_	200 kWh/m_

Source: Manderbach

Table 3: Where the residues match the energy needs.

Structure of wood complex	Available residues	Residues versus energy needs	Conclusion
Sawmill + plymill	All	All energy needs (thermal and electrical)	Excess residues for sale and/or for excess power
Sawmill/plymill + furniture, moulding, frames	All	All energy needs (thermal and electrical)	Excess residues for sale and/or for excess power
Sawmill/plymill + board factory	Bark, sawdust, sander dust, board edging	Only thermal needs covered	Extra residues to be bought if power generated from biomass equipment
Furniture, moulding + board factory	Bark, sawdust, sander dust, board edging	Only partial thermal needs covered	Extra residues to be bought for heat and for power if generated from biomass equipment

Table 4: Economic data for a cogeneration plant installed in a Malaysian wood complex.

Capital investment cost	2 147 500 US$
Annual operating costs	103 470 US$
Labour costs	37 470 US$
Maintenance costs	66 000 US$
Annual income from using wood compared to grid	1 023 581 US$
Electricity savings	760 411 US$
Demand charge savings	80 680 US$
Residue disposal savings	182 490 US$
Net Present Value [NPV]	8 673 090 US$
Internal Rate of Return [IRR]	49.57 %
Pay-Back Time [PBT] after commissioning	2.20 years

Source: Gonzales A., Cogen Programme

Profitability of producing energy with wood residues

The following example consists in a cogeneration plant in Malaysia using wood residues as the fuel source (1.5 MW power plant installation). The integrated wood mill complex which includes sawmilling [4200 m^3 output/month], kiln drying operations [1400 m^3 capacity], and other downstream processing activities such as moulding and furniture making. The cogeneration plant consists of a boiler and two turbines, one backpressure [600 kW] and one fully condensing [900 kW]. The steam [4 t/h, 6 bar] used for the process [kiln drying] is taken after the backpressure turbine.

The above results indicate that investing in a wood-fired cogeneration plant compared with purchasing electricity from the grid gives a pay back time of less than 2.5 years. Similar results are obtained where the investment is compared to the production of electricity with a diesel engine [PBT = 2.33 years].

Examples from the real world

One of the main purposes of the EC-ASEAN COGEN Programme over the last few years has been to demonstrate the technical reliability and the economic viability of technologies using biomass residues as fuel in wood and agro-industries. As a result, sixteen Full Scale Demonstration Projects (FSDPS) involving European and ASEAN industrialists were selected. Most of these have already been implemented. Ten, out of these sixteen projects, are in the wood sector, and summarised in Table 5.

A brief description of these ten projects as well as some of their economics (cost, pay back period) can be found in appendix.

Conclusions

Well proven and commercially available technologies exist for producing energy [heat and electricity] from all kind of wood residues. Characteristics of wood residues influence the technology to be used. The more coarse and wet is the residues, the more heavy and expensive is the technology to implement.

Through its Full Scale Demonstration Projects in ASEAN, the Cogen Programme has shown that producing energy from wood residues in the forest industry can be very efficient and economically viable. Even if every single mill has got its own quantities of residues as well as its own energy requirements, and thus requires a kind of tailor-made solution, it remains economically attractive and can be paid back in around 3 years.

In addition, current situations could favour the governments' decision to provide better conditions for private power using renewable energy technologies. These conditions include the governments' desire to promote 'green' or non-polluting technologies, the ongoing threat to the security of supply of conventional fuels, and financial capability of the governments to provide added capacities for power generation. All these factors should give a cause for some optimism that biomass energy projects could take off within the next few years, particularly in the wood industry in ASEAN, and especially in Malaysia and Indonesia.

References

Cogen Programme, "Competing in the ASEAN Biomass Energy Market – Wood Residues in ASEAN – Market opportunities, Trends, Dynamics", 1997.

Grulois C., Van Belle J. F., "Machinery suitable for chipping forest residues and green waste", CRA, 1997.

Kara, commercial documentation.

Lambion, commercial documentation.

Lacrosse L., Schenkel Y., "Utilization of Sawmill Wastes for Steam and Power Generation", 1995.

Manderbach M., "Wood and Biomass Firing – A State of the Art of Technologies".

Mitchell C. P., Hankin C. M., "Forest residue harvesting system", ETSU contract, 1995, 142 p.

Pennington M., Lacrosse L., Gonzales A. "Implementing clean and efficient energy projects within the wood sector in ASEAN", 1997.

Schenkel Y, Carré J., "Specificity of Cogeneration in Wood and Agro-Industries."

Table 5: FSDPs implemented by the EC-ASEAN COGEN Programme in the wood sector in ASEAN.

no.	Industry	Country	Equipment	Capacity	Cost	Pay-back period
1	Parquet	Thailand	Hot water boiler	1 250 000 kcal/h	180 000 US$	2.9 years
2	Sawmill	Malaysia	Steam boiler	5 tph; 12 bar	274 800 US$	2.9 years
3	Wood frame	Thailand	Hot water boiler	400 000 kcal/h	342 000 US$	2.7 years
4	Plymill	Indonesia	Steam boiler	35 tph; 35 bar	1 600 000 US$	2.4 years
5	Wood complex	Malaysia	Cogen plant	1.5 MW	1 611 000 US$	3.5 years
6	Wood complex	Malaysia	Cogen plant	1.65 MW	1 994 000 US$	3.1 years
7	Rubberwood	Thailand	Cogen plant	2.5 MW	2 187 000 US$	2.9 years
8	Wood complex	Indonesia	Power plant	5.55 MW	4 488 000 US$	3.6 years
9	MDF plant	Malaysia	Thermal oil heater	22 Gcal/h	5 630 000 US$	3.5 years
10	Wood complex	Malaysia	Power plant	10 MW	7 045 000 US$	3.1 years

Appendix: Description of FSDP's implemented by the EC-ASEAN COGEN Programme in the wood sector in ASEAN

Project no. 1: Parquet flooring factory in Thailand

Brief description:
Sawdust and wood shavings are sucked by a pneumatic collection system to be used as a source of energy in the boiler supplying hot water to the kiln dryers.
Location: Srakaew
End User: Areechai Woodtech Co., Ltd.
Main Supplier: From Italy
Cost: US$ 180,000
Pay back period: 2.9 years

Project no. 2: Sawmill in Malaysia

Brief description:
Equipped with an automatic feeding system, the wood waste-fired steam boiler produces steam for the kiln drying plant. As part of the supply, there is also a wood dust extraction system from the wood moulding plant.
Location: Gemas, Negeri Sembilan
End User: Bekok Kiln Drying and Moulding Sdn. Bhd.
Main Supplier: From Denmark
Cost: US$ 274,800
Pay back period: 2.9 years

Project no. 3: Wood frame factory in Thailand

Brief description:
Manufacturing top quality frames for export, the company decided to invest in a dust extraction and storage system and to use their wood residues as a source of energy for kiln drying. The residues are being combusted in a hot water boiler with a total capacity of 400,000 kcal/hr.
Location: Laem Chabang, Chonburi
End User: Laem Chabang Industry Co., Ltd.
Main Suppliers: From Italy and Belgium
Cost: US$ 342,000
pay back period: 2.7 years

Project no. 4: Plywood in Indonesia

Brief description:
The steam produced by the wood waste-fired boiler is used for the process as well as to run an existing turbo-generator with a net output of 3200 kW. The boiler replaces two old boilers which are not able to provide sufficient steam for the turbine.
Location: Palembang, South Sumatra
End User: P.T. Kurnia Musi Plywood Industries
Main Supplier: From Denmark
Cost: US$ 1,600,000
Pay back period: 2.4 years

Project no. 5: Wood complex in Malaysia

Brief description:
The 1.5 MW cogeneration plant (one boiler, one back pressure turbo-generator and one fully condensing turbine) supplies all the electricity needed for the complete factory (sawmill and moulding), as well as 4 tonnes of steam for the kiln drying operation.
Location: Bentong, Pahang
End User: IB Timber Industries Sdn. Bhd.
Main Suppliers: From Belgium and Germany
Cost: US$ 1,611,000
Pay back period: 3.5 years

Project no. 6: Wood complex in Malaysia

Brief description:
The 1.65 MW wood waste-fired power plant consists of a boiler supplying steam to a fully condensing turbine. Power is being supplied to the sawmill, while part of the steam is used for kiln drying.
Location: Sarikei, Sarawak
End User: Homet Raya Sdh. Bhd.
Main Suppliers: From Denmark and Germany
Cost: US$ 1,994,000
Pay back period: 3.1 years

Project no. 7: Rubberwood complex in Thailand

Brief description:
The 2.5 MW cogeneration plant consists of a boiler supplying steam to a 5-stage extraction/condensing turbo-generator. Part of the steam is to be used for kiln-drying operation (Project under implementation)
Location: Surat Thani
End User: TRT Parawood Co., Ltd.
Main Suppliers: From Belgium and Germany
Cost: US$ 2,187,000
Pay back period: 2.9 years

Project no. 8: Wood complex in Indonesia

Brief description:
The 5.5 MW wood waste-fired power plant consists of a steam boiler and a fully condensing steam turbine. The electrical power output of the plant will be utilised by the wood processing plant within the complex while excess electricity will be sold to a neighbouring subsidiary. (Project under implementation)
Location: Pekenbaru, Riau
End User: PT Sink Raya Timber
Main Suppliers: From Germany and UK
Cost: US$ 4,488,000
Pay back period: 3.6 years

Project no. 9: MDF factory in Malaysia

Brief description:
The 22 Gcal/h energy plant burns wood wastes to heat thermal oil up to 280 °C. The heated oil is then used for heating tile continuous press, for generating 10 tonnes of steam/hr in a separate boiler and for preheating the primary combustion air. The flue gas from the combustion chamber is cleansed in the dust cyclones and then used for drying the fibres before the manufacturing of the board.
Location: Kulim, Kedah
End User: Kumpulan Guthrie Bhd.
Main Supplier: From Denmark
Cost: US$ 5,630,000
Pay back period: 3.5 years

Project no. 10: Wood complex in Malaysia

Brief description:
The 10 MW wood waste-fired power plant supplies two-thirds of the existing power requirement of the wood complex, replacing existing diesel gensets.
Location: Keningau, Sabah
End User: Pembangunan Papan Lapis (S) Sdn. Bhd.
Main Suppliers: From UK and Germany
Cost: US$ 7,045,000

Authors' address

Jean François van Belle, Y. Schenkel
CRA – Genie Rural
Ch. de Namur 146
B-5030 Gembloux, Belgium
e-mail: van_belle@cragx.fgov.be

Woodlots for Fuelwood in South Africa: The Past, Present and Future

Cori Ham

Synopsis

The rural population of South Africa largely depends on fuelwood as a primary source of energy. Woodlots[1] were planted to provide fuelwood and to preserve the natural resource base. They have, however, failed in their objective due to various reasons like wrong management approaches. A new approach towards woodlots, whereby it forms part of a broader social development process, has been developing since the late 1980's. Incorporated in this approach is small-grower schemes where the financial benefit of these woodlots is realised.

Introduction

South Africa is a country of stark contrasts where first world development can be found next to third world poverty. This is also reflected in its energy use patterns. Having 4 % of Africa's population, South Africa generates 60 % of the continent's electricity and yet less than a third of South Africans has access to electricity in their homes (*Oxenham* and *Eberhard*, 1990). This is despite huge excess capacity in Escom's (the public electricity utility) generation system and notwithstanding the fact that South Africa developed the ability to provide electric services as early as the 1880's. Kimberley had electric street lighting before London (*EDRC*, 1994).

Coal is the cornerstone of South Africa's energy economy, contributing approximately 90% of the total indigenous primary energy supply. The remainder comprises of renewable and nuclear sources, contributing approximately 8 % and 2 %, respectively. Biomass, mostly fuelwood, forms the greater part of the renewable component, followed by hydro-energy (*Oxenham* and *Eberhard*, 1990).

Although renewable resources like fuelwood represents only 8 % of the energy supply, fuelwood is the staple energy of the rural poor. Almost the entire rural population, comprising about three million households, depends mainly upon fuelwood for their cooking and heating needs (*EDRC*, 1994). The dependency on wood in the rural energy economy is expected to continue, in the medium term at least, even if there is a vigorous programme of rural electrification and access to transitional fuels is improved (*Gandar*, 1994a).

Gandar (1994a) estimated that the total annual consumption of fuelwood by low income households in South Africa is about 11 million tons, of which about 6.6 million tons is used in rural areas in the former homelands, about 3.5 million tons by farmworkers, only 0.7 million tons in urban areas, and a smaller amount by other communities outside the homelands. The mean annual consumption of fuelwood in villages is about 604 kg/annum/per capita and in peri-urban areas about 334 kg/annum (*Eberhard*, 1990 ex *Cooper* and *Fakir*, 1994).

It is estimated that two-thirds of fuelwood comes from indigenous woodlands, particularly savannah. A sizeable portion of the remainder comes from the commercial agriculture and forestry sector. Self-seeded exotics are important in certain areas. Woodlots, however, which cover an estimated 62000 hectares in the former homelands, provide relatively little fuelwood (*Gandar*, 1994a).

Fuelwood deficits in South Africa are primarily attributed to population location, and are especially severe in the former homelands, where population densities are much higher than in the rest of South Africa. Woodlands are overused as already shown by the widespread denudation and wood shortages in most of the former homelands (*Cooper* and *Fakir*, 1994).

Former homelands

Most of the poverty stricken areas of South Africa, where fuelwood is an issue, are in the former homelands. During the previous government, four "independent" states with their own governments, but nearly totally dependent on South Africa, were established. They were Transkei, Bophuthatswana, Venda and Ciskei (TBVC states). Six self-governing national states were also established. They were KwaZulu, Qwaqwa, Gaazankulu, Lebowa, Kwandebele and Kangwane. All of them are collectively referred to as "homelands". This was part of the Government's policy of separate development for different race groups. Overpopulation, unemployment, corruption and mismanagement of these entities caused severe environmental degradation and poverty. These entities were re-incorporated into the nine provinces of the Republic of South Africa after the elections in 1994.

The "fuelwood crisis" and woodlots

There has always been an underlying threat of running out of natural resources like fuelwood in South Africa. The shortage of timber at the Cape of Good Hope was already considered in a serious light in 1704, as illustrated by a proclamation in which it was stated that "None of the inhabitants shall cut fuel other than by permit and at the appointed places, nor take more than permitted to him" (*Grut*, 1977).

The traditional and widely held view of energy consumption and environmental problems in rural areas has been premised on an assumption that observed instances of deforestation have been caused mainly by fuelwood collection. By extension of this view, all woodlands that have been denuded, have ended up under the cooking pot. These assumptions were enhanced by the oil price shocks of the early 1970's, when it became natural for the fuelwood issue to be regarded in much the same way as the oil issue: problems of increasing global scarcity. Consequently, the gap between fuelwood supply and demand was frequently extrapolated into the future, to the point where it was predicted that wood supplies would become fully depleted at some specific future date (*Van Horn* and *Eberhard*, 1995).

In line with this increasing fear of the depletion of natural resources, woodlots were established. The first woodlots for poles and fuelwood for rural communities in South Africa were established more than a century ago by municipalities (in small rural towns) and departments of forestry in remoter areas (*Eberhard* and *Van Horen*, 1995). These early woodlots were planted mainly for environmental reasons, i.e. to stop the degradation of natural woodland which was ascribed to the harvesting of poles and firewood. The price of wood has accordingly been set very low in order to attract people away from cutting the indigenous vegetation (*Gandar*, 1994 ex *Williams* et al., 1996).

Woodlots
Historical perspective

The history of woodlots in South Africa can be divided into two periods; from 1890 to the 1980's and from the 1980's onwards.

Period from 1890 to 1980's

The first woodlot to provide firewood and hut material for rural people was established in 1893 near King William's Town. Wattle plantations were established in the Ciskei shortly thereafter, and in the Transkei at the turn of the century. Since then woodlot development continued slowly but accelerated in the 1970's and early 1980's, particularly in the Transkei. It was only from the mid-seventies that proper woodlot programmes were put into place outside of Transkei and Ciskei (*Gandar*, 1994b).

During this period woodlots fell into four broad categories:

Traditional Authority (TA) woodlots

The usual practice in woodlot programmes was for the relevant department to establish the woodlot and for the traditional authority (so-called "tribal authority" [TA]) to take responsibility for management, maintenance and harvesting. Some woodlots remained under departmental control for several years and were only handed over when the trees were mature. Revenue from the sale of wood accrued to the TA (*Gandar*, 1994 b).

Institutional woodlots

By "institutional woodlot" was meant a woodlot for which some state, parastatal or local government body has responsibility. In most instances the institution was a homeland government department, parastatal agricultural development corporation or, occasionally, a rural municipality (*Gandar*, 1994b).

These woodlots were usually on land released for the purpose by the TA. The department was responsible for establishment and running of the woodlot, born all the costs, and sold the poles and firewood to the local population. The department may pay the TA a nominal rental for the land but there was, however, no formal or legal binding lease agreement with the TA's regarding land provided for the woodlots. The departmental woodlots were considerably larger on average than TA woodlots and some were more like small plantations than woodlots. The management and condition of many institutional woodlots were better than TA woodlots. People living near both TA and departmental woodlots have said that they prefer to use the latter (*Gandar*, 1994b).

Private homesite woodlots

Small homesite woodlots date back at least 60 years. In some areas a high percentage of households owns their own woodlots, generally between 0.1 and 2 ha in size. These have been established with virtually no outside intervention. Some of the homesite woodlots have a commercial orientation, producing wattle bark and timber (*Gandar*, 1994b).

Farm woodlots

Apart from the homelands, farm woodlots on white-owned commercial farms have a long history and provided firewood for labourers and their families. A postal questionnaire of farms in KwaZulu Natal and the former Transvaal indicated that 30 % of farms have woodlots primarily for on-farm requirements (*Gandar*, 1994b)

Mid 80's until now

From the mid-80's, there has been a growing disillusionment with woodlots. Many of the homeland administrations ceased to take a pro-active role in woodlot development or abandoned woodlots altogether. By 1990, woodlot development was virtually at a standstill apart from the conspicuous exception of small grower schemes (*Gandar*, 1994b).

It is not clear what brought about this change of heart. After all, the poor conditions and low success rate of woodlots were nothing new, and there were at least some tangible benefits coming from woodlots. There was, however, a disposition towards critical examination of rural development and particularly of the "top-down" approach that characterised most woodlot programmes. This helped to focus attention on the deficiencies of woodlots (*Gandar*, 1994b).

Biomass initiative

The efforts by the South African government and the governments of the former TBVC states to provide in the fuelwood and building needs of local people, culminated in the establishment of the Biomass Initiative by the Department of Mineral and Energy Affairs in 1992. The aim of this project was to set up a range of research and demonstration projects nation-wide to collect information on the availability of fuelwood in South Africa. This information would then be used to guide the development of government policy for national community forestry activities while pilot projects would form the basis for a full scale national community forestry programme (*Kotze*, 1994).

Results from the Biomass Initiative emphasise the role of community involvement in community forestry projects and suggest that the shortage of fuelwood be placed in the wider context of rural poverty. The Biomass Initiative can be seen as a turning point in rural fuelwood supply policy in South Africa.

Timber small-grower schemes

While the South African government was still busy trying to find its role in the community forestry field, the commercial forestry companies saw an opportunity in making communities business partners. The first timber company (SAPPI) entered the arena of small-grower schemes in 1982 and since then this type of scheme has picked up momentum (*Gandar*, 1994b).

These small-grower schemes work on the basis that the grower enters into a contract with the company to supply timber to it. The company in return provides loans, seedlings, and advice and make advance payments on the future crop. Depending on which company is involved, seedlings may or may not be free and loans may or may not be interest-free (*Gandar*, 1994b).

In October 1993 there were four main schemes running, mainly in KwaZulu-Natal, representing a total of 7735 growers and 11699 hectare (*Christie* and *Gandar*, 1995) (Table 1). They are Sappi's Project Grow, Mondi's Khulanathi, the Lima Rural Development Foundation schemes and the South African Wattle Growers Union's Loan Scheme (*Gandar*, 1994b). Recent figures for Project Grow, Khulanathi and Lima showed a large increase in the number of growers and the area planted (Table 1). These schemes provide the people with an income so that they can afford alternative sources of fuel for living instead of just providing fuelwood. The extension work done by the companies is generally much better than that done by the Government extension service because the companies have a commercial interest in the crop.

Table 1: Area planted by small-growers in KwaZulu-Natal by October 1993 (Christie and Gandar, 1995) and most recent figures for Project Grow, Lima and Khulanathi (Sappi Forests and Mondi Forests, 1998).

Company	No. of Growers 1993	Hectare 1993	No. of Growers 1998	Hectare 1998
Sappi Project Grow	1 538	3 058	2 315	6 213
Lima	1 600	1 084	3 742	2 061
Mondi Kulanathi	1 553	1 039	2 451	4 965
Independent	364	746		
Wattle bark growers	1 900	7 772		
Total	7 735	11 699		

Possible reasons for the failure of woodlots in South Africa

There are roughly 62000 hectare of woodlots of various types (Table 2) of which 68 % are in the Transkei. While the overall productivity of the woodlots is not known, it is clearly below potential. Some woodlots may provide significant amounts of building material locally, but they yield perhaps only 1 % to 3 % of the total fuelwood used (*Christie* and *Gandar*, 1995).

The condition of woodlots has become disappointing. A study of woodlots in the Ciskei revealed that only 21 % of woodlots are being managed at a reasonable level. Fencing has been maintained at only 52 % of woodlots, and in half the cases it has disappeared. Sixty percent of woodlots are being grazed by cattle. No preparation of firebreaks was noted. Where felling takes place it is uncontrolled and often at a height of up to 1 m or more above the ground, resulting in poor coppice growth and loss of biomass. In many of the woodlots the trees are too large for poles and firewood. In two cases the large trees have been felled, the thinner tops utilised, and the rest, too large for poles and firewood, left to rot (*Bembridge*, 1990). This is typical of other areas as well.

The question to be asked is where did it all go wrong? The intention of providing wood for the rural poor and alleviating their needs is a good one. Possible answers to this question could be the following:

Control over community forestry projects

In many of the woodlot projects, control was exercised by an outside agent, usually a government or statutory body. A degree of local participation was often encouraged at stages of the project implementation and maintenance, but not in planning. The participation usually involved a Tribal Authority (*Gandar*, 1988).

When there is very little involvement of people in the various activities of establishment and management of the woodlot project during the initial period of establishment, the people will never view the woodlot as their own. They will rather consider it merely as a Forestry Department activity where they can find employment as wage labourers (*Sen* and *Das*, 1987).

An investigation by Bembridge (1990) concluded that because of the "top-down" approach to establishing woodlots, there was a lack of knowledge on the part of the chiefs and tribal authorities of the management and utilisation of a valuable asset in their area. For the same reason, there was uncertainty and apathy as to what roles the chiefs, tribal authorities or local people had in running or use of the woodlots. In many instances people believed that woodlots belonged to the Government, and therefore it should be their function to hire labour to manage, protect and harvest the timber.

People's needs

In the whole "top down" approach it was assumed that people want trees and that it can be used as a tool to alleviate rural conditions, especially in terms of fuelwood collection. The question can be asked if community forestry programmes were primarily implemented to benefit the people or to prevent unsightly environmental degradation.

One of the reasons why woodlot programmes were not successful in the past might be that people did not see a need for trees as source of fuelwood.

Table 2: Total area of different types of woodlots (Gandar, 1994a).

Type of Woodlot	Hectares
Traditional authority	16 036
Institutional (e.g. Dept or municipal)	17 450
Private non-commercial	5 295
Small-grower	10 927
Community and other unclassified	12 513
Total	**62 287**

According to a study undertaken by *Bembridge* (1990) in the Ciskei, the rural people did not perceive the supply of fuelwood as an important issue. Clean water supplies, food, health services and improved education facilities were seen as higher priorities.

Rural women in South Africa have to make an average of three trips per week, each lasting about two to three hours to collect fuelwood (*Van Horen* and *Eberhard*, 1994). The first reaction from outsiders is that ways must be found to alleviate the plight of these women, but however strong the need may appear from the outside, people will only take part in tree growing activities that are both feasible and attractive from their point of view (*Foley* and *Barnard*, 1985).

Experience indicates that most groups will first choose activities that can help them to remove the constraints on their economic development. Once they have achieved success in this area, they will often decide to move on to areas that affect the quality of their lives such as water, sanitation, curative and preventative healthcare (*Bembridge*, 1990). The fact that fuelwood is not very high on the list of priorities could have been realised if planning was based on "... a realistic appraisal of people's own perceptions of their needs, priorities and capabilities" (*Foley* and *Barnard*, 1985).

Wrong assumptions based on the "fuelwood crisis"

The fuelwood crisis was initially defined as a resource crisis, and up to a point it is. Scarcities of fuelwood do exist and woodland is declining. The early analyses that concentrated on supply, demand and shortages did serve a valuable function in drawing attention to the problem and expressing it in quantitative terms (even if data available at the time were woefully inadequate) (*Gandar*, 1994 a).

Having defined the firewood crisis as a resource problem, resource solutions were sought. These were concerned primarily with increasing the supply by planting woodlots and reducing the demand by promoting fuel-efficient stoves. The spectre of imminent environmental collapse injected a measure of alarm and urgency and large-scale afforestation projects were hastily implemented (*Gandar*, 1994 a).

There are obvious flaws in trying to solve a potential fuelwood crisis by means of a supply-enhancing and demand-limiting approach. Clearly the problems faced have not been properly understood, and in the words of *Munslow* et al. (1988 ex *Williams* et al., 1996): "The fuelwood trap, into which governments and donor agencies fall, is to assume that they have identified an obvious problem and consequently there has to be a simple solution. Unfortunately this is not the case."

One of the main failures in this approach has been the failure to consider the complex social, political and economic issues, which impact upon the people's interactions with their natural environment. The development issues surrounding the supply of and demand for wood are easily neglected: the role of land access, the availability of labour for collecting wood and attending fires, and the position of women in social structures (*Van Horen* and *Eberhard*, 1995).

Another factor to consider is the different objectives of afforestation. *Leach* and *Mearns* (1988 ex *Gandar*, 1994 a) concluded that agriculture and land clearing were far more significant causes of deforestation than fuelwood gathering. Moreover, there are many factors which act simultaneously and interactively on woodlands, making it difficult to single out factors. For example, the impact of wood harvesting is strongly dependent on the intensity of grazing or browsing which accompanies it, and the frequency and timing of veld fires (*Gandar*, 1994 b).

Improving fuelwood forestry in South Africa: The way forward

Change in approach

The objectives of woodlot development need to be reassessed. The original notion of providing poles and firewood for rural populations thereby rescuing indigenous vegetation and easing rural drudgery, has proved inadequate as an objective (*Christie* and *Gandar*, 1995).

Social forestry and woodlots should be looked at in their entirety, with all possible benefits. It must be established that it is a sensible form of landuse in given situations, with potential benefits comparable to or in excess of alternative forms of landuse. Complementarity with other landuse must also be considered (*Christie* and *Gandar*, 1995).

If social forestry and/or block afforestation are favourable options, then these should be implemented so that the benefit stream is developed as far as possible. The main benefits will depend on the situation and may indeed be poles and firewood for local consumption. Other might include income earning, secondary micro-enterprises, employment, integrated small-farm systems and environmental rehabilitation. The objectives would thus be phrased in terms of contributing to an appropriate sustainable landuse mix, and to rural upliftment (*Christie* and *Gandar*, 1995).

Approaches should focus more on social forestry that can be defined as the planting and/or management of trees in populated environments by local individuals, communities or groups to meet local needs, whether economic, subsistence or environmental. Social forestry can encompass agroforestry (where trees are integrated into farming systems), homesite tree planting (including micro woodlots), tree delivery systems based on a network of village nurseries, village greening, and reclamation forestry (using trees in soil rehabilitation and conservation) (*Eberhard* and *Van Horen*, 1995).

Social forestry intervention can be centred around job creation and natural resource rehabilitation (*Fenn*, 1994). An expanded social forestry programme should include small grower schemes, some large woodlots where effective management is possible, tree dissemination from a network of village nurseries and support for the redistribution of local fuelwood surpluses by the informal sector (*Eberhard* and *Van Horen*, 1995).

Leach and *Mearns* (1988 ex *Van Horen* and *Eberhard*, 1995) have identified three fundamental principles which should be recognised in fuelwood interventions:

- the importance of local assessing and actions, rather than large-scale aggregates, in recognition of the diversity of social, natural and economic systems;
- the need for indirect approaches to fuelwood issues which are process-

orientated, rather than delivery/package-orientated; and

- the need for decentralised and multidisciplinary approaches which utilise competent and trusted "grassroots" agencies.

Added to this, *Gandar* (1994 a) concluded that contemporary analysis has redefined the fuelwood problem in a more holistic way, acknowledging the social dimension, the context of poverty, and linking the environment to development. In practical terms this means:

- a shift away from narrow interventions focused only on fuelwood, instead of on the full potential role of trees in the rural economy and environment;
- due recognition to the value of woodland and woodland products to rural communities, and the importance of including sustainable management of woodland in wider rural development strategies;
- people-driven development, building on local practices as far as possible;
- linking the fuelwood issue to other aspects of development and the alleviation of poverty.

This rethink which took place during the 1980's around the fuelwood crisis has fundamental implications for policy interventions aimed either at improving rural energy supplies, or at preventing and reversing the environmental decline associated with forestry (*Van Horen* and *Eberhard*, 1995). The provision of fuelwood should not be a means to an end in itself, but should be part of a broader more holistic approach towards the alleviation of rural poverty. The aim should be on community forestry development programmes of which small grower schemes can form an important component. The influence of rural electrification should also be considered.

Small-grower schemes and rural electrification: Possible solutions in rural energy needs

Small-grower schemes

The basic idea behind small-grower schemes is for many individual farmers in one district each to grow a *Eucalyptus* woodlot that they manage themselves under the guidance of an extension forester. A private forestry company provides the inputs, such as plants and fertiliser, as well as the extension service. Ideally the growers do the forestry work (planting, weeding, etc.) themselves, for which they are paid a rate per area (*Cellier*, 1991).

The costs of plants and fertiliser, as well as the direct payments made to the growers, are charged to the grower's account on which simple interest of about half the current prime rate in South Africa is charged. The cost of extension service is borne by the company. The growers enter into a contract with the company which binds them to sell all the timber to the company at harvest at a market-related price (*Cellier*, 1991).

It is important to recognise that the whole programme must be attractive to the growers to be sustainable. One of the traditional constraints of private farmers growing trees has been the time taken for trees to mature. However, by planting with hybrid *Eucalyptus* clones and practising intensive silviculture, the rotation length can be kept to a minimum. In northern KwaZulu-Natal it is estimated that trees should be ready for harvest in six to seven years. This has a significant effect on the economic viability of the programme. A cash incentive is also offered to the grower at the end of each year to ensure that the trees are well maintained and have adequate firebreaks (*Cellier*, 1991).

There is, potentially, a reasonable profit for the small-scale commercial timber grower. A survey of growers in the different schemes showed that the net profit of timber for 1993 was R 2124[1] per hectare for the first rotation. On average, the mean age at felling was 6.24 years (which is about one year earlier than the economic optimum), so the annual net productivity was R 340 per hectare (*Cairns*, 1993 ex *Christie* and *Gandar*, 1995).

Large areas of South Africa receive a low rainfall, where commercial forestry is not viable. The Faculty of Forestry of the University of Stellenbosch is currently selecting and breeding drought tolerant species. *Eucalyptus* species and provenances with a mean annual increment (MAI) of 11 cubic metres per annum have been identified in an area with an annual rainfall of less than 400 mm. This can make small grower schemes in low rainfall areas a possibility in future.

These small grower schemes will not only bring economic benefit to the growers and the surrounding communities, but jobs can be created in the form of small scale contractors, contracting various silvicultural operations. The harvesting of slash will also provide a source of fuelwood, and alternative energy sources like electricity should become more attainable.

Electrification

One of the goals set out in the Reconstruction and Development Programme of the Government of National Unity is the provision of an additional 2.5 million electrical connections to low-income households between 1994 and 1999, thereby increasing the level of access from about 36 % to 72 % (White Paper on Reconstruction and Development, 1994).

Complementing this aim is the accelerated electrification programme, which was launched by Escom and a number of local authorities in 1991. By the end of 1995, approximately 1.5 million new grid connections had been made, at an average capital cost of R 3162 per connection. The level of household access to electricity by the end of 1995 was estimated to have risen to around 50 % (*Van Horen* and *Simmonds*, 1996).

Above mentioned figures seem to be very encouraging but if "rural" is defined as all the households outside proclaimed towns and cities, the rural population accounts for approximately half of the total population. Within this rural group, 21 % of households had electricity in 1996 (Table 3) (*Davis*, 1996). Another significant factor to consider is that every percent growth in the population equates to about 80000 new households without electricity (*Eberhard* and *Van Horen*, 1995).

Very few households using electricity can afford to purchase cooking appliances or the operational costs associated with using them. Even in households where electric cooking appliances are used, only a portion of the fuelwood consumption is substituted with electricity. Certain foods are better suited to fuelwood cooking, cooking appliances

1 All currency units quoted in this paper are in South African Rands; as of December 1997, the exchange rate was R 2.77/DM 1.

Table 3: National electrification statistics, December 1995 (Davis, 1996).

Province	Households (000)	Access to Electricity %		
		Urban	Rural	Total
KwaZulu-Natal	1 796	79	14	43
Eastern Cape	1 393	67	6	28
Gauteng	1 751	78	54	77
Northern Province	1 055	71	24	29
Western Cape	933	88	47	82
Northwest	710	70	21	36
Free State	599	68	33	53
Mpumalanga	589	59	37	45
Northern Cape	183	76	47	66
Total	**9 009**	**76**	**21**	**50**

may not be available or in disrepair and pots may not be suited to electric cooking appliances (*James*, 1995).

Therefore electricity will probably not replace fuelwood as an energy source in rural communities altogether in the near future. Fuelwood will remain the primary source of energy but through an integrated socio-economic approach fuelwood can be supplied without exploitation of natural resources.

Conclusion

A simple energy policy of supply and demand with the main objective being the protection of natural resources, has proven to be a failure. Although thousands of hectares of woodlots have been established the rural energy need still remains. In recent years, a shift has occurred away from the perception of fuelwood harvesting and collection as the major cause of deforestation in developing countries. Instead the increasing scarcity of wood resources observed in many rural areas is being seen in a broader context which acknowledges the more complex issues of land and labour availability, resource ownership, and access to political and economic power. The fuelwood problem and potential solutions are therefore also no longer conceived in narrow "energy" terms (*Williams* et al., 1996).

The supply of fuelwood to the rural poor should form part of a much broader social process, not dictated by what government and other policy formulators perceive as important to rural people, but by rural needs. Ways of not only providing in fuelwood needs but also in broader economic needs should be investigated. A possible solution is the propagation of small-grower schemes. Considering the figures on rural electrification, fuelwood will remain a very important source of energy in rural areas.

References

Bembridge, T. J., 1990: Woodlots, Fuelwood and Energy Strategies for Ciskei. South African Forestry Journal No. 155: 42–51.

Cellier, G. A., 1991: The potential for economic development in rural Kwazulu through the use of commercial Eucalyptus woodlots. IUFRO Symposium. Intensive Forestry: The role of Eucalyptus, Durban, South Africa: 834–845.

Christie, S., Gandar, M. V., 1995: Commercial and Social Forestry. Land Agricultural Policy Centre Working Paper 18: 86 pp.

Cooper, D., Fakir, S., 1994: Commercial Farming and Wood Resources in South Africa: Potential Sources for Poor Communities. Land and Agricultural Policy Centre Working Paper 11: 1–12.

Davis, M., 1996: South Africa's Electrification programme: Progress to Date and Key Issues. Development Southern Africa, 13 (2): 189–204.

Eberhard, A. A., Van Horen, C., 1995: Poverty and Power: Energy and the South African State. Pluto Press, London and UCT Press (Pty) Ltd. Cape Town, South Africa: 227 pp.

EDRC, 1994: Power to the People: The Energy Policy Research and Training Project. Indicator South Africa, 12 (1): 83–87.

Fenn, T., 1994: What is Social Forestry. Paper presented at the Plant for Life Conference, Pretoria.

Foley, G. Barnard, G., 1985: Farm and Community Forestry. ODI Network Paper 1B.

Gandar, M. V., 1988: Planning Village Scale Forestry for Rural Areas. Abstract of presentation to Forestry Research 88 Symposium, Pretoria.

Gandar, M. V., 1994 a: Afforestation and Woodland Management in South Africa, EPRET Paper No. 9, Energy and Development Research Centre: 104 pp.

Gandar, M. V., 1994 b: Woodlots – A New Role. Paper presented at the Plant for Life Conference, Pretoria.

Grut, M., 1977. Notes on the History of Forestry in Western Cape, 1652–1872. South African Forestry Journal. No. 100: 32–37.

James, B., 1995: The Impact of Rural Electrification: Exploring the Silence. Energy and Development Research Centre Report: 1–29

Kotze, I. A., 1994: Opening and Background to Biomass Initiative. Opening speech at the Plant for Life Conference, Pretoria.

Mondi Forests, 1998. Personal communication.

Oxenham, P., Eberhard, A. A., 1990: Fuelling the Crisis. In Graham Howe (Ed), Rotating the Cube: Environmental Strategies for the 1990's. Durban: University of Natal: 61–63.

Republic of South Africa, 1994: White Paper on Reconstruction and Development, Notice No. 1954 of 1994. Government Printer, Cape Town.

Sappi Forests, 1998. Personal communication.

Sen, D., Das, P. K., 1987: The Management of People's Participation in Community Forestry: Some Issues. ODI Network Paper 4D.

Van Horen C., Eberhard, A. A., 1994: Power to the People: Widening Access to Basic Energy Services in South Africa. Paper delivered at Regional Energy Forum for Southern and East Africa Countries, Cape Town.

Van Horen, C., Eberhard, A. A., 1995: Energy, Environment and the Rural Poor in South Africa. Development South Africa 12 (2): 197–211.

Van Horen, C., Simmonds, G., 1996: Energy Efficiency and Social Equity in South Africa: Seeking Convergence. Submitted to Energy Policy: 21 pp.

Williams, A., Eberhard, A. A., Dickson, B., 1996: Synthesis Report of the Biomass Initiative. Biomass Initiative Report PFL-SYN-02. Department of Mineral and Energy Affair: 120 pp.

APPENDIX

FUELWOOD FORESTRY IN SOUTH AFRICA – FACTS AND FIGURES

Demographic information regarding fuelwood

Table 1: Characteristics of households in former homeland areas (Viljoen, 1994 ex Williams et al., 1996).

Region	% female respond.	% male H/Hold heads	H/Hold size	Av. age respond.	No. of H/Hold Members away for >5 days/wk
Venda n=129	72	79	5.75	41	2.07
Gazankulu n=221	49	86	5.53	37	1.44
Lebowa n=681	68	73	5.59	43	1.71
KaNgwane n=116	57	80	6.34	41	1.79
KwaNdebele n=150	53	84	4.35	41	1.55
Transkei n=499	87	59	5.64	49	1.72
Ciskei n=250	87	65	5.77	51	1.25
Bophuthatswana n=386	81	67	6.86	47	1.29

Table 2: Income characteristics of households in the former homelands (Viljoen, 1994 ex Williams et al., 1996).

Region	Average household income	% <R400	% >R850	Three most important sources of income		
Venda n=129	R846	38	73	salaries (41%)	pensions (19%)	remittances (11%)
Gazankulu n=221	R701	24	78	salaries (73%)	pensions (13%)	remittances (7%)
Lebowa n=681	R870	17	60	salaries (48%)	pensions (21%)	remittances (21%)
KaNgwane n=116	R847	29	66	salaries (48%)	pensions (16%)	self employed (8%)
KwaNdebele n=150	R1483	12	28	salaries (79%)	pensions (8%)	remittances (6%)
Transkei n=499	R754	21	74	salaries (38%)	pensions (25%)	disability grants (17%)
Ciskei n=250	R753	21	72	pensions (42%)	salaries (41%)	remittances (8%)
Bophuthatswana n=386	R531	47	83	salaries (30%)	pensions (27%)	remittances (20%)

Table 3: Expenditure on fuel (mean) (Williams et al, 1996).

Region	Expenditure on fuels	% Expenditure	% Income
Venda	R42	11	7
Gazankulu	R57	11	9
Lebowa	R41	10	5
KaNgwane	R63	13	9
KwaNdebele	R72	10	6
Transkei	R42	11	7
Ciskei	R55	10	6
Bophuthatswana	R59	14	11

Table 4: Prevalence of different fuels (Viljoen, 1994 ex Williams et al., 1996).

Region	Fuel Prevalence (%)					
	Paraffin	Coal	Gas	Bought fuelwood	Collected fuelwood	Dung
Venda	87.6	2.3	16.3	41.9	81.4	3.1
Gazankulu	92.3	0.0	4.1	32.1	63.8	0.9
Lebowa	91.5	21.2	9.0	18.7	55.1	4.7
KaNgwane	85.3	14.7	12.1	12.1	81.0	0.0
KwaNdebele	81.3	25.3	8.7	20.7	42.7	0.7
Transkei	95.4	1.8	7.0	27.3	62.1	31.3
Ciskei	94.4	0.4	13.2	24.0	68.8	24.8
Bophuthatswana	93.0	30.1	14.5	36.5	56.5	27.5

Table 5: Estimates of fuelwood consumption by rural communities in the former homelands (Gandar, 1994).

Region	Annual consumption per household (kg)		Estimate of total annual consumption (000) tons	
	rural	sr/pu	EPRET	EDRC
Bophuthatswana	2 400	1 400	483	678
Ciskei	3 400	2 280	193	266
Gazankulu	4 100	3 200	452	414
KaNgwane	4 000	3 200	283	237
KwaNdebele	2 400	1 400	98	102
KwaZulu	3 910	2 890	2 193	1 102
Lebowa	3 800	2 850	1 271	1 054
QwaQwa	1 000	340	26	12
Transkei	2 950	2 300	1 311	1 332
Venda	4 200	3 280	315	291
Total			6 625	5 488

Table 6: The consumption of fuelwood for domestic energy in low-income households in South Africa (Gandar, 1994).

Region	Fuelwood consumption (million tons/year)
Homelands (rural & semi-rural)	6.6
Farmworker families	3.5
Other rural	<0.5
Urban	0.7
Total	**11.3**

Table 7: The available and sustainable supply of fuelwood from indigenous woodland in the homelands, with estimated consumption and the surplus (deficit) for each homeland (Aron et al., 1989, ex Gandar, 1994).

Region	Supply	Consumption	Surplus/deficit
Bophuthatswana	757	483	274
Ciskei	351	193	158
Gazankulu	870	452	418
KaNgwane	178	283	(105)
KwaNdebele	60	98	(38)
KwaZulu	650	2 193	(1 543)
Lebowa	1 088	1 271	(183)
QwaQwa	0	26	(26)
Transkei	1 198	1 311	(113)
Venda	651	315	336
Total	5 803	6 625	(882)

WOODLOTS AND SMALL-GROWER SCHEMES

Table 8: Estimated whole-programme costs of different types of woodlot strategies (1992 costs) (Gandar, 1994).

Programme costs	Departmental	Community	Small-grower
Establishment costs (R/ha)			
Direct costs	2 200	800	600
Indirect costs	700	4 000	800
TOTAL	2 900	4 800	1 400
Maintenance costs (R7ha/yr)			
Direct costs	60	0	110
Indirect costs	20	100	0
TOTAL	80	100	170

MONDI LTD
Extract from their homepage:
http://www.mondiltd.co.za/mondi4.htm

Some 6 years ago, Mondi launched a project called Khulanathi: Zulu for "grow with us". This is a unique self-development scheme assisting subsistence farmers in rural KwaZulu/Natal to grow eucalyptus trees as a cash crop. Currently involved are over 1600 Zulu farmers while woodlots cover some 2300 hectares. Each receives the benefit of Mondi expertise, a guaranteed market at Mondi Kraft's giant Tichard Bay mill, superior clonal propagated plants from our nurseries. And financing. As well as breathing new life into marginal communities, the scheme has inspired a unique form of agroforestry. Between the rows of trees, the women grow traditional crops such as cowpeas and groundnuts which not only provide additional food for their families but also supply valuable nitrogen to the growing trees. The Khulanathi project is just one of the ways in which Mondi fosters rural upliftment. It's part of our partnership with the communities we serve.

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Author's address

Cori Ham
Faculty of Forestry
University of Stellenbosch
Private Bag X1
Matieland 7602, South Africa
e-mail: ch2@land.sun.ac.za

Forestry with a Conscience Survival of Sri Lanka Tea

Dr. E. S. Mahendrarajah

More time is spent on data collection and still more money is expended on data analysis, while the forest areas keep dwindling at an alarming rate, keeping everyone guessing as to what the next calamity is going to be.

The basic scenario in Sri Lanka is no better than what one sees in other developing countries. There are hundreds of NGO's and a couple of international organisations involved in forestry related environment works. Whether they have had the expected impact on their subjects is yet to be gauged. The general belief amongst villagers is that the members of these organisations benefit themselves, beyond reasonable proportions in the name of helping the peasants. These presumptions of the villagers have been widely recognised and understood to be true by independent observers.

In this paper I wish to address one particular area which cries out for our collective efforts and that is the tea estate sector of Sri Lanka. As you are aware, the world's best teas are produced in Sri Lanka and we are the biggest exporters of such quality teas all over the world. Our country earns the biggest slice in foreign exchange via this agricultural commodity, which keeps the development processes in the country on top gear.

The irony of the whole situation is that this vital sector of our economy is dependent on the fertility of a very fragile ecosystem. This aspect has received very little attention by the different ministries involved in development in our country due to various idiosyncratic reasons.

It should be specifically noted that most of the perennial rivers of the country including the biggest called the Mahaweli originate in these tea gardens. Silting of reservoirs and denudation of catchment areas is the order of the day. The reasons are never difficult to come by. Systematic neglect of the estate workers by consigning them to a standardised poverty, depriving them of adequate housing, fuelwood and lighting, has caused a vicious nexus. This devastating cycle can be easily corrected with foresight, determination and courage.

Lighting and Fuelwood

Most workers possess dairy cattle to earn an additional income. By assembling 20–30 cows in a common dairy shed, a sizeable biogas plant can be operated to run a 10 kW generator. The electricity generated can be supplied to their cottages for about three hours every night for lighting purposes. The modern CFL bulbs can provide adequate light to help their children study and become better citizens.

Calliandra calothyrsus planted on contours can be harvested rotationally every 45 days providing the cattle with good food and the twigs remaining from the troughs, as fuelwood for the workers. In addition to this multipurpose legume, sweet sorghum and ramie can be cultivated as additional fodder and industrial crops. The ramie fibre production can create additional job opportunities, cane, bamboo and cauasa, wax producing plants can be grown on stream banks.

Woodless Construction

Presently the great majority of the tea estate workers live in hovels – 10 feet by 10 feet, known locally as "Line Rooms". If the woodless technology can be introduced, vaulted and domed roof houses can be constructed with self help – at low cost. Turkey, Egypt, Iran, Syria, Tunisia and other countries where this technology has evolved over the last 5000 years can help us with technicians and engineers to quickly implement this noble project.

Bamboo as Roofing

In Vietnam, bamboo is chipped and bound with resins and pressed into corrugated sheets. Such technologies should be transferred to us for successful implementation.

Paper Pulp Production

Ceiba pentandra which grows very fast is processed for shuttering boards and the outer boards are wasted for there is no use found for it. If ecofriendly paper pulp production technologies can be introduced to us, we can use bamboo, crotalaria and other short duration fibre crops to produce paper.

By implementing such projects on the tea estates, the lands can be conserved for sustainable development, and the workers provided with decent living conditions, helping them to contribute their best for the well-being of all concerned.

Author's address

Dr. E. S. Mahendrarajah
7/4 King Street, Matala P. C.
21000 Sri Lanka
e-mail: lex_mail@sri.lanka.net

Note on Firewood and its Efficient Use

Waclaw Micuta

Importance of firewood

Firewood was the first fuel to be used by human beings for cooking and heating. It was readily available and easy to ignite. Even today about a half of humanity, living mainly in developing countries, depends on wood for preparation of its daily food.

Unfortunately, excessive use has resulted in a serious depletion of the earth's forest reserves, leading to massive soil erosion, desertification, change in climate and considerable human suffering. If we are to curb these catastrophic trends before it is too late and to help people, who still depend on wood for their survival, we have to promote a more rational use of this precious source of energy.

The scope for wood saving is immense when it is considered that, in many regions of the world, up to 90% of all the wood cut is used for cooking and heating purposes.

The economic use of firewood is not a new problem for human beings. In many countries of Asia, Europe, North and South America people have been experimenting the efficient use of firewood for centuries. In most European countries farmers have been solely dependent on wood as a fuel even in the recent past. It suffices to talk today to old people in European villages, to learn all the secrets of proper handling of firewood. To learn and to understand these secrets one must be aware of the nature of wood.

Characteristics of firewood

Wood is a pure product of nature. Since about three billion years the leaves of plants have developed a green substance called chlorophyll. Sunshine falling on chlorophyll provokes a complicated chemical process, which absorbs carbon dioxide (CO_2) from the atmosphere, and water with mineral salts which is sucked up by plants, through their roots, from the soil. This process results in production of cellulose, the main component of wood.

It is important to note that, during this chemical process, oxygen, a gas necessary for all life on the earth, is released into the atmosphere. Thus the growth of plants and particularly trees, is essential for the survival of humanity and all other creatures living in the world, as they produce oxygen and absorb carbon dioxide.

In every combustion process carbon dioxide is released into the atmosphere. When we burn wood we also send some volume of this gas into the air. If this takes place in an environment filled with plants and trees, a moderate amount of carbon dioxide is welcome. It helps the growth of plants and increases production of oxygen. It becomes dangerous when humans burn millions of tons of fossil fuels, such as crude oil, its derivatives, hard coal, or peat. The plants cannot absorb it and the gas is accumulated in the atmosphere, preventing natural heat radiation into space, increasing the average temperature of the earth and threatening the earth's climate.

Composition of wood

The chemical composition of wood varies according to different wood species. On the whole, wood consists mainly of cellulose, lignin and a certain amount of water. Cellulose and lignin are organic compounds composed of carbon, hydrogen and oxygen. When cellulose and lignin are exposed to a high temperature they decompose and create combustible gas. The gas reacts with oxygen in the air to form carbon dioxide and water vapour with considerable production of heat. An excess of carbon produces charcoal, which by reaction with oxygen gives embers, producing again carbon dioxide and heat. The advantage of burning wood as against charcoal is that it recuperates all combustible gases which are lost during production of charcoal.

Heat value of firewood

People all over the world know, by experience, which species of wood are good for cooking and heating. In Europe the preference goes to hard wood such as hornbeam, beech, or oak. The soft and resinous wood, such as pine or spruce, are preferred for starting or boosting fires. Unfortunately, it is not always easy, particularly in developing countries, to choose the best wood. Most people have to make do with whatever species are available locally. One may say here that even poor firewood, if dried and cut in small pieces, does burn well and if mixed with pieces of better wood results in a good fire.

In general the heat value of any variety of wood depends on its density and water content. It is usually defined as the quantity of heat extracted from 1 kg of wood burned, measured in kilo calories (kcal/kg) or kilo joules (kJ/kg), (one kcal equals 4.18 kJ). In Europe, well-seasoned hardwood with 15 to 17 % of water content has a heat value of about 15500 kJ/kg. When various wood species are dried in laboratory conditions, the difference in heat value between various species diminishes quite considerably. The importance of dry wood is presented in Table 1:

Moisture content

It follows that good firewood must be dry. Wet or green wood also burns, but the heat produced will be first used for

Table 1: The heat value of firewood in relation to moisture content.

	kcal/kg	kJ/kg	in % of newly cut wood
Newly cut wood	1 950	8 200	100%
Wood well dried in open air	3 700	1 500	190%
Wood dried in oven	4 500	1 800	231%

Source: Chauffage Moderne au Bois, Office Forestier Suisse, CH-4500 Soleure, Switzerland.

evaporation of water to the detriment of cooking or heating. Wet wood lowers the temperature of the fire-box, slows the combustion process, and prevents the complete combustion of gases which results in the appearance of dark smoke, harmful for people's health and depositing inflammable substances provoking chimney fires. Wet wood has on the whole only half the heat value of the same wood properly dried in the open air. Thus burning of wet wood is an inexcusable waste of this important and precious source of energy. Introduction of fuel efficient stoves is fully justified only if people decide to use dry firewood.

To establish the degree of water content one should weigh a piece of wood, say 1 kg, cut it in small pieces and dry it in a hot oven. When the weight ceases to diminish and remains stable, say at 700 gr, it indicates that the wood contained 300 gr of water or that the moisture content was 30 %. In Europe people consider wood as suitable for combustion when the moisture content falls below 20 %. Any percentage below this limit is welcome. Careful users manage to use wood of 10 to 15 % moisture content.

Drying of firewood

Firewood dries slowly. Left in logs in Europe, it dries about 1 cm per year. In hot and dry countries this process is more rapid, but still needs several months. To accelerate the drying process, logs or branches should be sawn and split in relatively small pieces. This work should be done while the wood is wet (it is much harder to saw and to split dry wood). Also saws last much longer. In Europe trees for firewood are cut in winter when the sap is not circulating and water content is relatively low. The fallen trees are left in the open air exposed to snow and rain. Towards the end of the summer logs are sawn and split in relatively small and thin pieces. They are stocked crosswise, in the open air but well sheltered from rain, snow and mud. The air should circulate freely among all the pieces. Very often the wood is placed against house walls exposed to wind. Air movements dry the wood well and in addition the wood protects and insulates the houses. The wood remains in these conditions at least for two years. Hard wood is kept longer, often for three or even four years. Also, a small stock of wood is always kept close to warm stoves to complete the process of drying. Every day the stock is replenished so that only very dry wood is burned.

In some countries or regions termites or other insects may present a danger for a stock of dry firewood. In such situations standard measures used locally should be applied to keep away the insects.

Drying firewood in a humid climate

There is no problem of having dry wood in dry and hot countries. However, even in these countries it is not always easy to keep firewood dry during the rainy season. In countries with frequent rain, mist or fog the humidity of the air may reach or even surpass 80 %. The question arises whether it is possible to dry wood in such conditions.

The answer is positive, but it demands additional efforts. A simple experiment may prove the point. Freshly washed clothes, or linen, hung in humid air, but sheltered from rain and exposed to air movement, do dry. With the occasional spell of sunshine it dries much better.

This experiment applies also to firewood. Firewood must be sheltered from rain and mud and exposed to fresh air. If the cover is made with sheet metal, painted black, the occasional sunshine will heat it and serve as a solar drier. The heap of wood could also be covered with a black or transparent plastic sheet. In this case care should be taken to ensure the circulation of air and expulsion of wet air from under the plastic. After some time, firewood would dry and be adequate for cooking or heating purposes.

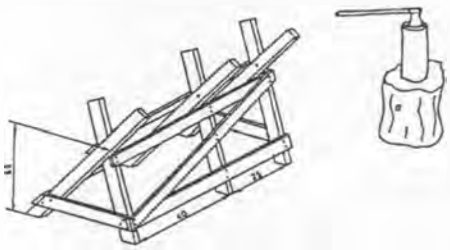
Size of firewood

It was mentioned above that under the influence of heat the combustible parts of wood change first into gas and later into flames. Thus, it is important to bring wood rapidly to a high temperature. Yet, wood is a good insulator, which means that heat tends to penetrate its inner layers very slowly. Therefore, the thicker the wood, the slower the gasification and less rapid the combustion. For these reasons it is recommended to use wood cut in relatively small pieces. Such pieces heat rapidly, release gases easily and give off a steady flame. The length of the pieces depends on the size of the stove. They must easily fit the fireboxes. Their diameter should be about 3 to 5 cm. When preparing firewood, it is advisable to have pieces of wood of different diameters. Some of them should be very thin and some larger than average. This will facilitate keeping a steady fire with bright flames. When the fire tends to die a few small pieces will revive it. When the fire is strong and intended to last longer one adds bigger pieces of wood.

Firewood workshop

Practical experience in many countries proved beyond any doubt that efficient use of firewood is not possible without firewood properly prepared by users themselves or by reliable suppliers. This work cannot be performed well without a minimum of tools and facilities. Unfortunately such tools are not always available for poor people in developing countries, who need them the most. This problem must be resolved sooner or later if the firewood is to be used efficiently. Preparation of firewood is done mostly by users in their own firewood workshops.

Two simple appliances form the core of a wood workshop. They are a sawyer's jack for sawing wood and a piece of tree trunk for the efficient and easy splitting of wood. Making of a sawyers' jack is not difficult. One may do it with any pieces of wood available around the house. The drawing below gives a rough idea of this appliance.



It consists of four or six long pieces of wood of the same length. Each pair of pieces are attached together in the middle by nails, bolts or cords. Their lower parts are put aside so that they can stand firmly on the ground. These two or three trestles are fixed together with additional pieces of wood. When wood to be sawn is placed on the jack, it should rest firmly and at the height of the workers' hips. The third trestle makes it possible to saw shorter pieces of wood. This appliance assures correct work with a relatively small expenditure of energy.

For small families a one person saw is quite adequate. It should be a saw for green wood, with larger and more spaced teeth and not a joiner's saw with numerous teeth, destined for more precise work on dry wood. For larger consumers it would be necessary to procure a large saw operated by two persons. When buying a saw it is advisable to also buy an appropriate file and ask for instruction on how to sharpen a saw at home.

The next tool needed in the workshop is an axe, firmly fixed to a handle. If possible, it is good to have more than one, for cutting smaller or larger pieces of wood. It is also useful to have a piece of tree trunk, standing firmly on the ground. Its height should be a bit lower than a worker's hip. This position assures a good force for an axe cutting wood.

To split larger pieces of wood it is necessary to have wooden, or preferably steel, wedges of different sizes, and a heavy sledge-hammer. One wedge might not be enough, as it could become imprisoned in the wood and difficult to remove.

Starting and managing the fire

As previously mentioned in this note it is important to create a high temperature in a stove as soon as possible. This is done by using very dry resinous wood, cut in very thin pieces. Such wood is usually called "kindling wood" and is kept for starting fires. Ignition of this wood should be instantaneous and result in vivid flames. The flame temperature easily reaches 80°C. It heats firewood placed in the stove, fire box and the rest of the stove. It should be remembered that a cooking pot with water or food cools the stove.

It is important to maintain the flames and to develop a strong fire. At this stage of combustion it is not advisable to economise on wood. The operator should however avoid the danger of overcharging the fire with wood, which might result in the decline or disappearance of the flames. If this happens, the wood starts to smoulder. Combustible volatile substances which do not burst into flame, leave the firebox in the form of dark smoke, which deposits creosote and tar, a black inflammable substance, which may cause a dangerous chimney fire.

Once a fire and stove reach a high temperature, a new danger appears, namely that of turbulent combustion, which results in excessive consumption of wood. This danger may be avoided by diminishing inflow of air into the stove by setting the door ajar, by reducing the input of wood, or by both measures. In fact, one of the great advantages of cooking on firewood is the possibility of regulating fire power, which is much more difficult when burning charcoal.

To maintain a steady fire one may put into a stove bigger pieces of wood. This slows down combustion without reducing its efficiency.

Towards the end of the cooking process, one ceases adding wood. The heat accumulated in food, in the stove and glowing embers is sufficient to keep food simmering for some time.

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Author's address

Waclaw Micuta
- REDI -
Renewable Energy Development Institute
5 rue du Vidollet
CH-1202 Geneva
Fax +41-22-733 50 49

Should Charcoal Braziers be Promoted?

G. Rossier and W. Micuta

In most developing countries, the major domestic fuel is charcoal. The following text examines the nature of charcoal and its usage as compared with firewood. The authors prove that, in conditions prevailing in developing countries, it is possible to save 90 % of wood if it is burnt directly in fuel-efficient stoves instead of being converted into charcoal and burnt in traditional or improved braziers.

Production of charcoal

Wood consists of cellulose, lignine and volatile substances, mainly water. During the process of production of charcoal (pyrolysis), the volatiles are eliminated. The cellulose and lignine are decomposed by reactions of the following type:

$$\underset{\text{(cellulose)}}{Cn(H_2O)m} \rightarrow \underset{\text{(charcoal)}}{nC} + \underset{\text{(steam)}}{mH_2O} \quad (1)$$

Note:
n = number of carbon atoms in molecule of cellulose
m = number of oxygen atoms in molecule of cellulose

The reaction (1) is endothermic (takes in heat). Inside the charcoal heap this heat is provided by partial combustion of some of the carbon:

$$C + O_2 \rightarrow CO_2 + 393 \text{ kJ } (94 \text{ kcal}) \quad (2)$$

and

$C + 1/2\ O_2 \rightarrow CO + 109$ kJ (26 kcal) (3)

Both reactions (2) & (3) are exothermic (give out heat to the environment).

The efficiency of pyrolysis of chemically pure cellulose is shown from the following:

$(C_6H_{10}O_5)n$	$\rightarrow$ $6nC$	$+$ $5n\,H_2O$	(4)
$n \times 162$ g	$n \times 72$ g	$n \times 90$ g	
(cellulose)	(charcoal)	(steam)	

The yield (mass of charcoal / mass of cellulose) = 72 : 162 = 45 %, and the rate mass of cellulose/mass of charcoal = 162 : 72 = 2.25.

The last expression (4) assumes pyrolysis of pure completely dry cellulose, in an oxygen free atmosphere and externally heated. This cannot be achieved in charcoal production. If the wood contains 50 % of volatiles (methanol, acetone, tars etc.) and water, the yield becomes 22 % and the rate 4.5.

In practice, the heat needed for pyrolysis is provided by the partial oxidation of the carbon reaction (3). As a result about half the charcoal formed is lost, reducing the yield to 11 % and increasing the rate to 9.0. Finally, part of the crown of the tree is not utilised for charcoal making. An FAO report estimates this loss at 25 % of the wood[1]. Thus the final rate of wood (cellulose) mass to charcoal mass becomes: 9 : 0.75 = 12.

It follows therefore that artisanal charcoal production in the developing countries takes from 8 kg of very dry wood to 12 kg of ordinary wood to produce 1 kg of charcoal[2].

Lower rates of 5 to 6 kg of wood for 1 kg of charcoal can only be achieved with efficient kilns which collect the gases produced and use the combustion of CO to provide the heat needed for pyrolysis. In a traditional charcoal heap most of the heat comes from reaction (3) which is less exothermic than (2) and consequently more of the charcoal has to be burnt to sustain pyrolysis.

A yield of 1 kg of charcoal per 10 kg of wood is normal, although there are examples of higher yields. Thus, one needs ten times 13400 kJ to obtain 26750 kJ in form of charcoal:

$$26750 : (13\,400 \times 10) = 0.2 \text{ or } 1/5$$

Thus, 4/5 of the heat energy is lost in pyrolysis.

Calorific value (CV) of charcoal

Dry charcoal consists mainly of amorphous carbon and mineral ashes with, possibly, a certain amount of wood badly carbonised.

The CV of charcoal in reaction (2) is 393 kJ (94 kcal) per 12 grs of pure carbon, that is :

393 kJ/12grs × 1000 grs/kg = 32750 kJ/kg

The amount of ash depends on the charcoal (wood) but assuming 5 %, the CV falls to 31100 kJ/kg.

0,95 × 32750 kJ/kg = 31 100 kJ/kg

These values are for top quality charcoal entirely carbonised. Partially carbonised wood is often found in charcoal. In this case the CV is considerably reduced.

In addition some charcoal is lost in handling, in the form of small pieces or dust. During rain the charcoal becomes wet, increasing the weight, reducing the CV and wasting the heat needed to evaporate the moisture.

As a result of all the preceding, the CV of charcoal is usually taken as between 25000 and 26750 kJ/kg, (6000 to 6400 kcal/kg) which is about twice the usually accepted CV of dry wood, 13400 kJ/kg or 3200 kcal/kg.

Warning

In an incandescent stove, a chemical equilibrium tends to take place as follows:

$$CO_2 \leftrightarrow CO + 1/2\ O_2$$

and at higher temperatures the equilibrium moves to the right. The burnt gases give no smoke but contain a considerable proportion of carbon monoxide which is colourless, without smell and very poisonous. Even in low concentrations in the air it destroys haemoglobin in the blood and at high concentrations it is lethal. Cooking or heating on open charcoal braziers represents a definite health hazard to women and children in the vicinity. The lethal dose in two hours = 0.7 ‰ in the air.

Multi-fuel wood stoves

REDI has introduced multi-fuel stoves, with or without chimneys, which have much higher thermal efficiency than traditional open-fire or even the most improved stoves. These stoves are designed to burn wood but can be used for all sorts of waste such as bagasse, paper, cardboard, etc. REDI has also developed less costly kerosene or diesel oil burners without pressure-proof reservoirs, and thus with no explosion risks, and that can be used with the stoves. The stoves can also be fired with butane, propane or methane gas.

Several trials showed a specific fuel consumption of 50 g of wood to bring 1 kg of water to the boil. Cooking time is greatly reduced. The long ignition time needed for charcoal is cut down. Power regulation becomes possible. The thermal insulation, low fuel consumption and the removal of burned gases through the chimney mean that the cook suffers less from the heat and smoke. She or he is more comfortable and there is less risk to their health than with the traditional charcoal braziers used in developing countries.

Conclusions

It is established that the use of wood in the form of charcoal causes a loss of 4/5 of its calorific value. In addition the efficiency of charcoal braziers is moderate – 50 to 100 grs of charcoal are needed to boil 1 litre of water whereas a good wood stove has a specific fuel consumption of only 50 grs of wood per litre of boiled water.

It follows that when cooking on fuel-efficient stoves one burns 10 times less wood than while cooking on charcoal braziers.

Clearly a reduction in the use of charcoal in domestic and community stoves will make a significant contribution to saving trees in developing countries.

Unfortunately, there are many obstacles to the process of transition from charcoal to other fuels, such as an ignorance of the nature and properties of charcoal, deeply rooted habits, lack and/or cost of good multi-fuel stoves on the market and above all a powerful charcoal lobby earning money by manufacturing and selling charcoal.

A popular argument in favour of charcoal is its lower transport cost as compared with firewood.

1 See Bibliography position no. 1.

2 See Bibliography position no. 8.

This argument is less convincing if the calorific value of charcoal and that of wood transported are adjusted according to their fuel efficiency rate (FER) when burnt in good stoves, say 50 % for wood and 25 % for charcoal. In this case the transport cost of 1 unit of useful heat from wood or charcoal is about the same. This is illustrated by the following calculations:

Useful calorific value of 1000 kg of firewood burned in stoves of 50 % FER

1000 kg × 13400 kJ/kg × 0.50
= 6.7 million kJ

Useful calorific value of 1000 kg of charcoal burned in braziers of 25 % FER

1000 kg × 26 750 kJ/kg × 0.25
= 6.7 million kJ

This indicates that to obtain 6.7 million kJ one may transport either one ton of wood or one ton of charcoal.

However, it should again be stressed that to obtain 1 ton of charcoal it is necessary to cut about 10 tons of firewood. Thus, from the economic point of view, the values above should read:

1.0 ton of firewood used directly yields 6.7 million kJ of useful heat.

1.0 ton of firewood converted into charcoal yields 0.67 million kJ of useful heat.

This again shows that the heat obtained directly from firewood burned in fuel-efficient stoves is **10 times greater** than the heat obtained from charcoal produced from the same amount of wood, and that the transport of wood instead of charcoal may well be economically justified.

Wood stoves or charcoal braziers?

Comparison of REDI stoves using firewood, with traditional or improved braziers using charcoal:

Basis of the comparisons

Charcoal calorific value:	= 26750 kJ/kg
Firewood calorific value:	= 13400 kJ/kg
REDI stoves:	
Fuel Efficiency Rate	FER 45 %
Traditional charcoal braziers:	FER 15 %
Improved charcoal braziers:	FER 30%
Wood needed to produce 1 kg of charcoal:	10 kg

A. Wood stove versus traditional charcoal braziers

1) 1 kg of firewood burnt in a REDI stove gives:
total heat = 13400 kJ
useful heat (heat absorbed by food) = 13400 kJ × 0.45 = 6030 kJ

2) 1 kg of charcoal burnt in a traditional brazier gives:
total heat = 26750 kJ
useful heat = 26750 kJ × 0.15 = 4010 kJ

6030 : 4010 = 1.5

This indicates that useful heat obtained from 1 kg of wood on a REDI stove needs 1.5 kg of charcoal burned on a traditional brazier.

To produce 1.5 kg of charcoal one needs 15 kg of wood. The relation is therefore 1 to 15. In other words, cooking on a traditional brazier takes 15 times more wood than cooking the same amount of food on a REDI stove.

B. Wood stove versus improved charcoal brazier working at 30 % of FER

People often think that the use of considerably improved charcoal braziers might reduce significantly the consumption of charcoal as, for instance, in the present example where the consumption is cut by half. It is easy to prove that much better results could be achieved by burning wood directly in fuel-efficient stoves.

1 kg of charcoal burned on an improved brazier gives:
total heat 26750 kJ
useful heat = 26750 × 0.30 = 8025 kJ

6030 : 8025 = 0.75

Thus, to have useful heat of 6030 kJ obtained from 1 kg of wood on a REDI stove, one needs 0.75 kg of charcoal burned in an improved charcoal brazier, or 7.5 kg of wood. In this case, the consumption of wood, even on the improved brazier, is seven and a half times greater than on the REDI stove.

These calculations are ascertained by the tests currently carried out with REDI stoves and traditional or improved charcoal braziers.

In conclusion, one can confirm that cooking on charcoal entails an enormous waste of wood and accelerates deforestation in the developing countries.

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Bibliography

1. FAO, Reboisement et lutte contre l'érosion à Haiiti. – Rapport technique FO.DP/HAI/72/012, FAO, Rome 1976.
2. NUD, FAO, Descriptif du projet Boisement communautaire, Gouvernement de la République d'Haiiti (HAI/88/009).
3. Report on Charcoal, by D. E. Earl FAO, Rome 1974.
4. PNUD, FAO, Descriptif du projet Boisement Communautaire, Gouvernement de la République d'Haiiti. (HAI/88/009).
5. Charcoal. Forest Products Laboratory, Report No. 2213, July 1961. U.S. Department of Agriculture Forest Service.
6. Report on Charcoal Industry in Somalia (SI/SOM/78/803). UNIDO, Vienna. 8. Survey of Simple Kiln Systems, S1/20 9/79. German Appropriate Technology Exchange. (Gate).
7. Survey of Simple Kiln Systems, S1/20 9/79. German Appropriate Technology Exchange. (Gate).
8. Proceedings of the Seminar on the National Energy Policy on Tanzania. 10 to 14 September 1990, Arusha, p. 48.
9. W. Micuta "Modern Stoves for All". Intermediate Technology Publications Ltd., 1985. London WC2E 8HW.
10. Documentation REDI, 1990:
Essai du fourneau communautaire MIHA/REDI 50 litres,
Essai du fourneau REDI 15 litres. (Joli Feu).
Essai d'un réchaud traditionnel à charbon de bois.

Authors' address

Waclaw Micuta, G. Rossier
– REDI – Renewable Energy Development Institute
5 rue de Vidollet
CH-1202 Geneva
Fax +41-22-7335049

Forest Replacement: An Effective Model to Achieve Sustainability by Fuelwood Consumers[1]

Rogério Carneiro de Miranda

What would be an appropriate policy towards a factory in a developed country that emits uncontrolled smoke into the atmosphere, which has led to widespread respiratory infections of its inhabitants, in addition to the fog, the bad smell and visual pollution? Clearly, this factory should install filters to clean up the smoke emissions at its own cost, in order to reduce the public cost of treatment for widespread respiratory infections and other social costs.

What should be an appropriate policy towards the bakeries and brick manufacturers in a developing country, where fuelwood demand has led to widespread deforestation, including watersheds and forest reserves? Soil erosion has decreased agricultural productivity, the watershed has significantly reduced its level of water production and storage capacity (jeopardising the water supply), and the bio-genetic and ecotourism potential of the region has deteriorated. Clearly, those fuelwood consuming industries should make sure that their demand for fuelwood does not destroy a public good – forest resources – that guarantees a healthy environment for regional communities. The only way to do so is to consume fuelwood from ecologically sustainable sources.

Sustainably Produced Fuelwood

Sustainable sources of fuelwood are those harvested from (1) managed natural forests, (2) wood waste from forest industry and logging, and (3) fuelwood plantations. Natural forests harvested under a technical management plan are only viable in countries with the political will and financial means to enforce them. Since these are not common conditions in many developing countries, and since it is a much more expensive way to produce fuelwood, this option is not a strong one.

Wood waste from forest industry and logging are often freely available, since these materials constitute a disposal problem for industries and loggers. In developing countries, it is a common practice to burn waste in an open pit. This includes sawdust and other wood waste from sawmills and other wood-processing industries. Unfortunately, in most cases, the wood wastes are not close to the fuelwood-consuming industries, and there is not enough wood waste to supply the total demand by the consumers.

Fuelwood plantations are the best source of sustainably produced wood in situations where wood wastes or managed natural forests are not alternatives. Plantations are usually located on degraded/deforested lands, the fastest growing category of land in developing countries. Given this most common scenario, why are there no more examples of fuelwood plantations in Latin America? Small industries such as bakeries, tobacco producers, lime producers, brick factories, etc., simply cannot afford to buy land, or invest in a full forest operation. It would make a very expensive fuelwood, even if they could afford the capital investment.

An Old Problem – A New Approach

In order to guarantee a constant and sustainably produced supply of fuelwood to the small- and medium-sized consuming industries, a new approach is being implemented in Latin America. This approach reverses the cultural tradition of deforesting to supply fuelwood needs. The forests of the Atlantic coast of Brazil are a classic case study of the history of deforestation. The eastern coast of Brazil was colonized in the early 1500s. The Atlantic forest, a dense tropical hardwood forest, covered most of the region. Colonists began extracting Brazil wood, a tree that gave its name to the country, because it was abundant and highly valued as the source of red dye. Brazil wood extraction was the first main economic activity of Brazil under Portuguese colonization.

By the 1700s Brazil wood was becoming rare, and the remaining forest gave way to agriculture and settlements to extract the next main economic product of colonial Brazil, gold. Also during this period, the Atlantic forest gave up space to three of the world's main agro-commodities: sugar, cattle and coffee. Later in the 1900s, with rapid industrialization of the region, the Atlantic forest ceded its last major forest cover to over 70 million people that live in the region: urban areas, roads, industries, factories and agriculture.

Today, the Atlantic forest is one of the most threatened ecosystems in the world, with only 8% of the original Atlantic forest remaining. The other remaining forest cover in the region is in secondary (degraded) forests. Up to the 1980s, the fuelwood consuming industries relied completely on secondary degraded forests, often having to pay high transportation costs. In order to stop the unsustainable harvest of the secondary forests remaining in south-eastern Brazil, new environmental legislation was introduced by some states in the 1980s. The legislation requires small- to medium-sized fuelwood consuming industries to form regional Forest Replacement Associations – FRAs.

Forest Replacement Associations

The Forest Replacement Association is a win-win programme, since any forestry investment needs the three basic elements: labour, land and capital. The FRA model shares the costs equitably between consumer industries and resource-poor producers. Farmers traditionally are reluctant to invest in forestry activities due to the costs of the initial capital investment, and the length of time required for the return (usually five to 10 years with fast-growing trees). To resolve this problem, many countries offer subsidies such as tax breaks and fiscal incentives. In the FRA model, the industry provides the initial capital, but since they lack the land and labour they provide incentives to farmers to participate. Basically, a FRA is a reforestation agent for wood-consuming industries

1 First published in the Proceedings of the XI World Forestry Congress 13–22 October 1997 in Antalya, Vol. 3. Republication is authorized by the editors.

that avoids the high capital costs of land and labour for the operation and maintenance of self-owned reforestation projects.

Monthly, each industry contributes to a fund to reforest the amount of wood (trees) consumed. For instance, if an industry consumes 100 cubic metres of fuelwood in a specific month, they should reforest 600 trees, since in Brazil, with approximately six fast-growing trees harvested at age six, this will produce one cubic metre of fuelwood. The cost to reforest each tree is about US$ 0.25, including the seedling, technical assistance, fertilizer, wire, pesticides and administration.

With funds from all fuelwood consuming industries of the region, each FRA contracts forest technicians to promote reforestation among farmers from the area surrounding the industries. The trees are usually planted on small plots of land which are unproductive for agriculture, but which serve well for tree crops. Each farmer participating in the programme receives (free of charge) high quality seedlings, technical assistance, fertilizers, protective wire and pesticides. The farmers agree to dedicate at least half a hectare to fuelwood plots, give the necessary maintenance to the trees, protect against insects, animals and diseases, plant 10 to 20 % of the total area in trees with native fruits and wood species for conservation purposes, and give first refusal rights to the industries associated with the FRA when they sell the fuelwood.

By the time of harvesting, those industries that can prove that they are consuming the fuelwood produced by the farmers enrolled in the programme, a further incentive is a two-thirds reduction of their contribution to the FRA fund. This provides incentives for the industries to consume the fuelwood from the plantations and guarantees a market for the participating farmers. The reduced but continuous contribution is needed to support and maintain the reforestation base for sustainable industry consumption.

Why FRAs Work

In Brazil, FRAs have been successfully operating for over a decade. From 1985 to 1995, in the state of Sao Paulo alone, there were 13 FRAs created, with over 20 000 hectares of fuelwood plantations established, involving over 3000 farmers. Thousands of small industries in the state of Sao Paulo are currently consuming wood produced under FRAs. Recently, the states of Minas Gerais and Mato Grosso do Sul also have started adopting the FRA model.

What the FRA model does is to distribute better the cost and profits of the fuelwood. In the developing world, there are several disincentives to reforestation. Besides the long period before returns are realized, there is usually a low price paid to farmers for fuelwood products. For instance, a study made in Nicaragua by *Mayorga* (1994) demonstrates that, from the final price of fuelwood, only 2.2 % is related to the tree value. The remaining categories are: 13 % covers the extraction cost, the farmer/producer receives about 10 %, the middle man gets 20 %, and the final retailer gets 70 %. Another study carried out in Central America by *Reiche* (1985) confirm that, in general, the cost of the wood itself in relation to the final price of the fuelwood is only 5 to 8 %, while labour gets 40 %, transportation 32 % and profit 20 %.

In the FRA model, farmers avoid the capital cost for planting the trees, and industry avoids land and labour costs. Also, by reforesting closer to the consumer sources and trading through the FRA, the middleman and transportation costs are reduced. This decreases the final price of the fuelwood for the consumer industries, and transfers better profits to the producers.

In addition, the benefits to industry from this programme are not only financial. There is significant public relations value in being in compliance with environmental and forest regulations, e.g. consuming sustainable fuelwood. Other benefits include reduced risk of shortages due to a guaranteed supply of fuelwood nearby their plants, and the industries project a strong positive image in the region by supplementing incomes of local farmers.

Farmers benefit from the incentives for reforestation, as the capital is provided by the industries. They receive a guaranteed market with the consuming industries, and a higher profit by direct trading through the FRA. Other benefits include increased production on formerly unused land, protection of fragile soils, and diversification of economic activities.

Other Forest Replacement in Latin America

The big steel, cement and pulp industries in south eastern Brazil that consume wood for charcoal, firewood and fibre, are also implementing partnerships with farmers in the surrounding areas in order to reduce the costs of the wood. In a programme similar to FRA, called Forest Farmers, the capital provided by the industry is a loan, not a grant. On the signing of the contract between the industry and farmers, capital is provided in the form of inputs, equivalent to $350 per hectare. This is then repaid in the form of "n" cubic metre of wood in the future, based on the market price at the signing date of the contract. In general, the farmer uses approximately 30 % of the total wood production in order to pay back the loan. Giving first refusal rights to the financing industry, they can sell the extra wood produced at actual market price. In the Forest Farmers Programme, over 100 000 ha have been contracted, benefiting about a thousand farmers. This programme can generate a profit of approximately $ 200 and more per hectare per year, from a piece of land that usually is not productive under agriculture crops.

In Honduras, there is another successful example of forest replacement in operation. In the late 1980s, fuelwood-consuming industries began experiencing fuelwood shortages, with increasing transportation costs. Most of the industrial fuelwood available in the region comes from unsustainable harvest of the natural pine and hardwood forest of the surrounding mountains. Honduras is losing 80 000 hectares of forest every year, with the overall forest cover reduced from 71 % to 46 % from 1965 to 1992. Fuelwood in Honduras accounts for 65 % of primary energy needs, 80 % of all wood consumed, and over 70 % of the population relies on fuelwood for energy to cook.

A cigar manufacturing company, Tabacalera Hondurena S.A. (TAHSA), has helped tobacco farmers of northern Honduras to reforest for fuelwood. Some tobacco growers need fuelwood to dry and cure the tobacco leaves. In

1989, TAHSA started a programme to promote fuelwood reforestation among the tobacco farmers in order to meet the industry needs for a constant and sustainable supply of fuelwood. TAHSA provides inputs (as a loan) such as good-quality seedlings, technical assistance, fertilizers, pesticides and wire to protect the plantation against animals. The farmers, at the time they sell the cured tobacco leaves to TAHSA, pay back the loan. TAHSA guarantees a market for the farmers' tobacco, using it to manufacture cigars for the Honduran and export markets.

In the beginning, farmers did not like the imposition of TAHSA, asking why they should do the extra work of reforestation. After 1994, when the first trees were harvested, farmers found that the cost of fuelwood in the tobacco-curing process had decreased 30%, due mainly to very low transportation costs and better quality fuelwood. Today there are about 230 ha of eucalyptus in the northern region of Honduras, exclusively to sustain the tobacco farmers. Now most of the farmers support the programme, and some are even planting much more than they need, looking to a guaranteed fuelwood market in the near future as wood scarcity increases with deforestation.

Conclusions

Traditionally, fuelwood has been a very primitive sector, e.g. informal, unorganized and inefficient. Governments usually have allowed natural forests to be a free source of fuelwood, largely due to inaction. Traditional solutions have focused on giving farmers government and other aid resources to plant trees for their own consumption. This has been largely unsuccessful, since fuelwood has a very low price in the rural areas and small amounts of biomass are always available for free for family-level consumption in the rural areas. Also, these projects have a high cost for reaching out to the farmers to produce very small plantations.

The policy replacement concept, on the other hand, uses new and successful approaches: (1) hold commercial consumers responsible for the environmental impacts of their business (reversing the traditional business concept of privatizing profits and socializing costs); (2) reduce dependence on the public sector and foreign aid to finance reforestation; and (3) guarantee a commercial market and fair price for farmers.

The policy concept behind forest replacement may be used for any size of economy and even could be adapted to address commercial urban fuelwood demand, since there is profit behind it. For instance, in the capital of Honduras (Tegucigalpa) urban household consumers are paying over US$ 20 per ton of fuelwood, and in Managua, the capital of Nicaragua, the prices have reached US$ 60 per ton, making fuelwood for cooking even more expensive than electricity and LPG. At those prices, certainly some small portion of it could be redirected for a reforestation fund.

Forest replacement policy so far has shown to be a win-win solution, since industry benefits from lower transportation costs, law enforcement, better fuelwood quality and greater availability closer by. Farmers' benefits are free or low interest capital for reforestation, a guaranteed market at fair prices, diversification of economic activities, and use of land of low productivity. And finally, society benefits from the generation of jobs resulting from the injection of capital into the local forestry economy, reduced pressure on natural forests with conservation benefits, shifting responsibility to the private sector for environmental impacts on a public good incurred by industry, and building national pride by decreasing dependency on foreign aid for reforestation purposes.

Literature consulted

Mayorga Dilmes, Modesta Guadelupe. Comercializacion de leña en la subcuenca D de la cuenca sur del lago de Managua, Nicaragua. Boletin Silvoenergia, numero 59, septiembre de 1994. CATIE, Turrialba, Costa Rica.

Miranda, Rogério Carneiro de y Vallejo Larios, Mario Experiencias de fomento forestal en Brasil y Costa Rica (informe de viaje). PROLEÑA, Tegucigalpa, febrero de 1994, 47 páginas.

PROLEÑA. Primer Congreso Dendroenergético de Honduras. Memorias, 107 p. Tegucigalpa, octubre de 1994.

Reiche, Carlos E., La leña en el contexto socioeconómico de América Central. En Actas de los simpósios sobre Técnicas de Producción de Leña en Fincas Pequeñas. Turrialba, Costa Rica, 24 a 28 de junio de 1985. CATIE-IUFRO-FAO, páginas 355–70.

Sonzini Meroi, Luis Aduardo, Perspectivas sobre el comportamiento energetico nácional hacia el año 2010. DINOT, Universidad Nacional de Ingenieria, Managua, enero de 1993.

Toledo, Luis Roberto e Guimaraes, Odilon. Reflorestamento: Chama Viva. Revista Globo Rural, año 8, numero 94, agosto de 1993, páginas 35 a 38.

Author's address

Rogério Carneiro de Miranda
PROLEÑA
Apartado Postal C-321
Managua, Nicaragua
e-mail: rmiranda@sdnnic.org.ni

Nicaragua: An Overview – The Country and the Fuelwood Sector

Rogério Carneiro de Miranda

The country:

- Second poorest country in the Americas (450 USD per capita GNP)
- Population of approximately 4.5 million people
- 130668 km² of territory (largest country in Central America)
- Main economic activities: agriculture (corn, beans, rice, sugar, peanuts, tobacco, sesame, banana, coffee), forestry, cattle (beef & milk), mining (gold, silver), and industrial free zones

The forestry sector:

Main forest ecosystems:
Tropical dry forest
Tropical humid forest
Tropical cloud forest
Mangroves
Lowland Caribbean pine forest
Montane Oocarpa pine forest

40 % forest cover remains (11 % as protected areas, 10 % as commercial forests and 20 % as secondary forests)

400000 m³ harvested per year for saw mills, to produce boards, construction wood, furniture, plywood and export timber

3500000 m³ for fuel wood

The power sector:

360 MW of installed capacity
60 % petroleum derivates
22 % hydro power
18 % geothermal

48 % of the population are connected to the power grid

Electricity represented 8 % of the country's total use of energy in 1995

The demand for new power is growing about 5.7 % yearly

Fuelwood:

- Represents 53 % of the national primary energy supply
- Consumption of 2.5 million tons per year

90 % for the domestic sector
10 % for the industrial sector (bakeries, bricks, pottery, tobacco, lime, restaurants)

- Approximately 40 % is estimated to go through commercial channels
- The government only controls 5 % of the commercial fuelwood (tax USD 4.5/ton)
- Price of the fuelwood ranges from USD 0.05 to 0.10/kg for urban consumers
- Nation-wide 75 % of the population uses fuelwood (90 % rural areas and 60 % urban areas)

Sector's Limiting Factors:

- Primitive
- Lack of organization of producers, consumers and government
- Unsustainable production techniques
- Inefficient consumption
- Lack of appropriate policies to regulate and incentivate

Recommendations:

Modernize
Establish a strategic modernization policy with appropriate regulations and incentives

- Promote and provide incentives for sustainable production
- Promote more efficient and less contaminating stoves
- Promote the organization of responsible private and public organizations
- Promote new applications such as power generation

Actions:

Creation of PROLEÑA (Association for Wood Energy Development) in Honduras 1993 and in Nicaragua 1996:

- Organization of national wood energy congress
  - Meet all actors involved
  - Identify the major limitations to modernization
  - Recommend actions for modernization
  - Generate new partnerships, collaboration, ideas and actions
- New co-ordination between Ministers of forestry, energy, health and PROLEÑA
- Development of a strategic plan for Honduras (funds from FAO)
- Institutional development of a government wood energy office in Honduras (funds from IDB and FAO)
- Stimulate professional training (scholarship from Brazilian government)
- Development of demonstration projects
  - Develop a forest replacement association among fuelwood consuming industries in southern Honduras (funds from CIDA)
  - Disseminate improved wood stoves in the Honduran capital (funds from several sources)
  - Improve tax collection inside the Nicaraguan capital and redirect its resources as credits for forest replacement and improved wood stoves (funds from The World Bank)
- Create a bioenergy internet network in Latin America
- Providing consulting services for private and public organizations

Advantages of Fuelwood for Power in Comparison to Bunker:

- For a TIR of 25 %, the price of kWh is similar to bunker, e.g. around USD 0.055/kWh, and even lower for a smaller TIR
- 67 % of all resources invested stay in the local economy, against 14–29 % for bunker
- Generates 23 times more basic jobs opportunities
- Generates 35 less CO_2 and 30 times less acid gases emissions
- Can increase reforestation by thousands of hectares

Power Generation from Fuelwood by the Nicaraguan Sugar Mills [1]

Rogério Carneiro de Miranda and Richard van den Broek

Abstract

With new concept development for the sugar industry and with new power market opportunities, two sugar mills in Nicaragua initiated projects aimed at becoming power plants during the sugar cane off-season. Basically the idea is to use more efficient boilers and turbines, and generate power beyond the mill's needs fueled by bagasse during the sugar cane crushing season, and by fuelwood from eucalyptus plantations during the sugar cane off-season. The surplus power in both seasons will be sold to the public utility for grid distribution.

Introduction

Nicaragua is one of the poorest countries in Latin America and very much dependent on non-sustainable biomass to satisfy its energy needs (*Alves-Milho*, 1997). According to the Nicaraguan Energy Institute – INE, the total primary energy supply in 1995 was about 1.9 Mtoe, 62 % of which were biomass fuels (*INE*, 1996b) (Fig. 1). Most of the biomass fuel is used as fuelwood (93 %) by the domestic sector for cooking, and to a lesser extent by the industrial and commercial sector. Total consumption of fuelwood is estimated in 2.5 million tons annually (20 % mc). The remaining biomass sources used for energy are: bagasse (mainly at the sugar mills), rice husk, coffee parchment and other crops residues (*Miranda*, 1997).

In the past, against the background of low energy and high sugar prices the combustion of bagasse (a by-product of the process of producing sugar out of sugar cane) was seen as a method of getting rid of a residue. With the collapse of the world sugar market and the two energy crises, bagasse was seen more and more as a useful by-product to generate heat and power. The sugar cane industry has historically been using bagasse for generation of heat and power only to fulfil its own energy demand.

The sugar mills in Nicaragua are characterised by a more or less self sufficient energy supply from their bagasse and by a harvesting season which can last for half a year maximum. The rest of the year, both the sugar mills and their power plants are not utilised. However, in Nicaragua, at this moment, there are two sugar mills developing their potential to extend their power production and to sell power to the national grid, both during and outside the sugar cane crushing season. An innovative approach of using fuelwood from dedicated energy plantations to fuel the boilers outside the sugar cane season looks very promising. The largest sugar mill in the country, San Antonio (located near the town of Chichigalpa) is upgrading its power generation efficiency. Their plan is to come in a two step approach to a power sale of about 15 MWe (*Broek*, 1997a). In this paper we will focus on the other sugar mill which has similar plans: Victoria de Julio, situated just 30 km outside the capital Managua.

A detailed study is being developed at the moment by van den Broek (*Broek*, 1997b) in order to assess the possible advantages of this approach, which are: (i) increase in profitability of the sugar mills, (ii) increase the area under tree cultivation, (iii) increase new power capacity at lower cost, (iv) increase of employment opportunities, (v) import substitution of fossil fuels, and (vi) on a global basis reduce CO_2 emissions. Final results of this study are expected in 1998. However, some initial results are presented here.

Nicaraguan Power Sector

Since the creation of the national grid in 1958, the power sector in Nicaragua has been state owned. During the eighties, the period of the civil war and the USA trade embargo, the power capacity of the country remained around 330 MWe (*Miranda*, 1997). Since the end of the Nicaraguan civil war in 1990, the economy has been slowly recovering and new policies are being defined in order to attract the private investment. Just recently in 1997, a new law that allows and regulates private participation in power generation, has been enacted in Nicaragua.

With only 48 % of the Nicaraguan population connected to the national grid, electricity production comprises 6 % of the final energy consumption. In 1995 the maximum load was 327 MWe with a total installed capacity of 393 MWe (*INE*, 1996c), However, because some plants were operating below their nominal capacity, the actual capacity was only 330 MWe (*INE*, 1996a). With an overall load factor of about 60 %, the consumption of electrical energy was 1630 GWh. Figure 2 shows that almost 60 % of the electricity is generated from oil derived fuels (mainly fuel oil). Imports of oil and oil derived products in Nicaragua in 1995 constituted about 13 % of total imports (or 25 % of total export earnings) (*FIDEG*, 1996). About 26 % of this fuel is consumed in the power sector (*INE*, 1996c).

The Ministry of Energy of Nicaragua has estimated the electricity demand growth for the next 20 years between 5.4 and 6.1 % annually. This means that the installed capacity towards 2015 has to increase with a factor 2.3 to 2.7. A fast solution to the Nicaraguan power crisis has been the import of expensive power from neighbouring countries and a new 32 MWe contract with a private company with a pay back tariff of 0.088 $/kWh (*Gonzalez*, 1997).

Power Generation with Bagasse and Fuelwood in the Victoria de Julio Sugar Mill

The Victoria de Julio sugar mill is the second largest sugar mill of Nicaragua. This plant was designed and built by the Cuban government and later donated to the Nicaraguan government, but since 1993 it is owned by AGROINSA, a private enterprise. Construction took place in the beginning of the 80's and operation started in 1985. This sugar mill is a-typical since the concept of electricity as a second product was integrated in its original design, by generating excess power during the harvest season and by extending power generation into the non-harvest season, thus becoming a full power plant. In this last period,

1 First published in 'Energy for Sustainable Development', Vol. 3 No. 4, November 1996. Reprinted by kind permission of 'Energy for Sustainable Development'.

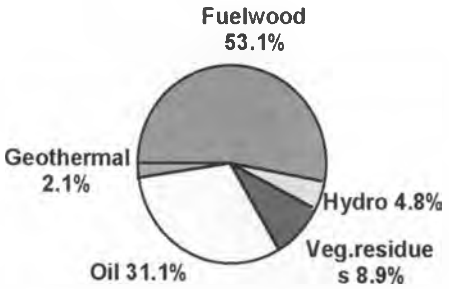

Fig. 1: Primary energy supply in Nicaragua in 1995 (INE, 1996b).

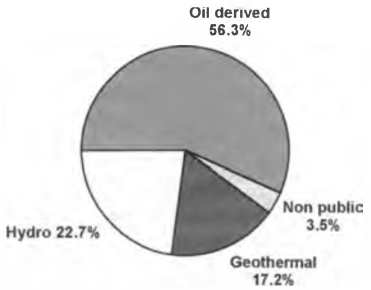

Fig. 2: Energy use for power generation in Nicaragua in 1995 (INE, 1996b)

Eucalyptus camaldulensis from dedicated plantations will be the principal fuel.

The unique concept of the sugar cane plantations is that they are settled up in a system which consists of squares of 100 hectares (1000 m × 1000 m). The sugar cane plantations are all irrigated by circular pivot systems with a radius of 500 m, which covers 80 hectares. The remaining areas not covered by the pivot system of about 20 hectares, are planted with eucalyptus. An excellent logistical system has been created, consisting of the more than 180 circles with roads running in between them and the sugar mill in the middle (*Detrinidad*, 1996).

The Fuelwood Supply

Besides the eucalyptus planted between the circular sugar cane plantations, also other soils that are not suitable for sugar cane are used for the eucalyptus too. Today there are 3675 hectares of eucalyptus plantations already established, and the future need will be for about 7354 hectares. Expansion of the plantations will probably take place by acquiring new land in the neighbourhood, and through contracts with local farmers to produce sustainable fuelwood.

A problem with the soils at Victoria de Julio is that they are vertisol, the type of soil that has a tendency to crack during the dry season, which can cause damage to the root system of the trees. Further the upper layer is highly compacted. In spite of this, subsoil treatment, which allows the roots to penetrate into the soil easier, has only been partly implemented here in the past. The planting of eucalyptus started in 1986, which means that some parts of the plantation are already harvested twice. Available yield figures are mentioned in Table 1.

With respect to the harvesting system, plans exist to use small scale transportable chippers in the future to chip the smallest branches in the field.

The eucalyptus trees will be harvested during the dry season (December to April) to facilitate air drying, down to a moisture content of about 20 % during a period of one month. The logs then will be chipped and fueled into the plant. The plant is expected to run about 150 days fueled by bagasse and 180 days fueled by fuelwood. Estimated fuelwood costs are around US$ 25.00/Ton (20% mc) (*Coronel*, 1997).

The Power System

Figure 3 shows the scheme of the Victoria de Julio sugar mill power plant. The plant was designed to have 36 MWe of total installed capacity for a crushing rate of 7000 tons/day. At the moment 12 MWe (3 × 4 MWe) is already installed. Although the other two turbines, on which the power sales are mainly based have been available at the sugar mill for more than 8 years, they were never installed. The main reasons were that due to economic recession in the country, the milling capacity was still heavily underutilised, and there was no demand for extra power capacity in the country.

Recently, with the privatisation of the mill and the opening of the electrical market for private investors, the original plans were revived again. The extension that is needed at this moment, thus mainly consists of the installation of the two 12 MWe turbines and upgrading of the existing boiler system.

One 12 MWe low pressure condensing turbine will be placed in series with the existing three 4 MWe turbines and generate power outside the harvesting season. The other 12 MWe turbine is a high pressure extraction-condensing turbine which can be used for power generation whole year round, but which could also back-up the three 4 MWe turbines as supply source of steam to the sugar mill. Because of the relatively low steam temperature, the net electrical efficiency will remain limited to about 20 % (at LHV).

At the moment, operating at 75 % crushing capacity, this mill is exchanging for few months each year 4 MWe with the national grid. In the future a contract is expected to be negotiated about 0.06 $/kWh (*Gallo*, 1997). By 1999 the plans are to further improve crushing capacity, to have the full 36 MWe installed, and to be able to deliver 16 MWe during the sugar cane crushing season, and 31 MWe during the off-season (Table 2). The self-consumption of the sugar mill and the power plant is about 8 MWe during the season and has a peak of about 4 MWe during the off-season.

Costs and Impacts on the Macro-Economy

Recently, data have come available from the earlier mentioned study by *van den Broek*, comparing power generation from eucalyptus by the sugarmills with power generation from fuel oil (*Broek*, 1997b). This study shows that power generation from eucalyptus can be delivered for about the same price as

Tab 1: First harvest results of Victoria de Julio. Figures refer to the harvested trunks at 0 % mc. About 15 % of the dry matter in the form of small branches and leafs are left in the field and not included in these numbers (Coronel, 1997).

Size of plantation harvested [ha]	Average yield [$tonne_{dry}$/ha.yr] of the first rotation (5years)	Average yield [$tonne_{dry}$/ha.yr] of the second rotation (4years)
4	5.4	8
14	6.2	9
19	7.1	10.5
15	7.1	10.6

Tab. 2: Power production (Mwe) and distribution for AGROINSA today and the near future (Detrinidad, 1996).

	Before 1 9 9 9		After 1 9 9 9	
Mw_e	Season	Off-Season	Season	Off-Season
Operational Capacity	12	0	24	36
Self-Consumption	8	4	8	4
Export	4	0	16	31

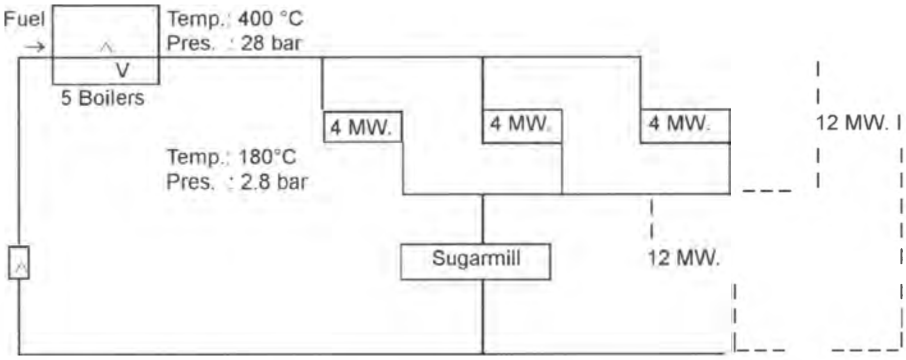

Fig. 3: Scheme of the Victoria de Julio sugar mill; dotted lines indicate the extensions.

power from fuel oil (0.066 against 0.065 $/kWh). Furthermore, considering the macro economic impact, with eucalyptus about 67 % of the price of electricity stays within the national economy (thus adding to the Gross Domestic Product), while with fuel oil this ranges between 14 and 29 %. Also, employment generation is about 3 times larger with eucalyptus.

Conclusions

In Nicaragua the economic reforms are opening the way to a more participatory and competitive presence of the private enterprises in the energy sector. The sugar industry is facing new opportunities to diversify its production into power generation. Here a new concept is being implemented where the sugar mills besides generating extra power for sale during the cane crushing season, also are becoming a full power plant during the off-season by burning fuelwood from plantations.

This initiative is among the first in the world to use a dedicated energy crop to generate power during the non-harvesting season. The impacts of this concept could be high, since all over the tropical sugar cane producing countries, new power is much in need, and the possibility of avoiding fossil fuel imports and promoting the cultivation of trees is very welcome.

While the cost of power production with eucalyptus by sugarmills is about the same as the cost with fuel oil, the socio-economic and environmental impacts appear to be significantly better. Power generation based on dedicated energy crops is not only a future option, but looks attractive at this moment for the Nicaraguan sugar mills.

Acknowledgements

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References

Alves-Milho, S., 1977: Dynamic of the Nicaraguan Forest Sector 1960–1995 (in Spanish), UNAN-UNA-ESECA. Managua 212 p.

Broek, R. van den, Miranda, R. C., Ad van Wijk, 1997a: Combined heat and power generation from bagasse and eucalyptus by sugarmills in Nicaragua. Third Biomass Conference of the Americas. August 1997. Proceedings, Vol. 2. 1389–400 p. Montreal.

Broek, R. van den, Ad van Wijk, 1997 b: Power generation from eucalyptus in sugarmills in Nicaragua: costs, macroeconomic and environmental impacts (in Spanish), Department of Science, Technology and Society, Utrecht University, presented at the "Regional meeting on biomass for the production of energy and food", 3–6 November 1997, Havana.

Coronel, R., 1997: Personal communication, AGROINSA.

Detrinidad, M. E., 1996: Promoting energy from wood in Nicaragua: Technical visit to the sugarmill AGROINSA and to the project Los Maribios in Nicaragua (in Spanish) Managua, MARENA – FAO.

FIDEG, 1996: "General assessment of the economic development. 1996 (in Spanish)." El Observador economico 1996, November 1996: 5–21.

Gallo, O., 1997: Personal communication, Instituto Nicaraguense de Energia: Direccion General Desarollo Energetico, Managua.

Gonzales, N., 1997: AMFELS sells the energy the cheapest (in Spanish). La Prensa Managua: 6A.

INE, 1996a: Expansion plan of the generation system of the interconnected national system: 1996–2015 (in Spanish). Managua, Instituto Nicaraguense de Energia: Direccion general de desarollo energetico.

INE, 1996b: National energy balance: 1995 (in Spanish). Managua, Instituto Nicaraguense de Energia: Direccion general de desarollo energetico.

INE, 1996c: Statistical compendium: 1991–1995 (in Spanish). Managua, Instituto Nicaraguense de Energia: Direccion General Desarollo Energetico.

Miranda, R. C., 1997: Waste biomass assessment in Nicaragua. Managua, PROLEÑA; 34 p.

Authors' addresses

Rogério Carneiro de Miranda
PROLEÑA · Apartado Postal C-321
Managua, Nicaragua
e-mail: rmiranda@sdnnic.org.ni

Richard von den Broek
Department of Science,
Technology and Society
Utrecht University
Paudualaan 14
3584 CH Utrecht, The Netherlands
e-mail: broek@nwsmail.chem.ruu.nl

Wood Energy in Indonesia

Tjutju Nurhayati*, Paribotro Sutigno* and Rizaldi Boer**

Summary

The forest area in Indonesia covers 60 % of the total land area and consists of 6 forest types, that is tropical rain, monsoon, mangrove, swamp, literal and peat forests. The total area of wood production from natural conversion and plantation forests was 23.74 million m^3 in 1994 and 23.94 million m^3 in 1995. These wood products were used as raw materials for the wood industry i.e. plywood, wood working, pulp, etc.

Logging wastes, thinnings and wood industry wastes are the main resources for energy from forests. Woodfuel consumption is significantly high and woodfuel is used for cooking in households, private industry, rural industry, estate products and wood industry. As a matter of fact, approximately 43 % of the need of national energy consumption is supplied by woodfuels and the rest (57 %) by commercial energy. The woodfuel consumption of Indonesian people in rural areas is 0.75 m^3 per capita per year. The proportions of consumption of energy resources are as follows: woodfuel as well as kerosene is 88 %, charcoal is 27 %, agricultural waste is 19 %, gas is 0.06 % and electricity is 30 %. The high woodfuel consumption as mentioned above is due to its price which is very low. As an illustration, the woodfuel price in 1992 was Rp 1.37/MJ; charcoal was Rp 6.06/MJ, agricultural waste was Rp 1.49/MJ, kerosene was Rp 8.43/MJ and electricity was Rp 39.42/MJ.

Although the consumption was high, it was not supported by marketing mechanisms; there was a gap in the local market between woodfuel and commercial energy. It was very difficult to gather information on woodfuel and markets. For example, collecting the data of production and markets for woodfuel from the private sector was more difficult than from the commercial energy sector (except those of woodfuel supply from formal sectors like from the Forest Estate (Perhutani) which was sold using auction systems).

The highest woodfuel supply came from mixed gardens of the private sector (58 %), followed by forests (28 %), plantations (6 %) and agricultural lands (8 %). The limited woodfuel supply from the forests was due to the uneven distribution of regional production and consumer demand. The highest woodfuel consumption was in Java, while the resources were huge outside Java and the fee for transportation was expensive. Woodfuel demand on Java Island was 53.35 million m^3 per year, while the land area and the population of the island were only 6.8 % and 60 %, respectively, of the overall in Indonesia. On the contrary, in Kalimantan the need for woodfuel was only 18.02 million m^3 per year whereas its land area and the population were 28.6 % and 5.1 %.

The sustainable development of woodfuel has good prospects. These opportunities are supported by the favourable tropical climate, thousands of wood species, the vast area of forests, and the high consumption of fuel. The planting of woodfuel species should be suited to the location and soil conditions. But, when selecting the species, they must have multipurpose uses such as Kaliandra, since its flowers can be used as bees fodder; the leaves of lamtoro gung are used as animal fodder and its seeds can be eaten by people; and so on. In the case of energy production, Kaliandra and lamtoro gung, both at a 4 year cutting period, can produce heat as much as 437 and 625 GJ/ha/year. In order to implement effectively the sustainable production and utilisation of woodfuel, several conditions are required as follows:

- the integrity of policy
- cost budgeting of government and international co-operation
- comprehensive management of the implementation
- R & D
- national actions for plantation
- human resources management
- improvement of the conversion technology
- present role and function of organisations.

The recommendations on woodfuel systems in Indonesia cover several significant items such as:

- the comprehensive and complete planning of the program
- the consumer who should be well informed and given enough support
- the non-governmental organisation and private sector which should also be well informed and take part in the program
- R & D institutions' support and co-operation in the program in all the level of authorities and the government
- international agency or private support of the program.

Authors' address

Tjutju Nurhayati, Paribotro Sutigno
Forest Products, Research and Development Centre
Institute of Agriculture
P.O. Box 182, K. Gunung Batu
Bogor Indonesia
e-mail: slitbang@pop.bogor.indo.net.

* Forest Products and Social Economic Research and Development Centre (FPSERDC)
** Bogor Agricultural Institute (IPB)

A Small Power Plant Running Solely on Biomass Derived Gas Many Applications, Many Benefits

Edan Prabhu

Reflective Energies is developing a small, reliable, commercial, low cost power plant from 30 kW to 1 megawatt in size, which would run solely on biomass derived gas with no other fuel needed. Such a plant does not currently exist. The plant would use a "microturbine-generator", and run on biomass gas produced in thermal gasifiers or digesters. The microturbine-generator, currently being developed in the U.S., Europe and Japan, consists of a small, high speed turbine, compressor and generator. Thermal and digester gasifiers are in common use in many countries such as India and China, but have not been major commercial successes as producers of electricity.

The new technologies are:

- Small, reliable, rugged, low cost "microturbine-generators", 30 kW and larger, will soon be commercial at prices below $ 400 a kW for the entire power plant. The little power plants will include all the controls and electronics to run grid connected or stand-alone. In addition, they will perform efficiently at high and low loads.
- Small gasifiers, 100 to 400 kW electricity capacity, are already commercial at prices below $ 500 a kW. The gasifiers are dependable, but the resulting gases have low energy content relative to natural gas.

The immense potential for biomass to energy has been well documented. The new plants will be able to run on as little as 1 to 5 tons a day of biomass. Rather than improve the quality of biomass gas, the fuel tolerance of the power plant will be significantly increased. The new approach eliminates the problems inherent with previous methods. Small plants can use local biomass, avoiding expensive transportation costs. Low fuel gas quality will be acceptable. Simple, low tech gasifiers, producing low pressure gas, will be acceptable.

The small size and simplicity of the plant give it tremendous potential in developing countries. Biomass (both wood and animal waste) is the most common fuel in poor countries, often providing 30 to 90 percent of energy needs. In most cases, the biomass is grossly underutilized, either used inefficiently for cooking or heating, or simply combusted to get rid of it. If a fraction of the biomass can be efficiently converted into electricity, there would be a net savings in biomass consumption, even when the electric stoves replace the biomass stoves. There would be many other benefits. The gathering and use of biomass locally for small power plants will produce local jobs. The electricity produced creates more, higher quality jobs. Cooking with wood in small huts causes severe respiratory and eye diseases; by switching to clean electricity, such diseases would be dramatically reduced. In remote areas and islands, the plant would produce electricity from clean, renewable energy at costs significantly lower than the diesel powered plants which are so common in such areas. In many developing countries power supply is sporadic and poor, raising the prospect that small remote areas far from the electric grid may actually receive better electric supply than big cities. This would reduce the flow of population from villages to overcrowded cities. Remote villages would no longer have to wait for modern infrastructure such as highways, power lines, fuel gas lines etc. as a precondition for development. As the technology takes root, energy plantations on marginal lands could supplement use of under-utilized or wasted biomass, maintaining the march towards sustainable development.

Unlike solar and wind power plants, biomass is the only renewable energy which can provide power twenty four hours a day, making it much more valuable than these other important renewable energy fuels.

In industrial nations, too, there are many potential benefits. Much of the biomass harvested is wasted. About thirty percent of the mass trees cut down for lumber and paper operations is otherwise unusable.

Crop and orchard harvests also have similar wasted biomass. Animal residues, traditionally used as fertilizer, are becoming an increasingly severe environmental issue as animal farms grow in size and density, and the waste is concentrated to such an extent that it contaminates streams, lakes, and local air. Forestry Departments are more and more cutting fire breaks as a fire-prevention measure rather than torching the forest with small fires set to prevent larger ones. They remove the biomass from the primary fire zone, but it continues to remain a fire hazard, with no immediate solution apparent. In many areas, laws are being enacted to disallow open field burning of biomass. All biomass, whether it be crop residues, animal waste or forest trimmings, is expensive to transport.

Another benefit is that such plants combat global warming. Every molecule of carbon in biomass was plucked from the air, and will once again be captured with new vegetation. In many areas, the biomass left untended would degrade to methane, which is twenty five to fifty times more potent a greenhouse gas than carbon dioxide. Furthermore, the low temperatures inherent in the little plants all but eliminates the formation of NO_x, which is the most significant factor in urban smog. Still another benefit is that the exhaust heat from these plants would be available for local cogeneration, such as space and water heating, low temperature drying and so on, improving the overall utilization of energy and further reducing global warming effects.

The project has already received strong words of encouragement from industry, governments, academia, research institutions and from multilateral institutions such as the World Bank and the Global Environmental Facility, and is seeking demonstration sites for the new technology.

Editors' comment

One of the demonstration sites will be located in Sri Lanka, in a remote village of tea plantation workers, as a result of the meeting of Edan Prabhu and Dr. Mahendrarajah at the forum.

Author's address

Edan Prabhu
Reflective Energies
22922 Tiagua, Mission Viejo
California, USA 92692-1433
e-mail: edanprabhu@msn.com

Biomass Based Rural Electrification

K. Krishna Prasad

Introduction

The fundamental assumption behind this paper is that electrification is the key to rural development. In fact rural electrification was included in the Constitution of India as a directive principle. The current experience around the world indicates that the main grid from centralised generating stations is unable to bring electricity for the majority of rural homes of developing countries in the foreseeable future. The reasons for this state of affairs are many. We shall just mention three. The major utilities are not enthusiastic about providing electricity to rural areas since these are primarily low load centres and they are rarely able to recoup the expensive outlay on transmission and distribution. Secondly, the majority of the rural families are simply in no position to pay for the initial cost of connection to the line even if it is within 10 to 20 metres from their homes and even if they are able to pay for the running costs of a couple of electric lights and possibly the use of simple equipment such as a radio. Finally there is a chronic shortage of electric power leading to the so-called "brownouts", load shedding and a rather severe regimen of rationing in most developing countries.

This situation has lead many a policy maker to rethink the method of achieving rural electrification. The rethink essentially involves going for decentralised electricity generation. As a consequence renewable energy technologies become attractive. There are two obvious advantages arising out of such an approach. By their very nature, renewable energy sources are highly distributed around the globe and thus are ideally suited for decentralised electricity generation. These technologies are more benign to the environment.

The present paper is really an argument in favour of biomass based rural electrification. The argument is firmly placed against the background of various ideas that have been advanced from time to time for achieving rural development. This will be followed by a brief look at the current rural energy needs and the future trends especially for the use of renewable energies. This points out the role of biomass among the different possibilities of renewable technologies and their cost competitiveness. The principal part of the paper is devoted to the policy support that is required to bring the promise of biomass technologies to reality on the ground. The paper's main focus is on India where over 70 % of the population live in rural areas. In spite of the fact that over 75 % of the villages in the country have been electrified, hardly 30 % of the rural homes have electric lights. The purpose of the paper is to look at the possibilities of bringing this percentage closer to 100!

Background

We will place the work against a background comprising of five propositions. The first proposition looks at the question: What does constitute development? The whole process of development is an extremely complex one as the following observation from Amartya Sen (1989) illustrates:

The observation of change is not, however, the same as evaluation of achievement. ... One broad issue relates to the question whether to concentrate on the nature of the economy (...), or on the nature of the lives that people have the opportunity to live. It is, of course, possible to have a bit of an argument on this subject, but it is fairly clear that the nature of economy can have ***only instrumental importance*** *– as means to valuable ends – and that what ultimately matters is the nature of lives people can or cannot lead. (emphasis is the present author's)*

Amartya Sen concretises this observation by quoting Jawaharlal Nehru, the first Prime Minister of independent India, during the formulation of the Second Five Year Plan in India in 1954:

We are starting planning for the 360 million human beings in India ... What do the 360 million people want? It is fairly easy to begin making a list – later there may be differences of opinion – but it is obvious enough that they want food; it is obvious enough that they want clothing, that they want shelter, that they want health. They want such things, regardless of the social and economic policies we may have in mind. I suggest that the only policy that we should have in mind is that we have to work for the 360 million people; not for a few, not for a group, but for the whole lot, and to bring them up on equal basis.

Two major points emerge from this quotation. This statement does not explicitly involve energy. Since the time of Nehru, the list he provided is now formally incorporated into what is called the basic needs model for development. This leads us to the second proposition which is neatly put by *Revelle* (1976):

An old saying has it, "slavery will persist until the loom weaves itself". All ancient civilizations, no matter how enlightened or creative, rested on slavery and on grinding human labour, because human and animal muscle power were the principal forms of energy available for mechanical work.

Without the intervention of modern forms of energy, the desires of Nehru will remain unfulfilled thus condemning rural populations to de facto slavery.

While these general statements are unquestionable, one has to have some practical means of implementing them on ground. However one invariably encounters serious difficulties in implementing these thoughts. Specifically we need to work under some well-defined constraints. These constraints are clearly indicated by the following quotation from *Schumacher* (1973), which will be our third proposition:

If you want to go places, start from where you are. If you are poor, start with something cheap. If you are uneducated, start with something simple. etc. etc.

Applied to the energy situation, this implies two things: (i) utilisation of local resources, and (ii) exploitation of local capabilities. In particular the latter has to account for crucial organisational questions. *Paul Streeten* (1984) while discussing the dichotomies involved in development debate presents several conclusions out of which we select two to form our fourth proposition:

(i) The basic needs work has shown that institutional arrangements are very important in meeting basic needs, and of the institutions – market, public sector, and household – the household until recently, has been neglected by economists.

(ii) Large-scale and small-scale should not be regarded as alternatives, but should be mutually supporting or at least not mutually destructive.

The above suggest that successful technical interventions for development require careful integration of different institutions and different scales of operation. Such integration is implicit in the fifth and final proposition that characterises all successful technologies:

The producers and users of a technology share a similar style of life.

It is precisely this element that is missing from the attempts made so far on behalf of rural electrification. The rural poor have no means of participating in the generation and transmission of electricity. In effect this is what one learns from the oft-repeated slogan of many an NGO that participation of people is essential for the development process to take firm roots. Further it is also taken as an article of faith in this paper that electric light in every home makes for an improvement of the quality of life of people returning to the point where we started. What is more the electric light – particularly for those without it (roughly half the population in India) – is not only a symbol of modernity and progress but also provides a level of comfort unmatched by any other artificial lighting source.

The rural energy scene

A fundamental problem about the description of rural energy scene is that data is scarce. This is a consequence of the fact that the so-called commercial energy is either not available in rural areas in general or when available is not affordable for the bulk of the rural population. Thus most of the energy used is biomass and it is collected from the nearest source for free. There is no continuous monitoring of this activity and thus national energy statistics more or less ignore this aspect. Over the past twenty odd years many attempts have been made to quantify the non-commercial energy use in rural areas. We give two rather old examples of such efforts from India (see Table1).

The data is outdated but illustrative. There have been many similar surveys conducted round the world in the last twenty years. Three principal features emerge from these surveys:

(i) The household is the principal energy consumer.
(ii) Cooking dominates the energy use in the household.
(iii) Biomass is the dominant fuel source.

Most of the surveys have several weaknesses. Most of them are sample surveys. The work of ASTRA is an exception in the sense it was a census survey. The surveys in general do not account for seasonal variations in energy use although there exists abundant anecdotal evidence on this aspect. Thus it should be stated that they provide a snapshot of the energy situation. The resource picture is also weak. There is work done on the hardships caused by deforestation resulting in people – mostly women and children – investing more and more time in collecting wood, animal and agricultural residues over the years. This is supplemented by data on the extent of deforestation. However the opinions are highly divided as to the extent of deforestation caused by fuel collection by the rural poor. In particular, the lack of resource picture in a sufficiently disaggregated form of renewable energy sources is a great handicap for a reasonable planning of rural electrification.

Thus while the surveys have provided for a deeper understanding of the rural energy problem, a national planner has to more or less rely upon some bold extrapolations. A redeeming feature of this process is shown in Table 1. The Revelle work is a desk study based upon national statistics. Yet the difference in the total energy use between the ASTRA figures and the Revelle figures is just about 13 %. Of course there are fairly large differences in the sectoral consumption. For example the Revelle estimate is a factor four higher for agricul-

Table 1: The Indian Rural Energy Scene.

Sector	ASTRA	Revelle
Agriculture	0.541	2.41
Household	11.1	6.97
Lighting	0.274	0.46
Industry	0.595	0.72
Transport	0.056	0.337
Total	**12.566**	**10.897**

Notes:
(i)ii The units are GJ/CapYr
(ii)i The ASTRA values are the average of six village surveys conducted in 1978 (ASTRA 1981)
(iii) The Revelle (1976) figures are based on National Statistics for 1975.

tural use and 50 % lower for household use when compared with the ASTRA work. In general this could be thought of as a reflection of the fact that ASTRA villages are poorer than the average village in India.

We can make other comparisons with global data that is available from different sources. The World Energy Council estimates that in 1990 the traditional biomass use in the world was 39.7 $\times 10^9$ GJ (*WEC* 1994). The world population in 1990 was 5283.9 million. As is commonly stated half the world's population eat food cooked on fires fuelled by biomass. This means that the per capita biomass use would be 15 GJ/CapYr in 1990. In other words these data while not exactly in agreement with one another, they are not wildly different from one another considering the gross nature of this arithmetic.

Before moving on, it is important to point out that electricity does not figure in any of these surveys.

Future prognostications

In the aftermath of the oil crisis of 1973 there have been many attempts made to estimate the energy demand and supply in the future. In some sense all these estimates reflect more or less the analyst's wishes. Needless to say, they cannot represent the reality since that is yet to materialise. It is not the point here to review the diverse types of projections, but to present the one made by the *World Energy Council* (1994), a conservative think tank, in Table 2. Here also we limit ourselves to renewable energies.

The above scenarios suggest that the "modern" biomass, solar and wind contribute 80–84% of the renewable energies whatever be the policy situation. What is more the lion's share is expected to come from "modern" biomass, mostly in the form of electricity and liquid fuels. It is useful to juxtapose these numbers against the traditional biomass use in developing countries. This is done in Table 3. The major conclusion that emerges from this table is that even in the ecologically driven scenario where the modern use of biomass increases by a factor of 3.5 compared with current policies scenario the traditional use of biomass is more than twice that of modern.

Table 2: "Minimum"/"Maximum" Contributions from "New" Renewable Energy.

	In 2020 „Minimum“		**In 2020 „Maximum“ with major policy support**	
Renewable Energy	**Mtoe**	**% of Total**	**Mtoe**	**% of Total**
„Modern" Biomass	243	45	565	42
Solar	109	20	355	26
Wind	85	15	215	16
Geothermal	40	7	91	7
„Small" Hydro	48	9	69	5
Oceanic	14	3	54	4
Total	**539**	**99**	**1345**	**100**
% of Total Energy	**3 - 4%**		**8 - 12%**	

Notes: 1990 Renewables contribution: 164 Mtoe (1.9 %); Mtoe – million tonnes oil equivalent

We can interpret these scenarios in different ways. We will use them to provide estimates of the populations using biomass in a traditional manner in 2020. Assuming that half the population in 1990 used biomass as their principal energy source, that is about 2642 million people, 838 mtoe translates into the annual per capita energy consumption of 13 322 GJ. Holding this as invariant with respect to time, in 2020 with the current policies scenario, there will be 3831 million people using biomass in a traditional manner. For the ecologically driven scenario this will become 3100 million people. In other words any interventions that purport to be development oriented should take this population into explicit consideration.

The technology picture

The received wisdom about electricity generation is that it can only be produced economically in a central unit with a capacity of 500–2000 MW. Bringing electricity to every user's door has been worked out through a complex network of transmission and distribution system which can run up to 40 % of the total investment cost (*Goldemberg* et al. 1994). This is a strong disincentive for the electric utilities – which are under pressure in developing countries to do without government handouts – to bring electricity to small load centres, which are the rural areas of this world. This is compounded by the lack of adequate capital among rural users to pay even for the connection to a distribution network which may just be next door.

The situation is thus tailor-made for electricity generation through renewables. There is however a catch here. The renewables are for most parts intermittent – in particular resources such as solar, wind and water. Storage of elec-

Table 3: Developing Country Scenarios.

	1990	**2020**
Current Policies Scenario		
Traditional Biomass	838	1216
Modern Biomass	75	123
Ecologically Driven Scenario		
Traditional Biomass	838	983
Modern Biomass	75	404

Notes: The units are mtoe.

tricity is quite expensive. There are many constraints in utilising even the widely available resource, biomass. A major source of biomass is the forest. The observed trends of forest depletion around the world questions the validity of treating this source as renewable. While one can grow and utilise trees on a renewable basis, the hundreds of forestry projects started in the eighties have shown a patchy performance (see for example *Skutsch* 1994). Agricultural residues and animal dung are two other important biomass resources. They do have important non-energy uses. What is unclear at the moment of this writing is the proportion of these resources that could be used for energy purposes.

We sketch below a brief review of the attempts to provide energy services to rural areas through renewables. We restrict ourselves to biomass, solar and wind which as pointed out earlier account for 80 % or more of the renewable energy possibilities in the WEC projections.

- Two biomass technologies – biogas and gasification – have had a long history but have really not matured enough to claim self-sustainability (see *Tomar* 1995 for biogas and *Stassen & Knoef* 1995 for gasification). The biogas plants are all family type that simply do not cater to the poor households.
- Solar thermal systems have been investigated for over 50 years now; again without any noticeable impact on the rural energy scene (see *Soponronnarit* 1995 on solar drying).
- Wind energy is primarily being advocated for small pumping applications and again have been stalled (see for example *Smulders* 1996).

Table 5: Private Sector PV Sales in Selected Countries.

Country	Typical Peak System Output (Wp)	Typical installed Price (US$)	Numbers installed
Dominican Republic	38	500	4000
Lesotho	35 - 40	900 - 1000	Hundreds
Kenya	50	1400	20000
Sri Lanka	18 - 35	240 - 395	4500
Zimbabwe	20 - 50	750	3000

This sounds discouraging, but valuable insights gained through these efforts, have resulted in a few success stories which we summarise in Table 4. The costs in the table compare favourably with the cost of centrally produced electricity, which is US$ 1200/kW. If the new technologies receive levels of R&D support as the centralised generation system, the prices will go down without doubt.

In the list of Table 4 we have omitted the most recent entrant into the field, the Solar Home System based on photovoltaic technology. The data in Table 5 is taken from an exhaustive review by *Foley* (1995) for the private sector indicates the progress and costs in selected countries. The costs in the Table ranges from US$ 13,000 to 28,000/kW. Thus this technology is accessible to only the rich in rural areas.

The major conclusion that emerges from this brief look at the technology situation coupled with the WEC prognostications for the future, biomass based electrification appears to be the most attractive proposition among the various alternatives.

Policy support

General

If rural electrification is to take root in the development scene there needs to be a significant amount of policy support from the government. Table 2 has quite clearly demonstrated what policy support can achieve. What is required is an integration involving several aspects of technology. The approach should be not merely one of building a prototype and demonstrating its operation. We see technology as an integration of several activities. Broadly the different classes of activities can be grouped under the following categories:

(i) Production
(ii) Marketing
(iii) Installation
(iv) Operation
(v) Maintenance
(vi) Financing
(vii) Research, Development & Design

Weakness in any of these activities can lead to unsustainability of the technology. A fundamental point to be remembered in connection with decen-

Table 4: Examples of Success Stories.

Technology	Place/Country	Capacity	Applications	Cost (US$)
Biogas[1]	Pura/India	5.2 kW; dual fuel with 30% diesel	Lighting and water pumping for drinking	1207/kW
Gasifier[2]	Hosahalli/India	4.4 kW; dual fuel with 30% diesel	Lighting and water pumping for drinking	1447/kW
Windmill[3]	Several	3.9m rotor	Water pumping	2440/kW

Notes: [1] *Rajabapiah* ***et al. (1993); costs 1989 US$;*** [2] *Mukunda* ***et al. (1993); costs 1991 US$);*** [3] *Smulders* ***(1996); costs 1996 US$ for average windspeed of 3 m/s and equal to 310 W peak rating of solar PV system.***

tralised electricity generation is the point that one could visualise a relatively large scale production system manufacturing the units such as gasifiers and biogas plants. This can lead to substantial cost reductions through economies of scale. Thus for decentralised electrification to become a viable option, it is necessary to shift the economies of scale from production of electricity to the production of electricity generation equipment. For this to happen one needs to look at a cluster of villages that can support such a manufacturing system.

A hypothetical village

Before going further it is useful to look at a hypothetical village in India. The population in India is expected to cross the billion mark in the coming 2 years or so. Roughly 70 % of them will be living in rural areas distributed in about 600 000 villages. Thus we choose 1000 to be the population of our hypothetical village. Needless to say the sizes of villages do vary. From Table 1 we gather that currently the household dominates the energy scene. What is more we learn from our discussion on development that it is vital to integrate the household as an institutional arrangement in any overall discussion of development processes. In the household cooking dominates the energy use.

It is also fairly well established that cooking in rural households takes place on fires fuelled by biomass. It is also well known that these fires are quite inefficient. Two avenues are available to improve the efficiency of cookstoves. One is fuel switch. If we take note of the progress of electrification in spite of heavy subsidies, it seems unlikely that people will be able to switch to more efficient stoves that use kerosene, LPG or electricity. Thus improved cookstoves that use biomass seem an attractive alternative. Even here the Indian stove programme does not seem to have penetrated much more than 20% mark. The general complaint in this connection is the subsidy programme. It is also doubtful that people would be willing to invest in cookstoves that save biomass. The principal reason for this is that people do not see any cash benefit by saving fuel since most of it is collected for free.

A way out of this impasse can be to couple the electrification programme with the introduction of improved stoves. The question obviously would be: how much electricity can a gasifier system provide with the wood saved by the adoption of improved cookstoves? For this purpose we will use the numbers presented earlier on biomass usage in developing countries. In particular the WEC figures are all global averages that include both urban and rural users on the one hand and industrial uses of biomass on the other hand. Thus we shall take the average of the two figures presented in Table 1 on rural energy scene, which turns out to be 9 GJ per capita per year. We will take a conservative estimate of 20 % as the possible wood savings from an improved woodstove. Much higher savings are possible, but at the current state of the woodstove technology this is relatively easy to achieve. Thus for our hypothetical village we can expect that wood/biomass to the tune of 1800 GJ/yr would be available. The gasifier electricity system has to pay for this wood. This provides a powerful incentive for families to invest in improved cookstoves. We assume a biomass to electricity conversion efficiency of 15 %. A conservative estimate for the operation of the electricity system can be taken to be 4000 hours per year, that is, a capacity factor of 46 %. With 30 % diesel use, the saved fuel can be used to operate a 30 kW gasifier-generating system.

The next question is: how much electricity is required for our hypothetical village? There are various ways of going about for arriving at an acceptable estimate. It seems best to approach the problem from a development perspective. Further it also seems useful to take on board the advice of Schumacher (1973) on starting from where one is at the present time. We add to this the experience indicated in Table 4. Thus we can draw up a priority list of services that can be provided by electricity in rural areas. The following is such a list:

(i) Lighting for every house
(ii) Drinking water supply
(iii) Public lighting – streets, schools, temples, etc.
(iv) Irrigation water
(v) Industries

If we start with lighting, it is reasonable to assume a 50 W connected load for each household. With the modern technology of compact fluorescent lamps, this will take care of the lighting requirements handsomely. Our hypothetical village can be assumed to have about 175 households and thus this represents just 8.75 kW. What is more this represents a little less than 1500 hours of operation (with an average of a little over 4 hours per day of lighting) for the system.

Next we turn to the drinking water supply. If we note the experience of Table 4 as an indicator, it appears that a 5 kW pump, operated for about 1000 hrs per year, should handsomely meet this need. Public lighting can account for about 1.25 kW of connected load again for 1500 hours per year.

The next priority item in our list is irrigation. Detailed data on the subject was not easily accessible for the author. We will use a recent work of *Srinivas* et al. (1998) as an illustrative example. They carried out a fairly detailed study on 24 villages and placed it in the context of overall features prevailing in the district in which the villages were located. The district has a population of 2.3 million with a rural population of 83.4 % (1.92 million). The district has about 600 000 ha of land devoted to agriculture out of which about 16 % is irrigated. About 26 % of this comes from what are called tanks (artificial lakes), 27 % from open wells and the rest from bore wells. The latter two use mechanical pumping. The detailed investigations in 24 villages show that the installed capacity of pumps was around 720 kW to irrigate about 3600 ha of land. Detailed breakup of capacities and duration of operation were not presented in their work. A rough analysis of their data does not show any significant difference in the pump capacity whether the water is drawn from an open well or from a bore well. The average capacity appears to be about 3.75 kW (5 HP). The pumps operate for about 900 hrs/yr on the average.

The above data can be used to construct the agricultural profile of our hypothetical village. The village can be expected to have about 300 ha of land devoted to agriculture. From the district data presented above the irrigation from tanks account for just about 4 % of the total agricultural land and we shall ignore this contribution. We will assume that the constraint on irrigation is water availability. The present picture can be taken as one of 50 ha of irrigated crops and the rest as dry land farming. One could visualise a new regime where the irrigated crop area is doubled and some modest amount of water is supplied as and when necessary for dry land crops. One can take 150 ha as the equivalent irrigated land. From the data presented above this will demand about 30 kW of pumping power operating for about 1000 hrs per year.

Finally we come to industries. It is reasonable to assume, at least in the initial stages, that industry will be exclusively devoted to processing of agricultural products on a small scale. The study quoted above suggests that roughly 6 % of the population in the district are engaged in small-scale industries. Obviously most of them are concentrated in urban areas. Thus our hypothetical village cannot be expected to be higher than this average. We will arbitrarily assign 20 kW as the installed capacity of these industries. We also assume a maximum of 2500 hours of industrial demand per year.

We have assembled this information in a concise form in Table 6. The table illustrates a principal difficulty of rural electrification. It is extremely difficult to get something like 4000 hours of operation for a 50 kW system. The questions that need to be resolved concern whether the industrial and agricultural demand occur at the same time. Since we have assumed that the industry is likely to be one of agricultural processing, it seems that the pumping and industrial demand will not occur at the same time. What is more, most farmers would like the irrigation to be carried out during the daylight hours. Similar is likely to be the situation with respect to the industry. Thus, for the situation sketched in Table 6, the daytime load will be only 60 % of the installed capacity. The system in the evening hours will be operative at about 20 % of the installed capacity. If we organise the pumping for drinking water to occur during the evening hours, this will increase to 30 %. Thus our 50 kW system will be working on an average of just 2000 hours per year. If the capacity is reduced to 30 kW the operational period will be a little over 3300 hours per year. These are the constraints that make the big utilities shy away from exhortations from well-meaning people to provide electricity to rural areas.

Table 6: The Demand Pattern for Electricity in the Hypothetical Village.

End-use	Connected Load kW	Annual operation Hours
Home Lighting	8.75	1 500
Public Lighting	1.25	1 500
Drinking water	5.00	1 000
Irrigation water	30.00	1 000
Industry	20.00	2 500

The table also sets the boundary conditions under which the planning and execution of decentralised electricity systems need to be carried out. It is simply unrealistic to expect the total load to materialise at one go. It will take time for the load to develop. Thus it seems prudent to begin by installing a 5 kW system and gradually expand to the maximum capacity over a period of time.

With a long-term view, if we are planning for a 50 kW system for the hypothetical village, the savings of wood through the introduction of improved stoves will provide just 30 kW. Two other possibilities exist to bridge this gap. The first is the biogas plant. According to *Rajabapiah* et al. (1993), the human/cattle ratio in the village of Pura (see Table 4) was 1.9. But the data of *Srinivas* et al. (1998) suggests a ratio closer to 4 for the whole district they studied. We will use this as conservative estimate. Thus for our hypothetical village the dung available from the cattle will provide for a biogas-electricity generation of 5 kW, again on the basis of a 4000 hour per year operation. This again has to be paid for.

The additional capacity will have to be provided by biomass plantations. Assuming a modest yield of 6 tons per hectare per year, the plantation area needs to be 9 hectares to power a 15 kW gasifier-electricity system. Presumably this land can be expected to be available if we note that the Government of India plans to reclaim 20 million hectares of degraded land for reforestation programmes. This is roughly one-eighth of the land used for agriculture in the country. Thus finding 9 hectares of land in a village that has about 300 hectares of agricultural land should not prove a big handicap. Once the plantation gets going, it can be gradually extended to provide the needed fuel supply for cooking. In fact the SuTRA team envisages biogas plants based on leafy biomass provided from such plantations to provide all the village cooking needs.

The above description provides for an integration of technologies, namely stoves, gasifiers and biogas. Depending on the resources in a given village different combinations of gasifiers and biogas systems are possible. The approach also provides for overcoming a principal shortcoming of the current scene in technology introduction which is highly fragmented: A is busy pushing cookstoves; B is concerned with biogas; C with gasifiers, D with solar PV's; E with windmills etc. The present approach attempts at least partially to overcome this problem.

We need to supplement the above integration of technologies with another type of integration, which we shall call spatial integration. The whole activity has to be planned to be carried out in a group of 1000 villages located in a contiguous area. For India with a rural population density of about 250/km^2, one can expect 1000 villages (roughly a population of a million) to be enclosed in a circle with a radius of about 36 km. Far too often, in the name of proving the technologies, so-called demonstration projects are started in individual villages that are highly dispersed. Such an approach is inimical to the development of the technology that can be sustained in the long-term.

A system conceived in the above manner has a number of merits to commend it. One can begin with by introducing stoves and biogas systems. Once the stove technology starts saving fuel in significant quantities, one can start with gasifiers. This can be followed up with developing biomass plantations. In other words, the process will provide time for the development of appropriate organisational/institutional structures in the villages concerned to convince people to adopt stoves, collect and deliver dung and saved wood to the village energy utility, and start on the plantations.

The 5 kW system

In the foregoing we have implicitly assumed that the unit size of the electricity generation system will be 5 kW. The following are some of the justifications for making such a choice:

- As already pointed out, it permits the full capacity of 50 kW per village to be attained over a period of time with the growth in demand for irrigation pumping, agricultural product processing, other small-scale industries, and possibly increased use of electricity in homes.
- The 5 kW system will accommodate more easily the variation in village sizes.
- One can account for the variation in the types of fuel available in different villages and different seasons with ease. Certain amount of fine tuning of design is feasible to accommodate these variations with the choice of a smaller unit.
- Yet another merit of working with units of 5 kW size is that failure of one unit in the system will not necessarily result in total failure of electric supply to the village.
- It will permit one not to distinguish between electrified and non-electrified villages. For example the approach will provide for electric lights to be available in about 145 houses as against the current average of about 48 houses. And to boot clean drinking water will be available for everyone.
- Since one is working with a sufficiently large number of villages, it is possible to conceive of a decent sized manufacturing system. In principle the industry can make gasifiers, metal components for biogas plants and metallic wood stoves. One can expect an industry production capacity of 1000 gasifiers per year. Such a size will permit the development of proper quality control and on site routine testing of the product before delivery – vital elements for the emergence of a mature technology. With time one can envisage improvement in the performance quality of the equipment.
- It will also be possible to place bulk orders directly with the engine-generator manufacturers resulting in reliable delivery and service contracts.
- Similarly long term supply contracts for diesel can be entered again assuring reliability of supply.
- Working with a group of villages in a contiguous area will provide for a professional class specialising in installation and maintenance of gasifiers, engine-generator sets, biogas plants etc. to emerge.

The approach thus combines centralised production of generation equipment with decentralised generation of electricity. One of the major costs associated with centralised generation is due to transmission and distribution. Apart from high costs, there result substantial losses in power not to mention theft of power. Technical losses will without doubt become smaller with decentralised generation. There have been many innovations in cost cutting in this field. While dramatic figures have been quoted by *Inversin* (reduction by factors of 2.5 or more compared to the conventional grid lines) based on work in Nepal (1995), there is little doubt that the costs can come down significantly. If the operation and management of the system is entrusted to the villagers through the establishment of village energy utilities mentioned earlier (see also later), the pilfering will also be reduced. In other words, the different steps mentioned above lead us to question the conventional wisdom that decentralised electricity generation is much more expensive than centralised generation.

It is not the intention here to adopt the 5 kW unit as a dogma. It is quite on the cards to construct the following type of scenario. The villages one starts with at the end of, say 1 year, are ready to absorb higher capacity. A second 5 kW system could be acquired by the utility. Say some 8 months later the utility sees the need for a further augmentation by another 5 kW. At this stage it is quite thinkable for the village to sell one of its 5 kW set to another village in the thousand village scheme and in its place install a 10 kW system. One of these days they might come to install a 20 kW system. At any rate to guard against a complete "black-out" due to the system failure it seems advisable to work with a minimum of three units per village. We are really working on the Schumacher principle of starting with small.

The holding company

We started this section stating that for a technology to be sustainable it is necessary to integrate some seven distinct activities. The argument so far covers to differing levels of detail four of the first five of these activities. There has been no mention of marketing. What is more there are several activities that have assumed the existence of a management entity that oversees a whole lot of activities that have to occur smoothly and reliably. Such a management entity could be a holding company. The typical functions of such a company could be the following:

(i) Formation of village energy utilities.
(ii) Placing orders for the generation equipment.
(iii) Installation of the systems.
(iv) Maintenance of systems.
(v) Collection of fees from the village energy utilities towards the cost of capital equipment and other services and raising capital.
(vi) Sponsoring of R&D work.

The village energy utilities would be responsible for a large number of activities. Few of them are listed below:

(i) The installation of improved stoves.
(ii) Collection of the saved biomass.
(iii) Collection of dung.
(iv) Sale of fertilizer from the biogas plant/s.
(v) Setting up and operation of the necessary biomass plantations.
(vi) Operation of various plants.
(vii) Provision of electricity connections to different classes of users.
(viii) Collection of charges for electric supply.

etc.

The holding company can provide facilities for training of people to install, operate and maintain the systems. It can raise capital from State Electricity Boards, national agencies (such as IREDA), banks and other private sources. In principle bringing electricity to individual homes is the responsibility of the village energy utility, but the holding company needs to play an important role here by bringing in the necessary technology (that is cheaper than the ones in common use in the systems operated by State Electricity Boards) and of course developing the necessary trained manpower. There are other functions of the holding company such as assisting the village energy utilities in fixing the tariff structure for acquisition of woody biomass, dung, and sale of fertilizer and electricity.

Financing possibilities

The fundamental question in any discussion of rural electrification is the financing of the system. We will start from the users' end and in particular lighting for households. As we have pointed out earlier the latter is one of the major indicators of development and thus the choice. Currently, the majority of the rural households rely on kerosene for their lighting. The study of *Srinivas* et al. (1998) suggests the kerosene use in an average household to be 3.5 l/month. In order to put a price tag on these we shall use the work of *Dutt* and *Ravindranath* (1993) along with the references on biogas plants and gasifiers of Table 4. *Dutt* and *Ravindranath* in their work on cookstoves use the following numbers: US$ 30/barrel including the costs of refining and distribution for kerosene, US$ 0.055/kg of wood from plantations in India; and US$ 0.09/kWh corresponding to the marginal cost of supplying electricity. The cost of lighting in these houses with kerosene will be US$ 0.66/month. If 50 W of lighting is used for 1500 hours per year, this will work out at the above rate to US$ 0.5625/month. The electric light is obviously cheaper.

The question is: can we supply electricity at this price from our systems. According to *Rajabapiah* et al. (1993) the cost of biogas electricity at 12 % discount rate and 10 hours of operation per day will be about US$ 0.12/ kWh. The cost of gasifier electricity according to *Mukunda* et al. (1993) will be about US$ 0.16. Currently the system is not operating for 10 hours/day. There are several extenuating factors that may yet produce cheaper lighting than that of kerosene lighting. As we already indicated, the fact that one is contemplating bulk production of gasifiers and placing bulk orders for engine-generator sets. This at the minimum will bring the costs down by 10 %. But by far the greatest savings can occur due to the fact that an eight watt fluorescent lamp produces 10 times more light than a kerosene wick lamp which is the predominant type of lighting device used in rural areas (*Foley* 1995). Thus one can manage with 25 W of electric lamps. This will bring the cost down tremendously.

The approach suggested in this paper of buying wood from the fuel collectors provides them an income. At the cost suggested by *Dutt* and *Ravindranath* and assuming a heating value of 15 MJ/kg (this conservative value is used since the moisture content of collected wood can be high), an average family will derive an annual income of US$ 37.62. The improved stove of the three pan variety, according to *Dutt* and *Ravindranath*, costs US$ 7.78 and has a life time of 3 years. Without going into elaborate arithmetic it is easy to see the saved money can pay for the electricity connections to every household provided the household is permitted to include this in their monthly electricity bill. Similarly delivery of dung will bring in extra income to families that have either cattle or those who go around collecting dung. The actual income is closely related to the manner in which the sludge – the effluent from the plant after the gas is recovered – is handled: it can either be returned to the cattle owner without a fee or sold as an organic fertilizer. The Pura plant (see Table 4) has adopted the former practice. The author was unable to verify whether there exist any plants using the latter approach.

Availability of electricity will produce opportunities for more land to be irrigated with attendant increase in productivity. In addition it will be possible to attract capital to establish small scale industries in the villages. The question would be whether capital for these activities will be forthcoming. The current textile industry scene in India seems to suggest that one could raise sufficient capital from informal sources rather than from the conventional banking sector. At any rate both these will result in greater employment opportunities allowing for the payment for electricity.

The foregoing discussion suggests that what is required is capital for setting up the system. It has to be raised in a manner similar to what is being done for large power stations. It is obvious that the user does not pay up front for the setting up of a large power station. Thus it will be repaid in virtually the same manner as happens with large systems.

Human resources

For the whole system to work effectively, a fundamental requirement is the development of the human resources. We will start with stoves in keeping with the arguments advanced earlier. An important point to mention here is that women are responsible for collection of fuel. It turns out in many cases they are also responsible for building stoves as the following quotation from *Santha Rama Rau* (1969) illustrates.

All this [stove building] was supposed to be done by the woman of the house, for it was considered both an art and a valuable skill. One of my aunts had quite a local reputation for expert and elegant chula [stove] building.

Stove dissemination campaigns have taken on board the Schumacher tenet of starting from where you are. Thus, the majority of rural stove programmes concentrates on mud stoves that have to be build in situ. These require certain amount of training in order to assure the promised performance from the designs. Thus the designers organise training courses for achieving the objective of introducing improved stoves. However, these courses somehow have not been able to exploit the circumstance described by Santha Rama Rau. Training courses are invariably provided for young adult males. Probably this is due to three reasons:

(i) The selection for attending these courses are made by a local male bureaucrat.
(ii) The courses are held in a far-off city for a period of ten days or so. Most rural women will find it difficult, if not impossible, to leave their homes for such a long period.
(iii) Finally the courses are given by people who have virtually no skill to communicate with illiterate women.

Some of these problems can be overcome if we follow the ideas used by General Motors (GM) during the second world war. A graphic description of this is provided by Peter *Drucker* (1979):

While I did my study at GM, Dreystadt – against the advice of GMs top management – bid on the nastiest defense job around, the production of a high precision item (I believe it was a bombsight, and the first one to use electronics). Everybody knew that the work demanded highly skilled mechanics. "It's *got to be done", said Dreystadt; "and if we at Cadillac can't do it, who can?". The only labour to be found in Detroit were superannuated Negro prostitutes. To everybody's horror Nick Dreystadt hired some 2000 of them. "But hire their madams too", he said. "They know how to manage the women." Very few of the women could read and the job required following long instructions. "We don't have time to teach them to read", said Nick, "and few would learn to anyhow." So he went to the workbench and himself machined dozen of the bombsights. When he knew how to do it, he had a movie camera take a film of the process. He mounted the film frames separately on a projector and synchronized them with a flow diagram in which a red light went on to show the operator what she had already done, and a green light to show what she had to do next and a yellow light to show what to make sure of before taking the next step. By now this is a standard procedure for a great many assembly processes; it was Dreystadt who invented it. Within a few weeks these unskilled illiterates were turning out better work than highly skilled mechanics had done before...*

In other words illiteracy need not be a hindrance for people to accomplish complicated tasks connected with newer technologies. If we note the availability of video systems, computer graphics and the relative simplicity of the equipment to be built, it should not be all that difficult to train women stove builders in rural areas.

More examples can be given to indicate the intelligent behaviour of so-called illiterate people as the following example from *Gowarikar* (1994) suggests:

The crude death rate in India fell by a gigantic 57 % between 1961–91. In spite of there being no monetary incentive, people have made use of vaccination and other medical facilities when in need.

This brings out two points:

(i) The policy support provided by the government in establishing the required medical services that have been provided freely has played a crucial role in attaining the objective.

(ii) People may be illiterate, but intelligent enough to make use of facilities that are of obvious benefit to them. In the scheme proposed in this paper, adoption of improved stoves results in an income to the family, an income that can be used for the provision of electric lights. It seems reasonable to assume under these conditions that people, especially women, would be enthusiastic in participating in such a scheme.

The projects of biogas and gasifier mentioned in Table 4 are operated by local people for nearly ten years now. Both the project introducers and beneficiaries have participated in an active and patient manner to make this possible. Yet another example of rural people working with complex technical projects is the PV based solar home systems project in Ladakh (India) described by *Roy* (1996). *Roy* provides a graphic description of the background of 25 odd people with less than high school education that is successfully installing and maintaining these ultra modern technological innovations. Over 850 systems have been installed electrifying over 730 houses in 35 villages.

The foregoing description suggests the possibilities that exist for training local people to install and operate fairly complex technical systems provided sufficient attention is devoted to training the people in rural areas. These can be significantly enlarged if certain modifications are introduced in the tertiary education. Most of these are far too specialist oriented. What is required is more of a general engineering education, training people who are at home with interdisciplinary work that one runs into in the area of rural development. *Narasimha* (1995) articulates similar thoughts and suggests an engineering education process leading to a degree in Bachelor of Engineering Arts.

Organisational questions

This is going to prove the biggest bottleneck. There are any number of activities that require a very careful organisation. To name just four: construction of stoves; delivery of saved fuel to the village energy utility, delivery of dung to and supply of sludge from the biogas plant, and collection of charges for the supply of electricity. All these need to occur regularly on time and thus demand considerable leadership. It is easy enough to draw up a block diagram indicating the diverse activities that are required to be carried out in running such a system. The trick is to get these done on the ground. What is required is a careful observation of current practices in rural areas in a diversity of activities, particularly on the part of the holding company. Here are a few examples that indicate the opportunities for organisations that exist in rural areas.

Makhijani and *Poole* (1975) relate an instructive story on providing irrigation water:

... an American missionary armed with wheat wanted to initiate some development in the hill areas of Orissa, among the poorest regions of India. When he started out 10 years ago, he asked people of the village where the program was to begin what the needs of the village were. The villagers wanted an irrigation tank, but claimed that the 700 people required for two or three months to build the project would not be available. The village could contribute, at most, a tenth of that number. The missionary advised the elders of the village to inquire in the neighboring villages whether the people would work if a day's wages were 4 kg of wheat and a few grams of cooking oil. He said he would be back in a week to see whether the construction of the needed earthen dam could be initiated. The following week 700 workers were on hand and the project was completed on time. This experience was repeated dozens of times during the 10 years he spent working in Orissa.

The second story comes from *Reddy* (1990). An unmissable feature of rice cultivation in much of Asia is the transplantation of rice seedlings. This is invariably carried out by literally an army of women. A common practice in many of the villages that *Reddy* knew was, that one woman negotiated on behalf of the rest with the landlord for the wages. Once the negotiations were complete, the woman apparently went back to her colleagues to tell them the terms and conditions. Once this was accepted the task was begun and completed on time.

The phenomenal success of Grameen Bank in Bangladesh is documented so extensively that it is superfluous here to go into a detailed description. Three features of the enterprise are worth mentioning here. The core of the enterprise consists in creating a so-called "lending circle" made up of a group of mostly five women who jointly manage and guarantee loans. This is followed by education on money management and small-scale development. They start with very small loans (US$ 20) and graduate with time to larger loans. The trust placed by the banking authorities along with the above features have resulted in a phenomenally high loan repayment rate of 98 % (*Kammen* and *Dove*, 1997)

These experiences taken together with other evidence we have presented earlier in this paper indicate that it is reasonable to assume that there is no dearth of capability in rural areas to carry out organisational tasks. What is required is a package of measures tailored to meet the perceived needs of the people and a surfeit of patience on the part of people who are trying to "sell" new ideas.

Conclusions

An attempt has been made in this paper to bring together a diversity of experiences that have been accumulated over the last hundred years in the development of technologies that have the potential to combat poverty especially in rural areas. The whole work is placed in the context of rural electrification, primarily in India. The principal emphasis has been on the tailoring of technologies to meet the prevailing circumstances in rural areas. The word "tailoring" is not meant here to get a garment made to suit individual sizes and tastes in a precise manner. It is used in virtually the same manner as the modem apparel industry uses. It provides sufficient variety in sizes, styles and costs, but yet it uses a reasonably well-developed mass production system. And to boot the system provides for a plethora of "producers" thus maintaining a modicum of competition which seems essential for innovative ideas to flourish. This is exactly what is being advocated here for rural electrification.

In the last ten years or so there has been great advocacy for the Solar Home Systems based on photo-voltaic technology. The promoters of this technology claim that costs will come down if the so-called modules of PV cells are produced in bulk. In view of this they demand that a level playing field be created for their products with the product of centralised electricity generation. What is being argued in this paper is that this level playing field be created for **all renewable energy technologies**.

A fundamental issue that has been taken on board in the present argument is an awareness of the present situation along with a desired objective for the future – not a distant one, but the immediate one. Thus the need of a household is fuel to cook but it also has the desire to have an electric light, both to be met with the resources at its command. Thus combining improved stove technology with that of gasifiers will meet both the need and the desire. The combination provides a handsome bonus in the form of drinking and irrigation water. Adding the collection of dung will provide additional power for meeting a modest amount of power for industry. In the medium term the setting up of plantations can provide for additional power for growing demand. In principle the PV system can provide all these services but at a price. What is more the technology treats the populace as mere consumers, but not producers. This is sought to be combated by the often quoted argument that doubling of production will result in about 20 % cost reduction. However there is no reason to believe why a similar argument is not applicable for the technologies advocated here.

We have not considered the questions of marketing and research and development in the discussion. The first one is where the PV manufacturers – mostly multi-national corporations – are the strongest. They are able to package their goods and services in a manner that is not merely convincing but also highly attractive. Such skills are sorely lacking for the technologies we are considering in this paper. One needs to start at the beginning as it were to develop marketing strategies for these technologies. This requires to be directed at two constituencies that occupy the extremes of a wide spectrum – the policy maker at one end and the user at the other end. Both are tough customers to please and substantial attention needs to be devoted to cultivate effectively these two constituencies. The developers of these technologies too often are convinced of being correct. So much, so they take a combative attitude towards the policy maker and a patronising attitude towards the user. That is precisely what marketing is not. There is a long road to cover in this territory. The question of R&D is the subject matter of a work under progress.

References

ASTRA, 1981. Rural energy consumption patterns: A field study. Centre for the Application of Science and Technology to Rural Areas, Indian Institute of Science, Bangalore.

Drucker, P. F., 1979. Adventures of a Bye-stander: Other Lives and my Times. Heinemann, London.

Dutt, G. S., Ravindranath, N. H., 1993. Bioenergy: Direct Applications in Cooking. In "Renewable Energy" (T. B. Johansson, H. Kelly, A. K. N. Reddy and R. H. Williams, eds.), Island Press. Washington D.C.

Foley, G., 1995. Photovoltaic Applications in Rural Areas of the Developing World. World Bank Technical Paper Number 304, Energy Series, World Bank, Washington D.C.

Goldemberg, J., T. B. Johansson, A. K. N. Reddy, R. H. Williams, 1994. Energy Efficiency from the Perspective of Developing Countries. Energy for Sustainable Development, Vol. 1, #2.

Gowarikar, V., 1994. Demographic Transition in India. Economic and Political Weekly, Vol. XXIX, #49.

Inversin, A. R., 1995. New designs for rural electrification. Energy for Sustainable Development, Vol. 1, #6.

Kammen, D. M., M. R .Dove, 1997. The Virtues of Mundane Science. Environment, Vol. 39, no. 6.

Makhijani, A., A. Poole, 1975. Energy and Agriculture in the Third World. Ballinger Publishing Company, Cambridge, Mass.

Mukunda, H. S., S. Dasappa, U. Shrinivasa, 1993. Open-top Wood Gasifiers. In "Renewable Energy" (T. B. Johansson, H. Kelly, A. K. N. Reddy and R. H. Williams, eds.), Island Press. Washington D.C.

Narasimha, R., 1995. Golden Jubilee Lecture, Department of Mechanical Engineering, Indian Institute of Science, Bangalore.

Rajabapiah, P., S. Jayakumar, A. K. N. Reddy, 1993. Biogas Electricity - The Pura Village Case Study. In "Renewable Energy" (T. B. Johansson, H. Kelly, A. K. N. Reddy, R. H. Williams, eds.), Island Press. Washington D.C.

Santha Rama Rau, 1969. Cooking of India. Time-Life Books, New York.

Reddy, A. K. N., 1990. Personal Communication.

Revelle, R. 1976. Energy Use in Rural India. Science, Vol. 192, p. 969.

Roy, S. 1996. De-mystification of SPVs to provide lighting: an example of community-supported on-site initiative in Ladakh in the Indian Himalayas. Energy for Sustainable Development, Vol. 2, #5.

Schumacher, E. F., 1973. Small is Beautiful: A study of economics as if people mattered. Blond & Biggs, Ltd. London.

Amartya Sen, 1989. Indian Development: Lessons and Non-Lessons Daedalus, Vol. 118, #4.

Skutsch, M. M., 1994. Social Forestry as Sustainable Development: Comparative Strategies in Sri Lanka. Ph. D. Thesis, University of Twente, Enshede.

Smulders, P., 1996. Windpumping: The Forgotten Option. Energy for Sustainable Development, Vol. 2, #5.

Soponronnarit, S., 1995. Solar Drying in Thailand. Energy for Sustainable Development, Vol. 2, #2.

Srinivas, C. V., Shantli Iyer, Shrinivasa, U., 1998. SuTRA Package for Yadavanne and Kodavathi Panchayats. Karnataka State Council for Science and Technology. SuTRA – A programme Unit of Society for Innovation and Development, Indian Institute of Science, Bangalore.

Stassen, H. E. M., H. A. M. Knoef, 1995. UNDP/World Bank Small-scale Gasifier Monitoring Programme. Energy for Sustainable Development, Vol. 2, #1.

Streeten, P. P., 1984. Development Dichotomies, in: Pioneers in Development, Edited by G. M. Meier and Dudley Seers, A World Bank Publication, Oxford University Press.

Tomar, S. S., 1995. Status of Biogas Plants in India – an Overview. Energy for Sustainable Development, Vol. 1, #5.

World Energy Council, 1994. New Renewable Energy Sources. Kogan Page, London.

Author's address

Dr. K. Krishna Prasad
Editor 'Energy for Sustainable Development'
Faculty of Physics
Eindhoven University Of Technology
P.O. Box 517
5600 MB Eindhoven, The Netherlands
e-mail: K.K.Prasad@phys.tue.nl

Wood Energy System in China[1]

Su Mingshan and Zhou Luping

Wood resources are still the main energy source for human beings, especially in China, where more than 800 million of the total population of 1.2 billion people live in rural areas.

Wood energy development in China has been the major issue in energy strategies since it provides the energy supply of 70 % of the rural population [1]. The Chinese government has paid due attention to rural energy and wood energy issues since the 1960's. It promoted the development of a fuelwood forestry and the dissemination of improved fuelwood stoves (IFS) in rural areas under several national programs [2]. Nowadays China is planning to develop a socialist market economy. Market mechanism will increasingly play an important role in economic and social activities. The policy to promote the development of wood energy has to be adjusted according to market oriented mechanisms.

On the other hand, more and more people are paying attention to local and global environmental issues and the sustainable development of human beings [3].

Wood energy development is the priority field of the government of China.

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Section 1: Current Situation of Woodfuel Production and Use in China

1.1 Wood Resource Supplies

1.1.1 Availability of wood resources by main agro-ecological zones

China has limited wood resources. The forest area in China just holds a proportion of 3–4 % of the global forest area. Wood resources in China are under great pressure by the demand of the 1.2 billion people which is about 22 % of the world's total population [4].

Table 1: Availability of Wood Resources by Agro-ecological zones (Zhang Zhida, 1996[5]).

	East	middle South and South West	North West	North and North East
available land for forestry planted	63%	26%	40%	58.20%
The proportion of different forest in the different areas:				
timber forest	58%	62%	48%	80%
shelter forest	7%	11%	34%	6%
economic forest	21%	17%	10%	8%
fuel forest	5%	5%	3%	2%
special forest	1%	2%	4%	4%
bamboo	9%	4%	2%	0%
subtotal	100	100%	101%	100%

The total land area in China is 9.6 million km^2, of which forests share 13.39 %. Different agro-ecological zones have their own characteristics as shown in Table 1 [5].

- Eastern China, including Shanghai, Jiangsu, Zhejiang, Shandong, Anhui, Jiangxi, Fujian, and Henan: 63 % of available land for forestry has been planted, of which 58.4 % are timber forest, 6.8 % are shelter forest, 20.7 % are economic forest, 4.8 % are fuel forest, 0.8 % are special forest and 8.5 % are bamboo.
- The Middle South and south-western China, including Yunnan, Guizhou, Hunan, Hubei, Guangxi, Guangdong, Hainan: 26 % of available land for forestry has been planted, of which 61.7 % are timber forest, 10.5 % are shelter forest, 16.7 % are economic forest. 4.8 % are fuel forest, 2.4 % are special forest and 3.9 % are bamboo.
- North-western China, including Sichuan, Shanxi, Gansu, Qinghai, Ningxia, Xinjiang, and: 40.3 % of available land for forestry has been planted, of which 48.27 % are timber forest, 34.27 % are shelter forest, 9.901 % are economic forest, 3.22 % are fuel forest, 3.63 % are special forest, and 1.60 % are bamboo.
- North and north-eastern China, including Beijing, Tianjin, Inner Mongolia, Hebei, Liaoning, Jilin, Heilongjiang: 58.2 % of available land for forestry has been planted, of which 80.4 % are timber forest, 6.1 % are shelter forest, 7.6 % are economic forest, 2.2 % are fuel forest, and 3.7 % are special forest.

1.1.2 Availability of wood resources by type of land use

The wood resource produces estimated 3.1 billion tons annually. Timber forestry has the highest proportion with 35 % of total production, as shown in Table 2.

1.1.3 Significant past trends in wood resource supplies

After about one decade of efforts to improve the wood resource in China, there is great growth, as shown in Table 3.

Table 2: Mix of Wood Resources by Supply Source (Mt/%)
Source: a) Zhang Zhida(1996)[5], b) Author's estimate.

	Wood Resources	Percent
sum	3 117	100%
timber forest	1 104	35%
shelter forest	177	6%
economic forest	501	16%
fuel forest	29	1%
special forest	33	1%
bamboo	120	4%
shrub forest	113	4%
spark forest	177	6%
four-sided forest	843	27%
other	22	1%

Table 3: Share of Woodfuels in Overall Wood Resource Production (Mt/%)
Source: Author's estimate based on Zhang Zhida (1996)[5].

	1987	1993
Fuelwood production (Mt)	141	143
Wood resource production (MT)	907	3117
Share of energy wood in total wood resource production	16%	5%

Table 4: Mix of Woodfuels by Supply Source (Mt/%, 1993)
Source: a) Zhang Zhida(1996)[5], b) Author's estimate.

	Woodfuels (Mt)	*Share (%)*
sum	143	100
timber forest	56	39
shelter forest	4	3
economic forest	11	8
fuel forest	29	20
special forest	1	0
bamboo	3	2
shrub forest	11	8
spark forest	11	7
four-sided forest	18	13
other	0	0

1.2 The Role of Energy in Total Wood Resources

1.2.1 Availability of woodfuels by type of land-use

Though fuel forest area is only 4.1 % of the whole country's forest area, it supplies about 29 million tons of fuelwood providing 20 % of the total national amount of firewood. The other important source of firewood is timber forest with a share of 39 %, seeing Table 4 for more detail.

1.2.2 Availability of woodfuels by type of producer system

In China, fuelwood forestry development is a joint effort of government, management and household participants. It is difficult to say how much wood is produced by government based or management based forestry. But it is true that large part of fuelwood produced from timber forest and shelter forest can be categorized as government owned or management owned while large parts of fuelwood from fuelwood forestry and from economic forestry can be categorized as private-owned or management owned. See Table 5 for detailed estimates.

1.2.3 Significant past trends in woodfuel supplies

The woodfuel supplies did not grow up at high rate (see Table 3) because fuelwood forestry starts to produce fuel in its 5th or 6th year after planting.

1.3 Main Uses of Wood Energy

Direct burning for cooking and house heating in rural areas are the main technologies adopted for wood energy utilization. We can see from Table 6 that rural households consumed a large proportion with about 84 % of total wood energy in China. Urban areas of China did not rely much on wood energy.

Section 2: Essential Conditions Determining Actual Contribution of Woodfuels

2.1 Rural Areas

2.1.1 Extent of commercialization of wood energy markets in rural areas

Just a small proportion of fuelwood, about 9 %, are traded through markets. Although the figure is not very accurate since detailed studies are not available, experts feel that the proportion cannot be high. The price for fuelwood and its substitutes are listed in Table 7.

2.1.2 Typical wood energy flows in rural areas

In China, most fuelwood is collected for households' own use. The typical wood energy flow in rural areas is shown in Figure 1.

2.1.3 Key determinants of woodfuel availability and use in forest areas

Key determinants of woodfuel availability and use in forested areas are different from other areas. To illustrate the key determinants we select a typical county for a case study [6].

Case Study Point: Xiushui County in Jiangxi Province

Xiushui County is a typical forest area in eastern China. The forest land accounts for 74 % of the total land in the county.

a) Ecological conditions
Xiushui is also a mountainous county, the mountainous area accounts for 65 % of the total. There are 332 500 hectares of land suitable for forestry, of those 222 400 hectares were developed in 1992. Forest coverage is 55.68 %. There are 5700 hectares of forest which serve as fuelwood forest. Annual fuelwood output is 10 ton/hectare. It is estimated that the area affected by soil erosion totals 118 700 hectares.

b) Economic conditions
The National Output Value in 1990 was 430 million Yuan, output value of the rural industry was 49.4 million Yuan, farmer's per capita income was 524 Yuan. The county suffers a shortage of electricity and the price of electricity is high.

c) Socio-cultural conditions
The ratio of land and population is 0.64 hectares per capita. Since fuelwood is the main fuel for household energy consumption, women and children play an important role in wood collection and use. As a result of the national improved firewood stove program, the households are aware of woodfuel sustainability considerations and of indoor air quality issues.

Table 5: Woodfuels by Type of Producer System
Source: Author's estimate based on Zhang Zhida(1996)[5].

Woodfuel production by	Mt	%	MGJ	%
Government or management	69	48%	1 034	48%
Private or management	74	52%	1 121	52%
subtotal	143	100%	2 155	100%

Table. 6: Rural and Urban Wood Energy Consumption by Type of Use (1995)
Source: Author's estimate based on Zhang Zhida(1996)[5].

types of use	consumption (Mt)	consumption (MGJ)	percent
households in rural areas	179	2696	84%
households in urban areas	19	284	9%
rural industries	15	232	7%

Table 7: Current Prices of Woodfuels and Woodfuel Substitutes in Rural Areas (1996)
Source: ITEESA database.

coal, average	220	Yuan/ton
LPG	50	Yuan/15 kg
oil	3.3	Yuan/kg
woodfuel	140	Yuan/ton
electricity	0.7	Yuan/kWh

d) Technological conditions
The extent of rural electrification is limited. Total electricity consumption in the county was 37.9 million kWh. The county has no coal mine itself, but there is a small coal mine in the neighbouring county.

e) Development options
The county government plans to develop fuelwood energy in the county. The county is listed as one of the 100 counties for integrated rural energy development during the 8th five year plan period.

2.1.4 Key determinants of woodfuel availability and use in agricultural areas

As for agricultural areas another case is selected [7].

Case Study Point: Yuhang County in Zhejiang Province

Yuhang County is a typical agricultural area in eastern China.

a) Ecological conditions
Yuhang is located north to Hangzhou city. The total area is 1403 km^2 where plains cover 54 %, hilly areas cover 32 % and rivers and lakes 14 %.

b) Economic conditions
There are 867000 people living in the county. Total National Output Value in 1990 was 6.2 billion Yuan. Farmer's per capita income was 1368 Yuan. A large proportion of commercial energy is supplied from outside the county. Since it is close to Hangzhou city, the cost of energy is not very high. There are 46700 hectares of land suited for forestry of which 36000 hectares have been planted. Forest coverage is quite variable in different regions of the county. It ranges between just 6 % in the plains up to 46.6 % in the hill area.

c) Socio-cultural conditions
The ratio of land and population is 0.16 hectare per capita. Fuelwood is not the main fuel for household energy consumption. Some women work in Town and Village Enterprises (TVEs) enhancing the family's income. As a result of the national improved firewood stove program, households are aware of woodfuel sustainability considerations and of indoor air quality issues.

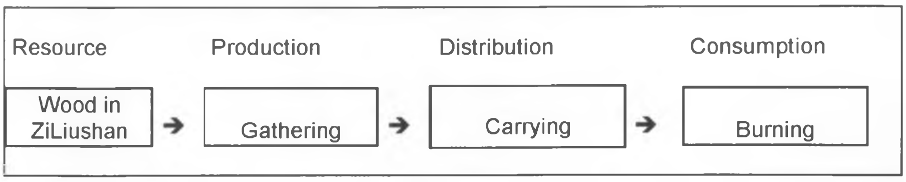


Fig. 1: Typical Wood Energy Flows in Rural Areas.

d) Technological conditions
The extent of rural electrification is limited. Total electricity consumption in the county was 37.9 million kWh. The county has several coal mines but the coal's heating value is not high.

e) Development options
The county government plans to develop fuelwood energy in the county to supplement the conventional energy supply. The county is listed as one of the 100 counties for integrated rural energy development during the 8th five year plan period.

2.2 Urban Areas

2.2.1 Extent of commercialization of wood energy markets in urban areas

Fuelwood consumed in urban areas is mainly traded. The price for fuelwood and its substitutes in urban areas is shown in Table 8.

2.2.2 Typical wood energy flows in urban areas

The typical wood energy flows in urban areas are more complicated than those in rural areas, as shown in Figure 2.

2.2.3 Key determinants of woodfuel availability and use in urban areas

Case Study Point: Dengcheng District of Changde City in Hunan Province

Dengcheng district in Chengde City is a typical urban area in southern China [8].

a) Ecological conditions
Dengcheng district in Chengde City is located in the south west of Dongtenghu Lake. The potential forest area covers 67000 hectares of which 5300 hectares are developed for forestry. The potential fuelwood supply will be 60000 t annually.

b) Economic conditions
0.93 million people live in the area. Farmer's per capita income averages 864 Yuan.

c) Socio-cultural conditions
The ratio of land and population is 0.27 hectare per capita. Fuelwood is not the main fuel for household energy consumption. Some women work in industry enhancing the family's income. As a result of the national improved firewood stove program, households are aware of woodfuel sustainability considerations and of indoor air quality issues.

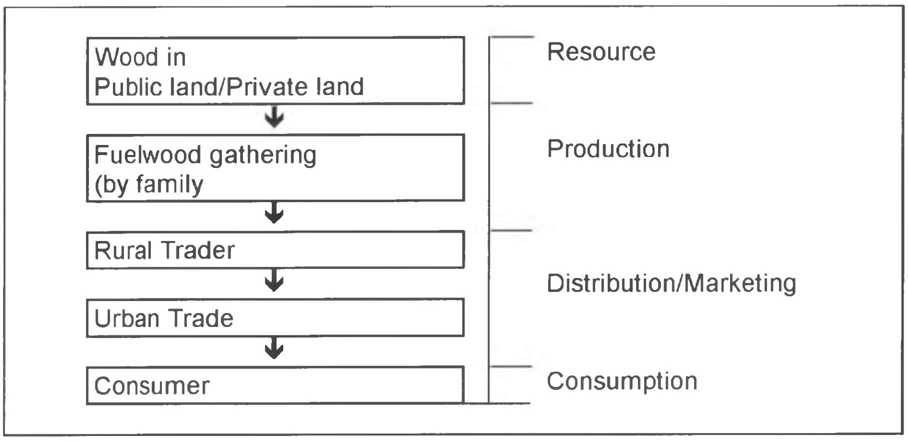


Fig. 2: Typical Wood Energy Flows in Urban Areas.

Table 8: Current Prices of Woodfuels and Woodfuel Substitutes in Urban Areas (1996) Source: ITEESA database.

coal, average	190	Yuan/ton
LPG	35	Yuan/15 kg
oil	3	Yuan/kg
woodfuel	150	Yuan/ton
electricity	0.5	Yuan/kWh

d) Technological conditions
Total electricity consumption in the county was 3.84 million kWh. The district has coal mines, the coal price is relative low.

e) Development options
The county government plans to develop fuelwood energy in the county to supplement the conventional energy supply. The county is listed as one of the 100 counties for integrated rural energy development during the 8th five year plan period (case study of a typical urban area).

Section 3: Evaluation of Status Quo

3.1 Critical Shortages/Surpluses of Wood Energy in the Country

In general, China has a deficiency in wood energy, as shown in Figure 3.

District	Provinces including	Shortage	Surplus	Reason for shortage
Desert Area in north-east, north-west, north of China	Shaanxi, Gansu Quinghai	2.00		1. arid environment 2. scarcity of woodfuel substitutes
	Xinjiang, Ningxia, Inner Mongolia, Liaoning, Jilin		15.53	
Upper and middle reaches of Changjiang River	Sichuan, Yunnan, Guizhou, Hunan, Hubei, Jiangxi, Anhui, Henan, Southem Shanxi	40.28		1. scarcity of coal and oil 2. badly destroyed wood resource 3. far from wood resource site
Loess plateau	North-western Shanxi, Southern Ningxia, Eastern Gansu, North-eastern Qinghai, non-coal area in Shanxi	0.15		1. less economic development 2. high transport costs 3. rarely rainfall, scarcity of wood resource
Littoral areas and islands	Guangxi, Zhejiang, Guangdong	5.36		1. scarcity of energy 2. far from wood resource site
	Fujian		0.97	

Source: Gao Shangwu (1991)[9]

Fig. 3: Geographic Distribution of Critical Wood Energy Demand-Supply Gaps: 1993 (million TCE).

3.2 Factors Affecting Wood Energy Management Practices

3.2.1 Sectoral development policies

Forestry issues in China are related to energy, forestry and agriculture sector policies. Energy, forestry and agriculture are all priority sectors in national development policies.

Commissions or ministries related to energy and forestry sector management in China are: State Planning Commission (SPC), State Economic and Trade Commission (SETC), State Science and Technology Commission (SSTC), Ministry of Forestry (MOF), Ministry of Agriculture (MOA), Ministry of Electricity (MOE), Ministry of Water Conservancy (MOWC), Ministry of Coal (MOC)[10].

3.2.2 Cross-sectoral development policies

Forestry issues are also related to cross sector development policies. In China, all the land belongs to the State and is collective property. Rural development is the priority area of China's government. China promotes urbanization based on small towns. Poverty alleviation is the key governmental target during the 9th five year plan period. The main measure to deal with the employment issue is to encourage the development of rural industry and the development of small towns in rural areas. The role of women in China's society is promoted since the end of 1940.

3.2.3 Laws, regulations and institutional structures

Laws, regulations and institutional structures can be modelled with the help of a decision flow framework.

Vertical and horizontal flows of energy sector decision-making processes affecting wood energy are shown in Figure 4.

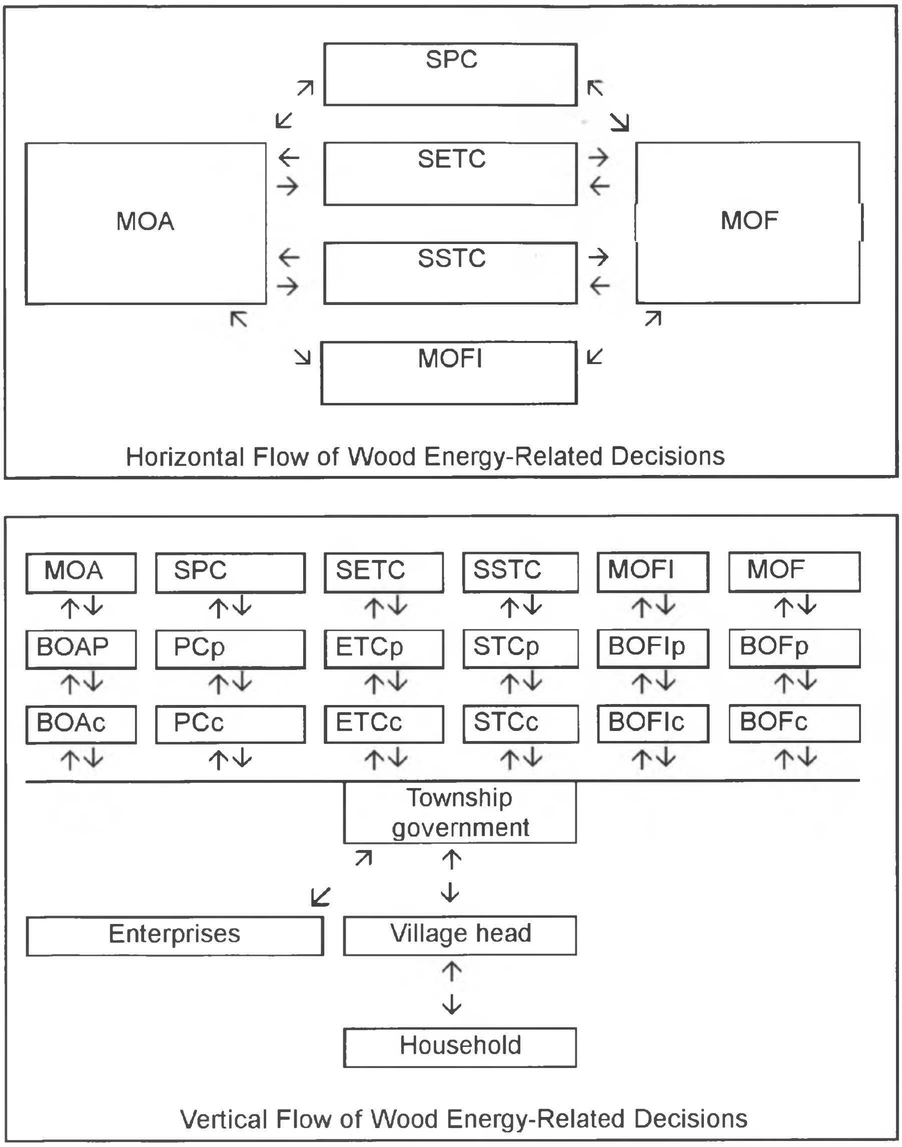
3.3 Factors supporting sustainable wood energy management practices

Laws and regulations that affect energy and forestry development are listed in Table 9 [10].

Section 4: Identification of Opportunities and Barriers for Sustainable Woodfuel Production and Use

4.1 Opportunities for Improving the Sustainability of Wood Energy Systems

1. Financial assistance in key areas where firewood shortage is serious;
2. Raising money from various sources: government, finance department, local, production unit and the masses (labor) with the rate of 2:3:1:2:2;
3. Establishing the policy that "he who plants trees has the ownership, he who operates trees gets the benefits" encouraging individual afforestation for energy use;



Glossary of terms:

BOAc	Bureau of Agriculture in County-level
BOAp	Bureau of Agriculture in Province-level
BOFc	Bureau of Forestry in County-level
BOFp	Bureau of Forestry in Province-level
DAM	Department of Affor estation and Management
DIE	Department of Industry and Energy
DRCCU	Department of Resource Conservancy and Comprehensive Util ization
DREE	Department of Rural Energy and Electrification
DTE	Department of Transportation and Energy
ETCc	Economic and Trad e Commission in County-level
ETCp	Economic and Trade Commission in Province-level
MOA	Ministry of Agriculture
MOC	Ministry of Coal
MOF	Ministry of Forestry
MOFI	Ministry of Finance
PCc	Planning Commission in County-level
PCp	Planning Commission in Province-level
SETC	State Economic and Trade Commission
SPC	State Planning Commission
SSTC	State Science and Technology Commission
STCc	Science and Technology Commission in County level
STCp	Science and Technology Commission in Province level

Fig. 4: Vertical and Horizontal Flow of Wood Energy-Related Decisions in the Energy Sector.

4. Auction off barrier hills and mountains with bad condition among public or individual operating units;
5. Exemption of taxes, tax holiday;
6. Providing loans with low interest rate, or letting farmers get the benefit of fuelwood for his labor;
7. Setting up a system of wood prices, enacting and improving policies for directing wood trade;
8. Drawing funds from the beneficiary of wood energy consumption to assist R&D for high-yielding tree species;
9. Setting up a system of responsibility for forest protection using the data of increasing or decreasing forest area to evaluate the achievement of a local leader's official career;

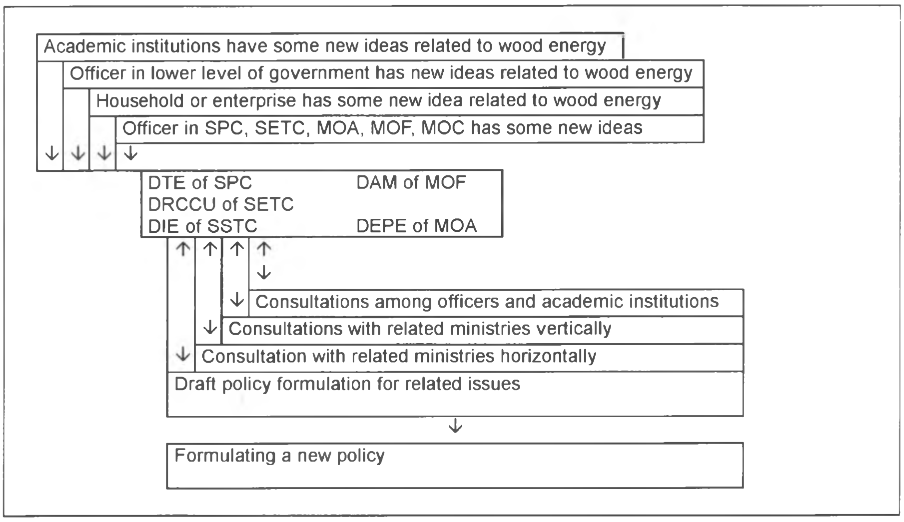


Fig. 5: Summary of Wood Energy-Related Decision process at the National Level.

Tab. 9: Laws and Regulations affecting Energy and Forestry Development. Source: SETC (1997).

Laws and Regulations	A	F	E	I	T	C	CS
the National Ninth-five-year Application Plan for the Forest Energy Engineering (1996)		✓					
the Information of Developing the Comprehensive Use of Rural Energy During the Period of the Ninth-five-year Planning (1995)	✓						
the Forest Action Plan for Agenda 21 (1995)		✓					
the Outline for the Development of Non-conventional Energy and Renewable Energy (1995)			✓				
the Outline for the Establishment of a Comprehensive National Rural Energy System (1995)							✓
Forestry Law of People's Republic of China (1984)	✓	✓					
Wild Animal Protection Law of People's Republic of China (1985)	✓	✓					
Prevent Desertification Law of People's Republic of China (1988)	✓	✓					✓
Resolution of Promoting Nation-wide Voluntary Plantation (1985)		✓					
Environmental Protection Law of People's Republic of China (1989)		✓					✓

Note: A = agriculture, E = Energy, F = Forestry, I = Industry, T = Transportation, CS = Cross-sector
Recent policy, legislation and institutional innovations are:

- ***China-Agenda 21(1995)***
- ***China Agenda 21-Forestry Action Plan(1995)***
- ***National Integrated Rural Energy Development Program based on Counties (NIREDPC),***
- ***Implementation Plan during ninth five year period for National Wood Energy Program (IPNFNWEP)***
- ***Outline of New and Renewable Energy Development Plan***
- ***China New Century Green Engineering Program[11]***

10. Enhancing the service of science and technology for forest energy engineering by collaboration of science and technology institutions, universities and production units.

4.2 Barriers Hampering the Realization of Above Opportunities

4.2.1 Economic barriers

The economic incentive for wood energy projects is not strong enough to encourage the participation and adoption of the options to plant fuelwood forests.

International assistance seems not strong enough to encourage a more wider adoption of wood energy development options, such as fuelwood plantations and dissemination of improved firewood stoves although these technologies are positive externalities to the international society.

Existing institutions are not in favour of energy programs which are comprised of many small scale decentralized energy projects, such as IFS, household gasifier. The participants of the decentralized wood energy programs are small enterprises or households.

Being small business, they are poor market competitors. The business skills of new and renewable energy firms need improvement. There exist financial barriers both for a decentralized program and a small business. For a small business it is not as easy as for a large company to get financial support from financial institutes in the domestic investment market as well as from an international development bank.

4.2.2 Institutional and socio-cultural barriers

It seems that existing management systems for a renewable energy industry need to be improved since overlapping of functions between different ministries or commissions are still continuing in spite of some efforts of co-ordination.

There exist information barriers for wood energy development. Information barriers derive from uncertainty in the development of renewable energy programs. Uncertainty can be divided into two aspects: a) incomplete information, b) asymmetric information.

There are uncertainties regarding the design and evaluation, which result in uncertainty about the performance of the person who participate in the program. As a result, many participants change their original position to another position in another trade.

Besides, there exist asymmetric information between different agents involved in renewable energy development. Asymmetric information can be characterized as a situation where one party is in possession of information that is relevant to the decision-making of the other party, but does not disclose that information to the other party.

Next, regulations did not cover many energy consumption activities. There are now no regulations on environmental pollution from coal combustion in households. Regulations on straw combustion in farm fields are now under formulation [12].

4.2.3 Technological barriers

Compared with conventional fossil fuel technology, traditional wood energy technology has a low efficiency while input for research and development for new wood energy technology is strong enough.

4.2.4 Other barriers

Finally, some of the technical standards are not sufficient for the evaluation of the technological performance.

Section 5: Recommendations for Action and Conclusion

5.1 Recommendations for Action

5.1.1 At governmental level (national, provincial, local governments)

It is recommended
1. to clarify the ownership or the right for use of forest.
2. to strengthen the quota system of wood cutting. Only those who have all three of the prerequisites (cut target, cut license and cut area design according to the national tree farm and tree enterprise levels) can cut wood.
3. to set up more wood check stations, strictly executing the institution of transportation licence. Eliminate illegal wood processing plants.
4. to improve the supervising system of forest law enforcement in forest industry and to implement the institution of reconsidering forest administration and of forest lawsuit.

5.1.2 At the level of user communities (rural, urban)

It is recommended
1. to develop other production activities in order to improve financial performance of households which plant and manage wood resources.

5.1.3 At the level of NGOs and the private sector

The wood energy program is a decentralized program and bears the characteristics of information decentralization and decision decentralization. The transaction costs for this kind of program will be very high if we implement the program like conventional big energy programs. An additional option is to encourage the participation of local NGOs and the private sector.

5.1.4 At the level of national R&D institutions

Additional R&D is helpful to improve the technological performance of new wood energy technologies and, as a result, to improve the long term economic performance.

5.1.5 At the international level

Generally speaking, wood energy technology is an environmentally sound technology compared to fossil fuel both from the view point of China and that of the world. But it seems that people in China are not rich enough to have the strong willingness to pay more for the environmental benefits of wood energy technology. Therefore, development of wood energy in a greater dimension will depend on further or additional international assistance.

5.2 Conclusion

1. Fuelwood may play a less important role in China's future energy system in short to middle term if no additional important measures are adopted.
2. International joint effort may be the only option to overcome the economic barrier which is the key barrier and results from the existing institutional framework. The sleeping beauty of renewable energy, or wood energy in particular, probably can not be waken up unless all of us have more willingness to pay more for a better world and for a cleaner environment.
3. The great demand in rural China for high grade energy resources and the global environmental pressure jointly may promote the wood energy market development in the world.

References

1. *State Statistical Bureau* (1997), China Statistical Yearbook, China Statistical Publishing House
2. *CERS/RESC* (1994), Milestone for Rural Energy Development in China, China City Press
3. *SPC/SSTC/SETC/NEPA* (1994), China Agenda 21-White Paper for Population, Environment and Development in 21 century of China, China Environment Science Publishing House
4. *MOF* (1995), China Agenda 21-Forestry Action Plan, China Forestry Press
5. *Zhang Zhida* (1996), China Fuelwood Forestry Development Strategy, China Forestry Press
6. *Xiushui Government*, Integrated Rural Energy Development Plan in Xiushui County, 1992
7. *Steering Commission of Yuhang IREDP*, Integrated Rural Energy Development Plan in Yuhang County, 1992
8. *Dengcheng District Government of Changde City*, Integrated Rural Energy Development Plan, 1992
9. *Gao Shangwu*, Wood Energy Study, China Science and Technology Press, 1991
10. *SETC* (1997), Legislation and Policies Related to Resource Conservation and Comprehensive Utilization, China Economy Press
11. *NEPA/SPC/SETC* (1996), China New Century Green Engineering Program, China Environmental Science Press
12. *Su Mingshan* (1996), Institutional Barriers and Information Barriers for Renewable Energy Development in Less Developed Countries, in Proceeding of Tsinghua Development Research Study, Tsinghua University Press

Authors' address

Prof. Dr. Su Mingshan
Dr. Zhou Luping
Institute of Techno-Economics
and Energy System Analysis (ITEESA)
Tsinghua University
Beijing 1000084, P.R. China
e-mail: mingshan@inet.tsinghua.edu.cn

Workshop: Energy Systems in Modification

Local Development by Decentralized Energy Supply Based on Alternative Fuels

Andreas Franke and Dr. Olaf Schätzchen

Summary

The ESP*GEKO GmbH operates a thermal-electric power plant with grate combustion technology in modular construction in Hagenow (Germany, Mecklenburg-Vorpommern). The area and the main building of a former thermal power plant based on brown coal were refurbished and reused. The investment was appr. 35 million DM.

The project considered the local fuel and energy market. The fuels used are wood from building sectors, residues from timber industries and wood from agriculture and forestry. The input is approximately 48 000 Mg per year, including a quota of 10 000 Mg per year wood from plantations, delivered by a producer community. In this way, the production of biomass for utilisation in material or multi stage use is incited.

The electric power (install. 5 MW) of appr. 25 000 MWh per year is saled for legal fixed price to the regional supplier. Thermal energy is delivered as steam (12 Mg/h, 48 000 MWh/a) to the potato processing factory in the neighbourhood. Compared with oil, the steam processing costs are about 20 % lower.

The plant is subjected to the licence according to Federal Law for Air Pollution Control. The legal requirements on flue gas quality (Technical Guide "TA Luft") will be kept reliably resp. will be undercut.

The refurbishment of an industrial fallow, the low cost producing of thermal energy based on local fuels led to obvious local advantages. 17 jobs in the power plant, 20 additional jobs in the potato process owing to extended production were established.

The concept of technique and placement turns essential aims of the Concept for Climate Protection, especially CO_2-balanced energy production, by the Government of Mecklenburg-Vorpommern, Dept. of Air Pollution Control, into action. Two more plants are planned resp. established in M.-V. Further places will be verified for the use of a fuel mix with biomass, wood and municipal wastes.

Authors' address

Andreas Franke
Dr. Olaf Schätzchen
ESP*GEKO Energieversorgungssysteme und Umwelttechnologie GmbH
Werkstraße 215
D-19061 Schwerin, Germany

Biomass as an Environmentally Acceptable Fuel & Implications for the Kyoto Protocol

David O. Hall and Frank Rosillo-Calle

Abstract

Biomass energy is increasingly being associated with environmental sustainability and climate stabilisation when it is produced and used sustainably. Biomass offers various alternatives to fossil fuel and, particularly when used as a modern energy carrier, it provides a number of strategies which can be used to reduce greenhouse gas emissions including: i) sustainable production and use of energy resources which results in CO_2 neutral emissions; ii) sequestration of CO_2 which creates carbon sinks; iii) direct substitution of fossil fuels with the corresponding environmental and ecological benefits- examples are bioethanol for transport and co-generation of electricity and heat.

If the Kyoto Protocol objectives of GHG emissions reduction were to be achieved, this could have important implications for the energy sector in general and biomass energy (and other renewables) in particular. Although the Kyoto Protocol is a serious attempt to reduce anthropogenic emissions it suffers from a number of shortcomings. For example, the "carbon sequestration strategy" suffers from a number of difficulties, including: i) problems posed by large-scale forest plantations; ii) what to do with the forests once they reach maturity, e.g. use for energy to substitute for fossil fuels and/or long-lived products; iii) how to measure, with a required degree of accuracy, how carbon is released by forests as they grow, die or burn; iv) what kind of forests are to be planted; v) socio-economic implications at the local level e.g. what could happen to food supplies in some areas if C credits become a valuable commodity and who would benefit locally in the short and long term; vi) potential implications for protecting native forests; etc.

Keywords:

biomass energy, carbon sequestration, fossil fuel substitution, forests, Kyoto Protocol, ecological concerns, externalities.

1. Biomass Resources: Current and Future Uses

At present total world energy consumption is about 400 EJ/year of which biomass contributes about 55 EJ (14 % of the total). The future potential use of biomass energy is very large indeed but its use as a source of energy will depend on factors which are many and complex e.g. world and regional energy supplies, environmental and ecological demands, technological developments, political and socio-economic considerations, etc., all of which are notoriously difficult to predict. What is clear, however, is that energy demand will continue to increase significantly e.g. the IEA (1998a) predicts that oil demand in developing countries will grow by about 22 % over the next 15 years and that the world will consume a further 20 million barrels/day by 2010, compared to the present 65 million barrels/day (137 EJ per year). Thus it is imperative to have a more balanced energy mix.

Biomass resources are potentially the world's largest and sustainable energy source, a renewable resource comprising 220 billion oven dry tonnes (about 4,500 EJ) of annual primary production. The annual global bioenergy potential is estimated to be about 2900 EJ, though only 270 EJ could currently be considered available on a sustainable basis and at competitive prices. The problem is not availability but the sustainable management and delivery of energy to those who need it to provide modern energy services (*Hall* and *Rao*, 1994).

1.1 Future Energy Scenarios

A number of international studies have recognized bioenergy as being a potentially large-scale source of energy which can help to lead to climate stabilization. Table 1 summarizes the estimated potential of biomass energy use from eight major studies. These figures range from 59 EJ to145 EJ in 2025, compared to 55 EJ today. Table 2 summarizes current and projected use of biomass by region for the period 1990-2010 as percentage of total energy (*World Bank*, 1996). For example, in Sub-Saharan Africa biomass is predicted to continue to be the main source of energy with 80 % of the total energy consumption in 2010 compared to 85 % in 1990. If the objectives of the Kyoto Protocol are to be achieved, the role of biomass, particularly as a modern energy carrier, could increase even further as is already happening in various industrial countries.

The reasons why biomass energy is experiencing a surge in interest in many parts of the world are multiple (see *Hall* et al. 1996; *Hall & Rosillo-Calle*, 1998a). Of particular interest is the present and potential role of biomass energy and its considerable environmental, ecological and climatic benefits. In recent years there have been some significant changes with regards to biomass energy e.g. replacement by fossil fuels and the more primitive forms, but contrary to

Table 1. The role of biomass in future global energy use (EJ). (Present biomass use is 55 EJ out of a total of 400 EJ). (For further details of references see Hall and Scrase, 1998).

Scenario		Year	
	2025	2050	2100
Shell (1996)	85	200-220	-
IPCC (1996)	72	280	320
Greenpeace (1993)	114	181	-
Johansson et al. (1993)	145	206	-
WEC (1993)	59	94-157	132-215
Dessus et al. (1992)	135	-	-
Lashof and Tirpak (1991)	1300	215	-

Table 2. Current and projected use of biomass by region, selected years (as percentage of total energy used). Source: World Bank (1996).

Region	1990	2000	2010
Sub-Saharan Africa	85	83	80
South Asia	60	52	43
East Asia & Pacific	33	26	20
North Africa & Middle East	27	23	19
Latin America & Caribbean	26	22	19

Table 3. Changes in Energy Consumption in China in Rural Areas; 1979 and 1996 (Million Tonnes coal equivalent *). Source: Dai Lin et al. (eds), 1997.

Type	1979	1996
Coal	600.00	259.40
Petroleum products	14.30	46.30
Electricity	31.20	93.30
Biomass - firewood - stalks - others (biogas, solar energy, etc)	221.70 103.70 118.00 -	240.40 99.30 120.00 1.13
Rural electricity generation (GW)	142.50	358.30
Rural population (million)	800.00	860.00
Average energy consumption in rural areas (TCE/person)	0.14	0.47
Population without electricity (million)	450.00	110.00
Population facing energy difficulties (e..g. shortages of 3-6 months (million)	420.00	70.00

*MTCE (million tonnes coal equivalent- 28–30 GJ/t).
1 tonne oil = about 1.43 tonnes of coal, depending on the coal quality.

general belief it has not resulted in a overall reduction of biomass energy use. China illustrates well these changes (see Table 3).

Thus, current trends in biomass energy use can be summarised as follows: i) overall, biomass energy use per capita remains stable or declining slightly, but increasing in absolute terms due to population growth in developing countries and increased use in the industrial countries; (for details see *Hall* and *Rosillo-Calle*, 1998b); ii) an increase in modern applications and a gradual shift away from the most primitive uses of energy (e.g. the use of dung and straw for cooking); iii) greater efficiency of use e.g. improved cooking stoves; iv) more positive policy-maker attitudes towards biomass energy both in traditional and modern forms.

2. Traditional vs. Modern Applications

Biomass energy has traditionally been associated with poor households and as a fuel which is bulky and difficult to handle, a poor energy carrier, a competitor to food production, and often as a major cause of environmental degradation. Recent evident shows that this is not the case. Biomass is a source of energy for a large number of applications both in the industrial and developing countries. Bioenergy has played a key role in the development of artisan and cottage industries in many developing countries such as baking, brewing, textile manufacture, tobacco and tea curing, fish-smoking, brick making, etc. For example, in Asia, rural industries account for at least 20 % of the region's wood energy consumption (*FAO*, 1996). Charcoal is used in the heavy and light industries such as pig-iron, steel, cement, metallurgy and cottage industries e.g. in Brazil over 6 Mt of charcoal are consumed annually in heavy industry.

Industrial applications in developed countries include CHP, electricity generation, space and domestic heating boilers in households and public buildings, small industrial applications, decentralized energy applications, etc. An important characteristic is that biomass energy in the developed countries is evolving against a background where forests and woodlands are generally under-utilized and where people are able to choose among a range of energy options and have the purchasing power to be more selective e.g. green electricity.

2.1 Some Examples of Modern Applications of Biomass Energy

Three examples merit particular attention: fuel ethanol, biogas, and cogeneration of heat and electricity.

Fuel Ethanol. In 1996 the world ethanol production was about 31.2 billion litres of which 67 % (21 billion litres) were used as fuel in transportation. The countries with the largest use are Brazil (sugarcane derived) and the USA (maize) followed by the EU. The use of ethanol fuel is not new but received a considerable push during the 1970s and 1980s caused by the high oil prices. In the early 1990s interest subsided considerably as real oil prices declined. However, in recent years there is considerable interest in ethanol fuels as a sound environmental alternative to curtail environmental pollution caused by the rapidly growing transportation sector.

Automobiles generate more air pollution than any other human activity, contributing very significantly to the emissions of greenhouse gases, notably CO_2 (2.5 kg of CO_2 are produced for each litre of petroleum used in a car) and are the fastest-growing energy consumption sector world-wide. Each year the transportation sector produces 1800 million tonnes of carbon equivalent emissions (MtCe), or 30 % of the world's carbon emissions (*Difligio*, 1997).

In Brazil, the large scale use of ethanol fuel has played a significant role in reducing the level of pollution. For example, the introduction of ethanol-gasoline blends had an immediate impact on the air quality of the large cities particularly São Paulo. Lead additives were gradually reduced as the amount of alcohol in the gasoline was increased and finally were eliminated in 1991. The aromatic hydrocarbons, which are particularly toxic, were also eliminated simultaneously and in addition, many other pollutants were also greatly reduced (*Moreira* & *Goldemberg*, 1997).

Various studies have looked at the potential of reducing pollution by using cellulose-derived ethanol which offers the potential of reducing pollution from carbon emissions by 80–95 % in vehicles. *Difiglio* (1997) has estimated that in 2025 the use of 40 billion gallons (155 billion litres) of cellulose ethanol in the USA would reduce emissions by the equivalent of 100 MtCe, and the total cumulative GHG reduction at 930 MtCe. Various countries e.g. Mexico, India and Sweden, are seriously considering the introduction of national ethanol programs as a means of pollution abatement.

Cogeneration. Environmentally, cogeneration offers considerable potential for pollution abatement The use of CHP in Scandinavian countries has led to considerable reductions in CO_2 e.g. the substitution of a coal-fired boiler in 40 MWe power plant in Denmark in January 1998 is cutting CO_2 by 190,000 tonnes annually (*Kolbeck*, 1998). The potential of woodfuel to reduce GHG showed that, for example, in Sweden this ranges from 7–17 Mt CO_2 equivalent (12–30 % of the total energy-related GHG emissions in 1995); 5–10 Mt in Finland (9–18 % of GHG); 9–14 Mt in France (2–4 % of GHG); and Austria 4–6 Mt (6–10 % of GHG), respectively (*Schwaiger* and *Schlamadinger*, 1998). In Brazil the CO_2 emissions avoided with the use of ethanol and bagasse (for heat and electricity) correspond to nearly 18 % of total emissions from fossil fuels use.

Co-firing of biomass with fossil fuels is also a growing area of interest. It is increasingly being recognized as a flexible alternative for both pollution abatement and for increasing bioenergy production in the short term. Some of the advantages include: i) no new generation capacity is required; ii) considerable potential for reducing CO_2 and SO_2 emissions simultaneously; iii) utilization of local resources, etc. Experience so far indicates that when low cost biomass residues are used, the economics are generally quite favorable.

Biogas Production and Utilization. A significant change in biogas technology, in both developed and developing countries, has been the shift away from energy production alone toward more "environmentally sound technology" which allows the combination of waste disposal with energy and fertilizer production. Denmark is a leading example and its success reflects the country's commitment to renewable energy as a whole e.g. currently about 8 % of the energy consumption comes from renewables and is expected to reach

35 % in 2035. As with other renewables, the government provides fiscal incentives for biogas production e.g. about 20 % on funding investments for centralized biogas and 30 % for individual plants (*DEA*, 1996).

Over the past 10 years the interest has concentrated on large centralized biogas plants because of technological advances and other advantages e.g. these plants provide facilities for disposing of surplus manure which is a serious environmental problem in some areas of Denmark. In June 1996 there were 18 centralized biogas plants in operation, and others at the planning stage, with an annual input of 1.2 M tonnes of biomass (75 % animal manure and 25 % organic waste), and biogas production of 40–45 million m^3, equivalent to about 25 million m^3 of natural gas, about 2 PJ; the objective is 4 PJ in 2000 and 6 PJ in 2005 (*DEA*, 1996; *CBT*, 1998).

3. The Role of Forests after the Kyoto Protocol

In December 1997 the Protocol to the UN Framework Convention on Climate Change was agreed in Kyoto (*UNFCCC*, 1998). For the first time, legally binding reduction targets of greenhouse gas emissions by industrial countries were established. The Protocol requires that emissions by developed countries must be reduced on average by 5.2 % by 2012 compared to 1990 . The EU is committed to a reduction of 8 %.

If the Protocol objectives of GHG emissions reduction were to be achieved, this could have important implications for the energy sector in general and biomass energy (and other renewables). Considering that industrial countries already produce CO_2 about 13 % above the 1990 level, CO_2 would have to be cut by as much as 45 % if trends continue unchanged. This represents major changes in the way we produce and use energy in developed countries.

The Kyoto Protocol is a serious attempt to reduce anthropogenic emissions although it suffers from a number of shortcomings. For example, at first reading the Protocol appears only to advocate planting and conserving of trees "afforestation and reforestation" in order to create carbon sinks in the trees themselves and also in soils. Little is said about using the trees (and other) biomass as an energy source to substitute for the use of CO_2-emitting fossil fuels. However, it has been recognized for a decade that growing and using biomass on a continuous basis as a substitute for fossil fuels has clear advantages compared to using the biomass solely as a means to sequester carbon to create a carbon sink.

Renewably grown biomass is a CO_2-neutral fuel with a low sulphur content and can be converted to electricity, heat, and liquid and gaseous fuels. The biomass is grown perennially to generate energy so that environmental benefits such as soil conservation and biodiversity protection accrue in comparison to annual crops. In addition, rural communities gain jobs rather than removing land from productive use to only sequester carbon. Thus, there are numerous environmental and social advantages to be gained from growing and producing biomass energy (*Hall*, 1998).

3.1 Carbon Sinks versus Fossil Fuel Substitution

In our view the Buenos Aires Conference of Parties (November 1998) will have to address a number of unresolved issues related to the use of forests for carbon credits. Already some companies are trading in so-called "carbon credits" and indeed some experts believe this could be the start of a multibillion dollar business with carbon credits changing hands as yet another commodity. This could have serious implications e.g. Costa Rica has already sold benefits for more than 200,000 tC/yr for $10/tonne, but some analysts believe that once the system is up and running carbon credits could be sold at $100/tonne (*Pierce*, 1998). Considerable more work is still needed on international guidelines for project based trading mechanisms (see *OECD/IEA*, 1998).

The Kyoto Protocol allows countries to meet part of their pollution reduction targets by planting trees to create carbon sinks instead of making actual cuts in their pollution levels. In simple terms, this implies that the rich countries may continue polluting to greater or lesser extent. Given the many uncertainties with the "carbon sequestration strategy", it remains to be seen to what extent they can offset this pollution by planting forests thousands of km away in developing countries.

The "carbon sequestration strategy" worked out at the Protocol meeting in Kyoto suffers from a number of serious difficulties which would need to be addressed, including: i) problems posed by large-scale forest plantations; ii) how to measure, with a certain degree of accuracy, how carbon is released by forests as they grow, die or burn; iii) what kind of forests are to be planted. Forest plantations have to be diverse to preserve biodiversity, but different species grow at different rates and mature at different times; iv) socio-economic implications at local levels e.g. what could happen to food supplies in some areas if C credits become a valuable commodity. This could be particularly serious in the tropics where most of the plantations would be located. On the other hand C credits would have to be more profitable than cash crops if the local community were to be interested; v) potential implications for native forests; vi) what to do with the forests once they reach maturity. Further, the problems with carbon sequestration strategy is that: a) that once the trees/plants reach maturity they start losing their stored carbon and b) maintenance and protection costs are incurred throughout the lifetime of the trees.

However, when growing biomass with defined (short) rotations and using it as a source of fuel, income is generated continuously thereby creating local jobs and other benefits. Indeed, trying to maintain carbon sink forests for long periods of time may be very difficult unless rigid legal and fire protection systems are enforced. People may need to be excluded in order to prevent damage and loss of carbon sinks. This may not be feasible in many countries unless an effective long-term infrastructure exists. Naturally, where mature forests exist they should be conserved as both carbon sinks and deposits of biodiversity. Also, where biomass energy plantations are grown, probably on excess arable and degraded land they must follow ecological guidelines so as to improve above and below ground biodiversity and carbon sinks.

Balancing the short and long term carbon and income benefits of these two approaches- substitution (fossil fuel replacement) vs. sequestration (storage of C) – on a given piece of land depends on numerous factors such as yield and rotation which can be modelled. Biomass and some other renewable energies (solar, wind) have been predicted to be the major players in all new energy supplies after the year 2020. However, before then there is also every reason to believe that biomass could substantially substitute for fossil fuels (as we have said is already happening in a number of countries around the world) and thereby reduce CO_2 emissions nationally and globally. Therefore, biomass for energy to offset fossil fuel use, along with the interim sequestering of carbon in the growing biomass (and soils), should be a component of any clean development mechanism or joint implementation project – provided that verifiable and transparent monitoring is undertaken (from baseline to completion) while ensuring that local people benefit from the beginning to end of such land use projects.

An example of near-term relevance of biomass energy is in the European Union (EU) where a recent White Paper on Renewable Energy proposed that Europe could double its renewable contribution from 6 per cent today to 12 per cent by the year 2010. This would substantially help meet the Kyoto Protocol targets. It was proposed that biomass energy in total could contribute an additional 90 Mtoe (million tonnes oil equivalent) per year compared to today's annual contribution of about 47 Mtoe. Of this additional energy, "energy crops" (trees, woody grasses, and so on) are proposed to provide 45 Mtoe/year which could be grown on about 13 million hectares of land (4 per cent of total land at a yield of 10 t/ha and assuming a conversion efficiency of 75 %). This extra 45 Mtoe/year of renewable, carbon dioxide-neutral biomass energy would reduce carbon dioxide emissions by 50 million tonnes (Mt) carbon/year compared to the present European Union total carbon dioxide emissions of 890 Mt carbon/year. The contribution of all forms of biomass (137 Mtoe) to reducing carbon dioxide emissions would total about 150 Mt carbon by the year 2010, that is a reduction of 17 per cent, which is twice the European Union's obligation under the Kyoto Protocol.

A clear point for policy makers is that trees and other forms of biomass can act as carbon sinks – but at maturity or at their optimum growth rate there must be plans to use the biomass as a source of fuel to offset fossil energies (or as very long-lived timber products). Otherwise, the many years of paying to sequester and protect the carbon in trees will simply be lost as they decay and/or burn uncontrollably.

Biomass has many advantages for an environmentally-friendly future. To obtain maximum benefit, trees, other than in primary forests, should be used as an energy source (or long-lived product) at the end of their growing life. It is probably preferable in most circumstances (except mature and primary forests) to use the biomass on a continuous basis as a substitute for present and future fossil fuel use (*Hall*, 1998).

The Kyoto Protocol carbon sequestration strategy poses serious problems and challenges as the total area required for forest plantations will be large. Currently our understanding of how to manage efficiently and sustainably such large areas of forest plantations is limited but there is some experience in, for example, Brazil with its large charcoal plantations (*Rosillo-Calle* et al., 1996). Obviously, regulations and voluntary guidelines will be necessary to ensure sustainability and other positive contributions of such forests and plantations (see next section).

The Kyoto Protocol offers good opportunities for joint implementation and clean development mechanism (CDM) projects which should involve biomass energy in both developed and developing countries to offset fossil fuels and to sequester carbon in biomass and soil sinks. It is important that people involved in the Kyoto Protocol recognize the significance opportunities for using biomass energy which also complements the Biodiversity and Desertification Convention, by providing opportunities for enhancing biodiversity and reforestation specially in degraded lands.

As the *IEA* (1998 b) so clearly stated: "Long-term and continuous reduction of CO_2 emissions through land-based activities will to a large extent have to come from the use of wood for bioenergy and products. The provision of the Kyoto Protocol with respect to sinks can be seen as a valuable incentive to protect and enhance carbon sinks now, while at the same time providing the resources needed for the substitution of fossil fuels in the future".

4. Ecological Concerns

Currently there are in the world about 100 million ha of plantations. During the past decade about 40 million ha have been planted in developing countries, two-thirds in community woodlots, farms and small holdings, to provide industrial wood, environmental protection and energy.

It is clear that management practices are a key factor in the sustainable biomass production and use of biomass. While we can provide considerable data on traditional forms of management practices, particularly in the pulp/paper and cellulose industry, but by comparison relatively little is still known with regard to large-scale energy forest plantations or even agricultural and forestry residues for energy use. Thus little experience now exists on large-scale energy plantations, except for *Eucalyptus* for charcoal production and ethanol from sugarcane in Brazil (which in any case tend to follow traditional agricultural and forestry practices), and also willows for heat power generation in Sweden where there are about 16,000 ha which has also borrowed considerably from traditional forestry and agricultural activities.

There is a growing concern with the potential negative effects of large scale dedicated energy crops/forestry plantations. A considerable amount of effort has gone to address these concerns in recent years and some knowledge has been gained (see *Tolbert*, 1998; *Lowe* and *Smith,* 1997). However, much needs still to be learned in the case of large-scale dedicated forestry energy plantations. Recent concerns has resulted in the development of good practice guidelines for the production and use of biomass for energy e. g. Austria, Sweden, UK and USA have published guidelines and work is under way to develop Europe-wide guidelines. These guidelines recognize the central importance of site-specific factors, and the breadth of social and environmental issues which should be taken into consideration. The guidelines concentrate mostly on short rotation coppice, and in some cases, e. g. the US guidelines, also consider perennial grasses and some residues. In general residues, biogas and liquid fuels have not been subject to such detailed recommendations but they have wide experience under various conditions. This bias reflects the anticipated environmental benefits of woody and perennial energy crops for solid fuels compared to the other biomass options discussed above. However, given that residues may remain more widely used than energy crops for quite some time, guidelines are urgently needed on when it is appropriate to use residues for energy, what fraction can be used, and how best to maximize the environmental advantages this may offer.

A key message of these guidelines is that site and energy crop selection must be made carefully, and the crop must be managed sensitively. Energy crops should not displace land uses of high agricultural and ecological value. Consideration needs to be given to the landscape and visibility, soil type, water use, vehicle access, nature conservation, pests and diseases, and public access (*ETSU*, 1996; *Hall* and *Scrase*, 1998). The guidelines also stress the importance of consulting local people at the early planning stage, and ongoing community involvement in the development stages. Issues such as changes to the landscape, increased traffic movements or new employment opportunities in rural areas may prove to be very significant to local people.

There is no single best way to use biomass for energy, and the environmental acceptability will depend on sensitive and well informed approaches to new developments in each location. It is clear that biomass for energy can be environmentally friendly, and steps must be taken to ensure that it is, if biomass is to be accepted as an important fuel of the future.

But it is equally true that biomass energy, particularly in its traditional forms, can cause (as is often the case in some rural areas) serious environmental and health impacts e.g. low energy efficiency, exposure to many pollutants such as respirable suspended particulates, carbon monoxide, organic compounds, etc. This is the result of complex socio-economic and cultural factors which will have to be addressed if such negative effects are to be ameliorated, as biomass energy is often the only fuel available to many rural communities of developing countries. Many of these impacts could be significantly reduced by introducing more efficient technologies, improved ventilation, improved stoves for cooking and heating, changes in cooking practices, use of better quality fuels (e.g. fuelwood rather than dung and straw), and better education on the health implications of such exposure (*Smith*, 1996, *Hall* and *Rosillo-Calle*, 1998b).

5. Socio-Economic Issues

The general socio-economic implications of biomass energy have been widely reported as well as cost factors in production and use of biomass energy (see *Hall* et al., 1996, *Hall* and *Scrase*, 1998). In this paper we will consider briefly the potential implications of subsidies on biomass energy and the need to internalize the costs to put bioenergy on a more equal footing with fossil fuels. This is particularly relevant if some kind of "forest plantation energy strategy" was to be adopted.

A main argument against using biomass energy is that, currently in most cases, it is cost uncompetitive with fossil fuels and would have to be unfairly subsidized. However, rather than cost it is the way in which our energy system works which acts as the major barrier to the large scale introduction of new sources of energy. For example, a recent report has shown that the USA federal monetary support for energy was more than $ 270 billion between 1950 and 1997 (in $ 1997). The report states that "the conventional wisdom that the oil industry has been the major beneficiary of the Federal financial largest is essentially correct" (*RFA*, 1998).

Bioethanol production in the USA has been much criticized by opponents because it is said to be heavily subsidized. However, a recent study has shown that when all factors are taken into account the industry produces considerable net savings- an estimated $ 3.9 billion from 1996–2002. The report states that "the partial excise tax exemption for ethanol blends is a non-inflationary incentive that creates jobs, stimulates tremendous economic activity, and reduces our trade imbalance" (*Evans*, 1997).

External costs. Although the methodology for quantifying external costs of energy is notoriously difficult and imprecise, it is a method which will need to be employed more frequently in the future if biomass energy (and other renewables) are to have a more equal footing when competing with conventional fossil fuels. By expressing all external costs in monetary terms one can attempt to compare total impacts for different fuel cycles. The approaches diverge in that for an external cost to be estimated one must be able to clearly identify a pathway to a final impact or damage, and be able to put a monetary value on it. This 'damage function approach' thus depends on dispersion modelling and the definition of dose-response relationships between causes and effects. Often these relationships are difficult to estimate and may be very site specific. Monetary valuation adds another hurdle, in that by their nature these damages do not have clear market prices. The commonest means of deciding on a value is through asking respondents their 'willingness-to-pay' to avoid incurring such a cost. In fact the only types of external costs which have proven readily amenable to this approach to valuation are the effects of air pollutants on human health.

A recently completed study (*Bio-Costs*, 1998) aimed at overcoming some of these problems by assessing 8 bioenergy systems in 6 EU countries using a common methodology, based on the ExternE approach (*ETSU*, 1995). A full fuel cycle approach was used to analyse external costs in the categories of human health, global warming, impacts on soil and water quality, biodiversity, and rural amenity value. In addition economic and upstream impacts were also assessed using the input-output model 'Emittenstruktur', which calculates pollutant emissions in upstream activities such as the manufacture of machinery.

The monetary valuation of external costs is beset with problems which currently limit its usefulness as a decision making tool. In many cases the physical emissions and likely impacts are well understood, as in the case of global warming, but monetary valuation is too speculative to be meaningful. In other instances too little is known about the actual impacts themselves, as in the case of the impacts of bioenergy on the landscape or biodiversity (both of which would be very difficult to monetise even given some understanding of the impacts). Thus the external costs calculated can only be a subset of the total external costs, and caution is needed to ensure that other issues are not considered unimportant simply because they cannot be expressed in money terms at present. External costs aim to measure people's preferences as *consumers* of a healthy environment, whereas many feel that decisions should be reached by a more democratic, consultative approach. Nonetheless, external costs should be fully incorporated into the energy system.

Life-cycle analysis (LCA) aims to assess impacts of technologies, etc., on the environment and human health on a 'cradle to grave' basis (*SETC*, 1993). LCA approaches have also been employed to estimate the full fuel cycle emissions of greenhouse gases from biomass and other electricity generating technologies. For example, in the USA the National Renewable Energy Laboratory has carried out an LCA study for biomass gasification-combined cycle power generation. Using dedicated wood energy crops the system demonstrated that it generates 16 units of energy for each unit of fossil energy consumed. In their worst case scenario the energy ratio fell only to 11:1 (*Mann* and *Spath*, 1997; see also *Kaltschmitt* et al., 1997).

6. Conclusion

Biomass is an important, environmentally friendly source of energy which can also provide sound energy alternatives to ameliorate global warming. It is potentially the world's largest source of energy and is should play a key role in the future energy mix. It must also be recognized that biomass is already a major source of energy both in its traditional and modern forms.

The Kyoto Protocol, if finally implemented, will have a significant impact in the way we use and produce energy; it represents an important step forward to a more environmentally sustainable energy future. However, it suffers from a number of shortcomings. For example, the Protocol does not seem to pay sufficient attention to the implications of the "carbon substitution strategy", as it appears to advocate mostly the planting of trees (afforestation & reforestation) to create C sinks. The difficulties with this strategy have been outlined in this paper. In our view using a biomass energy based "carbon sequestration and substitution strategy" merits greater attention since it will bring greater benefits than a "carbon sequestration strategy" e.g. income is generated continuously thereby creating local jobs and other benefits. It is important to strike a balance between these two strategies and that all pros and cons are fully assessed.

The large-scale use of forests (plantation or native forest), regardless of the strategy(s) adopted, requires considerable understanding of all the potential implications, which currently are lacking. Ecological concerns have already resulted in various useful "guidelines" but much more need to be done in this area.

Environmental and health hazards related to both traditional and modern biomass energy conversion need to be studied in more detail e.g. with minor improvements in cooking practices, better ventilation, centralised provision of electricity and heat, gasifiers, etc., could reduce significantly negative impacts.

The socio-economic implications of biomass energy have widely been reported. Two particular aspects are briefly discussed in this paper: i) the need to develop a methodology that assist in internalizing all the costs and benefits of energy, so that bioenergy is put on a more equal footing with fossil fuels, and ii) the need to pay greater attention to the implications of subsidies paid to conventional energy sources.

References

BioCosts , 1998. Total Costs and Benefits of Biomass in selected regions of the European Union: Final Report on Phase 1 of the EU-JOULE project JOR3-CT95-0006, EU, Brussels.

CBT (Centre for Biomass Technology), 1998. Straw for Energy Production, CBT, Horsens, Denmark.

DEA (Danish Energy Agency), 1996. Biomass for Energy – Danish Solutions, DEA, Copenhagen, Denmark.

Difiglio, C., 1997. Using Advanced Technologies to Reduce Motor Vehicle Greenhouse Gas Emissions, Energy Policy, 14–15: 1173–1178.

Dai Li., Li Jingming, and *R. Overend*, 1997. Biomass Energy Conversion Technologies in China: Development and Evaluation, China Environmental Science Press, Beijing, China.

ETSU (Energy Technology Support Unit), 1995 ExternE Externalities of Energy Volume 2 Methodology. European Commission DGXII, Luxembourg.

ETSU, 1996. Good Practices Guidelines: Short Rotation Coppice for Energy Production. Department of Trade and Industry. Seacourt Press, London.

Evans, M. K., 1997. The Economic Impacts of the Demand for Ethanol, Northwestern University, USA.

FAO, 1996. Forests, Fuels and the Future, Forestry Topics Report No. 5, FAO Forestry Department, Rome.

Hall, D. O., 1998. Biomass as an Energy Substitute for Fossil Fuels or Sink for Sequestering Carbon-Implications for the Kyoto Protocol. Environment (in press).

Hall, D. O., and *K. K. Rao*, 1994. Photosynthesis, 5th Edition, Cambridge University Press, Cambridge.

Hall, D. O., and *F. Rosillo-Calle*, 1998a. Biomass Resources Other than Wood, World Energy Council, London, pp. 227–241.

Hall, D. O., and *F. Rosillo-Calle*, 1998b. Evaluating Environmental Effects and Carbon Sources and Carbon Sinks Resulting from Biomass Production and Use in Developing Countries. Proceedings: Biomass Energy: Data, Analysis and Trends, OECD/IEA, pp.294–314, IEA, Paris.

Hall, D. O., and *J. I. Scrase*, 1998. Will biomass be the environmentally friendly fuel of the future. Biomass and Bioenergy 12: 357–367.

Hall, D. O, F. Rosillo-Calle, and *J. I. Scrase*, 1996. Biomass: An Environmentally Acceptable and Sustainable Energy Source for the Future. Report prepared for the Division of Sustainable Development, UN Committee on Sustainable Development, New York.

IEA (International Energy Agency), 1998a. Biomass Energy projections: Approach and Results, IEA, Paris.

IEA 1998b. A Position Paper Prepared by IEA Bioenergy Task Force 25 Greenhouse Gases Balances of Bioenergy, IEA, Paris.

Kaltschmitt M., Reinhardt G. A. and *Stelzer T.*, 1997. Life cycle analysis of biofuels under different environmental aspects. Biomass and Bioenergy 12, 121–134.

Kolbeck, P., 1998. Installation of a Biomass-fuelled Boiler at an existing Coal-fired Plant, CADDET 2:16–18, EU, Brussels.

Lowe, A. T and *T. C. Smith*, 1997. Environmental Guidelines for Developing Sustainable Energy Output from Biomass, Biomass & Bioenergy , 13: 187–328.

Mann, M. K. and *P. L. Spath*, 1997. Life Cycle Assessment of a biomass gasification combined-cycle power system. US National Renewable Energy Laboratory report NREL/TP-430-23076, December 1997, NREL, Golden, CO 80401.

Moreira, J. R. and *J. Goldemberg*, 1997. The Alcohol Program. Report for the Ministry of Science and Technology (MCT), Brasilia, Brazil.

OECD/IEA, 1998. Status of Research on Project Baselines under the UNFCC and the Kyoto Protocol, OECD/IEA, Paris.

Pearce, F., 1998. Growing Pains, New Scientist 2157: 20–21.

RFA (Renewable Fuels Association) (1998). Washington DC.

Rosillo-Calle, F., M. E. Rezende, P. Furtado, and *D. O. Hall*, 1996. The Charcoal Dilemma. Finding a Sustainable Solution for Brazilian Industry, IT Publications, London.

Schwaiger, H. and *B. Schlamadinger*, 1998. The Potential of Fuelwood to Reduce Greenhouse Gas Emissions in Europe. Biomass & Bioenergy, 12: 369–377.

SETC (Society of Environmental Technology and Chemistry), 1993. Guidelines for Life-Cycle Assessment: A 'Code of Practice', SETC, Brussels.

Smith, K. P., 1996. Indoor Air Pollution in India, Natl. Med. J. India, 9 (3): 103–4.

Tolbert, V., ed., 1998. Environmental Effects of Biomass Crop Production. What Do We Know? What Do We Need to Know? Biomass & Bioenergy 1: 301–414.

UNFCCC, 1998. Kyoto Protocol to the United Nations Framework Convention on Climate Change, UNFCCC, Bonn, Germany.

World Bank, 1996. Rural Energy and Development-Improving Energy Supplies for 2 Billion People, World Bank, Washington DC.

Authors' address

Prof. David O. Hall
Frank Rosillo-Calle
Kings College London
Division of Life Sciences
Campden Hill Road
London W8 7AH, UK.
e-mail: david.hall@kcl.ac.uk;
frank.rosillo-calle@kcl.ac.uk

Holzvergasung als Teil globaler CO_2-Minderungsstrategie und regionaler Wirtschaftskreisläufe

Peter Haschke und Eberhard Oettel

1. Einführung

Wälder binden CO_2, und Holz, als Bau- und Werkstoff verwendet, hält über Jahrzehnte das CO_2 gebunden. Entsprechend dem Motto der Agenda 21 „Global denken – regional handeln" geht es aber auch darum, das Holz als ständig nachwachsenden und weitgehend CO_2-neutralen Energieträger durch konkrete Maßnahmen in verstärktem Umfang und mit höherem Wirkungsgrad einzusetzen.

Die gegenwärtigen Bedingungen für die energetische Nutzung von Holz in Europa sind durch 3 entscheidende Faktorengruppen gekennzeichnet:

1. Es sind große Energieholzpotentiale, insbesondere im Wald, aber auch in der holzbe- und -verarbeitenden Industrie und als Alt- und Recyclingholz vorhanden.
2. Die technische Entwicklung hat in den einzelnen Richtungen der Energiewandlung von Holz ein unterschiedliches Niveau erreicht. Die Verbrennung zur Wärmeerzeugung ist sehr weit ausgereift und wird kommerziell angewandt.
   An der Holzvergasung für eine motorische Nutzung wird international intensiv geforscht und entwickelt. Ausgereifte Systeme sind noch nicht vorhanden, aber in naher Zukunft zu erwarten. Bei anderen, energetisch interessanten Richtungen, wie z.B. bei Synthesegas oder der Nutzung in Brennstoffzellen, ist technisch wie ökonomisch in naher Zukunft noch keine Lösung abzusehen.
3. Bioenergie ist im allgemeinen gegenüber den billigen fossilen Energieträgern noch nicht konkurrenzfähig. Der Teil Wärmegewinnung aus Holz ist jedoch am weitesten an die Schwelle der Wirtschaftlichkeit herangekommen.

2. Forstliche Energieholzpotentiale in Deutschland

Die Bundesforschungsanstalt für Forst- und Holzwirtschaft hat 1996 das mittelfristige Rohholzaufkommen der BRD bis zum Jahr 2020 erarbeitet. [12, 13]

Unter Beachtung verschiedener, sich aus der Praxis ergebender Restriktionen sowie einer ständigen Vorratsanreicherung wurde für die übliche stoffliche Nutzung des Holzes als Stamm- und Industrieholz ein potentielles Aufkommen von 57 Mio m^3 ermittelt. Aber nur 40 Mio m^3 davon sind im Vergleich mit dem tatsächlichen Holzeinschlag der letzten 10–15 Jahre wirtschaftlich realisierbar. Unter Verwendung dieser Differenz und der nicht in der Nutzholzprognose enthaltenen Teile, wie schwaches Durchforstungsholz, Kronen, Äste und anderer Einschlagsreste sowie Rinde, wurde an der Fachhochschule Eberswalde ein nachhaltiges Energieholzpotential von jährlich 34 Mio m^3 ermittelt. [5] Dieser Wert ist insofern erstaunlich und stößt zunächst auf Skepsis, als in zahlreichen Veröffentlichungen der Jahre 1992–95 für Waldenergieholzpotential 10–16 Mio m^3 angegeben werden, die sich aber immer nur auf das sogenannte „Waldrestholz" beziehen.

Die 34 Mio m^3 Energieholz – zusätzlich zum Nutzholz eingeschlagen – würden 46 % des Gesamteinschlages ausmachen. Ein Blick in die Geschichte zeigt uns, daß beispielsweise Anfang des 19. Jahrhunderts der Brennholzanteil im sächsischen Staatswald 83 % und im preußischen 74 % am Gesamtholzeinschlag betrug. [6] Der Brennholzanteil am Weltholzeinschlag beträgt gegenwärtig immer noch 53 %. [1]

Obwohl die genannten 34 Mio m^3 Energieholz nur einem Energieäquivalent von rund 2 % des deutschen Endenergieverbrauches entsprechen, wären die sozio-ökonomischen und regionalwirtschaftlichen Auswirkungen bei ihrer Nutzung beachtlich. Es würden für die Energieholzgewinnung etwa 16000 bis 20000 Arbeitsplätze entstehen, und es könnte bei vorsichtiger Kalkulation eine territoriale Wertschöpfung von 1,5–2 Mrd. DM, wahrscheinlich aber mehr erreicht werden. Zusätzliche Arbeitsplätze und wirtschaftliche Effekte ergäben sich aus Bau und Betrieb der Energiewandlungsanlagen. Der Brennstoffimport würde verringert.

3. Elektroenergie aus Holz energetisch und wirtschaftlich vorteilhaft

Zu den Voraussetzungen für eine vermehrte Nutzung der Energieholzpotentiale gehört u.a., die Palette der Anwendungsmöglichkeiten zu erweitern und deren Wirtschaftlichkeit zu verbessern. Ein Weg dazu besteht insbesondere neben der ausschließlichen Wärmegewinnung in der Produktion von elektrischem Strom. Unter Beachtung der Marktnischen im Energiesektor und der möglichen Kosten-Erlös-Verhältnisse erscheint hierbei auf absehbare Zeit nur die dezentrale Kraft-Wärme-Kopplung (KWK) mit einem möglichst hohen Anteil verkaufter Wärmeenergie interessant.

Auf dem Weg über den klassischen Dampfprozeß (Feuerung-Kessel-Dampfturbine) werden dabei in Abhängigkeit von der Anlagengröße und den benötigten Parametern des Entnahmedampfes nur 15–20 % der eingesetzten Brennstoffwärme in Elektroenergie umgewandelt. [14] Aus investitionsökonomischen Gründen müssen diese Dampfkraftanlagen eine thermische Mindestleistung zwischen 5 und 10 MWth aufweisen. Dabei ist es wiederum schwierig, für die erheblichen Wärmemengen geeignete Absatzbedingungen zu schaffen. Außerdem besteht für manche große Unternehmen nur ein geringer Anreiz zur Eigenstromerzeugung, da sie als Großabnehmer besonders günstige Tarife von den EVU erhalten.

Auf dem Weg über die Holzvergasung und Verbrennungskraftmaschinen hingegen können ein höherer Anteil Elektroenergie und höhere Gesamtwirkungsgrade erreicht werden. Es werden gegenüber den Dampfkraftanlagen kleinere Leistungseinheiten wirtschaftlich realisierbar, was auch logistische Vorteile bringt. Daneben ist auch eine Prozeßgasnutzung möglich. Deshalb interessieren sich z.B. in Deutschland klein- und mittelständische Unternehmen besonders im Bereich der Holzbe- und -verarbeitung, der Umwelt- und Recyclingtechnik u.a. stark für diese Entwicklungen, die gleichermaßen für die Einbindung in existierende Strom- und Wärmenetze sowie für eine dezentrale Energieversorgung (Inselbetrieb) geeignet sind.

Es wird der Fall betrachtet, daß ein Anteil von 10 Mio m^3 Energieholz in zahlreichen Holzgas-Heizkraftwerken zum Einsatz kommt. Bei einem mittleren Heizwert von 2,3 MWh/m^3 (entsprechend einer Gesamtbrennstoffenergie von 23 TWh) und mittleren Wirkungsgraden von $\eta_{el} = 0{,}25$ und $\eta_{ges} = 0{,}7$ [10] können mit dieser Brennstoffmenge insgesamt 5,75 TWh elektrischer Strom und 10,35 TWh Heizwärme erzeugt werden. Kohlekraftwerke mit einem Gesamtwirkungsgrad von $\eta_{ges} = 0{,}38$ [9] würden für diese Menge Elektroenergie 14 TWh Brennstoffenergie und Nahwärmeheizungen für die Erzeugung von Raumwärme (η = 0,9) 11,5 TWh Brennstoffenergie benötigen, zusammen 25,5 TWh. Über die dezentrale Kraftwärmekopplung auf Basis Holzvergasung kann also auf Grund höherer Wirkungsgrade ein größerer Anteil fossiler Brennstoffe eingespart werden, als nur durch Verbrennung.

4. Vergasungsverfahren

Die Vergasung ist die chemische Umsetzung eines Brennstoffes mit Hilfe eines Vergasungsmittels (Sauerstoff, Luft, Wasserdampf oder Mischungen daraus) in einem Temperaturbereich zwischen 700 °C und 1800 °C mit dem Ziel der möglichst vollständigen und verlustarmen Überführung der organischen Substanz des Brennstoffes in ein Gemisch brennbarer Einzelgase. [8] Die Holzvergasung wird bei Temperaturen bis etwa 900 °C durchgeführt. [10]

Im Unterschied dazu wird bei der Pyrolyse in meist von außen beheizten Reaktoren bei 300 °C bis 600 °C die organische Substanz mit einem anderen Ziel gespalten. Es entstehen dabei organische Dämpfe, die zu Pyrolyseölen kondensiert werden (als flüssiger Treibstoff oder Chemierohstoff verwendbar), sowie Holzkohle und brennbare Gase. Durch die Prozeßführung (Temperatur, Dauer) kann der Anteil der genannten Produkte verändert werden. [14] Die für die thermische Zersetzung des Holzes notwendige Wärmeenergie wird durch die Verbrennung eines Teils des Vergasungsstoffes, d.h. des Holzes gewonnen.

Mit der Vergasung kann ein Umwandlungswirkungsgrad von Holz zu Produktgas (Kaltgaswirkungsgrad) von 70–85 % erreicht werden. [10] Die Wirkungsgrade der Stromerzeugung mit Holzgas betragen bei Kleinanlagen mit Verbrennungsmotor 12–25 % und bei Kraftwerken mit GuD 30–45 %. [10] Letztere erfordern aber wiederum große Leistungseinheiten mit hohen Investitionen, die eine Wirtschaftlichkeit fraglich erscheinen lassen. Mit Brennstoffzellen könnten theoretisch 50–60 % erreicht werden; bis dahin ist jedoch noch ein langer Entwicklungsweg nötig.

Nach den Verfahrensgrundsätzen werden Festbettvergaser und Wirbelschichtvergaser unterschieden. Festbettvergaser werden allgemein von oben mit kleinstückigen, schüttförmigem Holzbrennstoff beschickt. Durchströmt die Vergasungsluft die Reaktionszonen von unten nach oben, so handelt es sich um einen *aufsteigenden Gegenstromvergaser* (Abb. 1). Da die Schwelgase keine heiße Zone mehr passieren, ist das Gas sehr teerhaltig.

Strömen die Gase nach unten durch die Oxidations- oder Feuerzone, so liegt ein *absteigender Gleichstromvergaser* vor (Tab. 1). Gleichstromvergaser liefern ein teerarmes Gas, da die entstehenden hochsiedenden Kohlenwasserstoffe in der heißen Feuerzone gecrackt werden. Der Grad der Spaltung dieser Teerbestandteile hängt davon ab, inwieweit es verfahrenstechnologisch gelingt, über

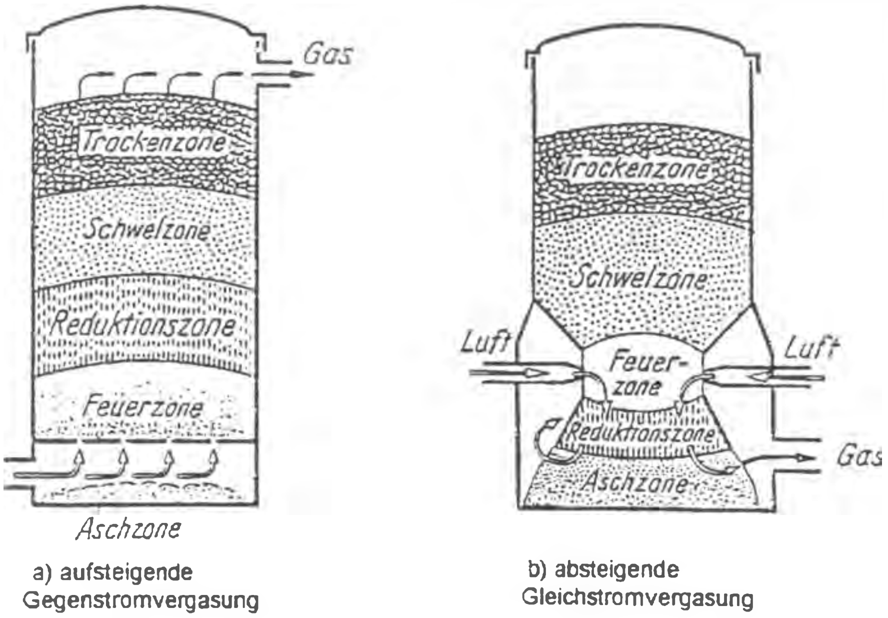


Abb.1: Festbettvergaser (Nach Klose, E., TU Bergakademie Freiberg [8]).

den gesamten Vergaserquerschnitt ein gleichmäßiges Glutbett mit hoher Temperatur zu erhalten. Dazu sind verschiedene Vergasermodifikationen und Zusatzeinrichtungen entwickelt worden.

Neben diesen einstufigen Vergasern werden auch mehrstufige entwickelt und erprobt, wobei die einzelnen Phasen des Prozesses wie Pyrolyse, Oxidation, Reduktion in getrennten Reaktionskammern besser gesteuert werden können. Jedoch sind derartige Systeme aufwendiger und mit wesentlich höheren Investitionen verbunden.

Insgesamt existieren in Europa über 100 Holzvergaser unterschiedlicher Modifikation im Leistungsbereich bis 5 MWprim und in unterschiedlichen Entwicklungsstadien. [11] Forschung und Entwicklung an diesen Vergasersystemen werden gegenwärtig vor allem in Deutschland und in Großbritannien durchgeführt. [3]

Bei Wirbelschichtvergasern werden feine Brennstoffpartikel durch von unten einströmende Luft in der Schwebe gehalten und vergasen dabei (stationäre Wirbelschicht). Mit höherer Gasgeschwindigkeit läßt sich der gesamte Reaktor mit einer homogenen Wirbelschicht bei optimaler Temperatur ausfüllen. Die dann in hohem Maße vom Gas mitgerissenen unvergasten Partikel werden in einem Zyklon abgeschieden und dem Reaktor wieder zugeführt (zirkulierende Wirbelschicht, ZWS).

Eine Erhöhung des Gasheizwertes und der Verfahrenseffektivität wird bei großen Anlagen durch Wasserdampf- und Sauerstoffzusatz und durch eine Vergasung unter Druck erreicht.

Mit ZWS-Vergasern werden hohe Vergasungswirkungsgrade (>80 % Kaltgaswirkungsgrad), ein stabiler Anlagenbetrieb und guter Ausbrand erreicht. Da das Gas aber einen sehr hohen Partikelgehalt und hohen Teeranteil aufweist, ist es zwar für den Brennerbetrieb, aber bisher nicht für eine motorische Verwendung geeignet.

Wirbelschichtvergaser können in großen Leistungseinheiten bis zu 100 MW_{th} gebaut werden. Wegen der hohen spezifischen Investkosten sind voraussichtlich Mindestgrößen von 20 bis 30 MWth erforderlich. Diese Entwicklung wird besonders in den nordischen Ländern vorangetrieben. Große Vergaser gewinnen auch für die Entsorgung von Rest- und Abfallstoffen Bedeutung, da belastetes Material im System der Vergasung leichter zu beherrschen ist als bei der reinen Verbrennung und durch die Entsorgungsgebühren die Wirtschaftlichkeit am ehesten zu erreichen ist.

5. Holzvergasung in der Energiewandlungskette

Wie dargestellt, liegt ein besonderes Interesse an der Holzvergasung in den Möglichkeiten der Verstromung. Deshalb müssen alle Elemente eines solchen Systems und ihr Zusammenhang betrachtet werden. Neben der sonstigen technischen Peripherie sind nach dem Vergasungsreaktor besonders Gasreinigung und Gasmotor oder -turbine entscheidend.

Da Verbrennungskolbenmotoren besonders gegen Teer und Staub im Gas und Gasturbinen gegen Staub und Alkalien empfindlich sind, ist auch bei dem relativ teer- und staubarmen Gas von Gleichstromvergasern noch eine

Tab. 1: Merkmale von Festbettvergasern (In Anlehnung an [10, 15]).

	Gegenstromvergaser	Gleichstromvergaser
Betriebsverhalten	stabil	störanfälliger gegen Brückenbildung und Durchbrände
Brennstoff	breite Palette hinsichtl. Stückigkeit u. Feuchte (u<50%)	gleichmäßig, kleinstückig geringe Feuchte (u=5...15%)
Teergehalt im Gas	hoch (>20g/Nm^3)	gering, bis herab zu 0,1 g/m^3
Verwendung des Gases	für thermische Zwecke	nach Reinigung für motorische Nutzung
Anlagenleistungen	100 kW...10 MW	50 kW...2MW
Kaltgaswirkungsgrad	~50% ohne Teer ~90% incl. Teer	70...80%

Gasreinigung notwendig. Da seitens der Motorenhersteller uneinheitliche und teilweise nicht überzeugende Anforderungen vorgelegt werden, zeigt Tabelle 2 bisherige Schätzwerte.

Die Entstaubung des heißen Gases direkt nach der Vergasung ist sehr effektiv, wofür Zyklone und in einer zweiten Stufe Keramikfilter eingesetzt werden. [14] Oberhalb 450 °C–550 °C kommt es noch nicht zur Kondensation der Teerbestandteile. Auch eine Kaltgasentstaubung mit Gewebefiltern ist möglich, wenn zuvor die Teerabscheidung erfolgt ist. Als geeignetste Technik dafür gilt gegenwärtig die Naßwäsche des Rohgases. [14] Die Gaskühlung ist gleichzeitig eine Voraussetzung für einen Mindestfüllungsgrad der Zylinder im Motor.

Die Gasreinigungsverfahren sind sehr energie- und materialaufwendig oder noch nicht wirksam genug und verursachen umweltrelevante Entsorgungsprobleme, so daß noch umfangreiche Forschungen und Entwicklungsarbeiten auch an diesem Teil des Systems notwendig sind. Darüber hinaus bestehen im Komplex Vergasung – Gasreinigung insbesondere infolge des Teergehaltes noch erhebliche gerätebedingte Probleme in der kontinuierlichen Messung des Gases und seiner Parameter.

Als Verbrennungskraftmaschinen zur weiteren energetischen Wandlung des Holzgases werden Kolbenmotoren eingesetzt. Gasturbinen sind nur bei sehr großen Leistungen in Verbindung mit dem Dampfprozeß (GuD) sinnvoll. Die Maschinen wurden bisher in keinem Fall speziell für Holzgas entwickelt. Holzgas ist mit einem Heizwert (Hu) zwischen rund 4,5 und 5,5 MJ/Nm³ [10] ein Schwachgas und hat einen etwa 6fach geringeren Heizwert als Erdgas. Vielmehr werden Serienmaschinen aus anderen Anwendungsbereichen angepaßt. Aus dem geringen Heizwert, anderen Gas-Luft-Verhältnissen, unterschiedlichen Verdichtungen und Massenströmen und aus anderen Faktoren, die teils gegenläufig wirken, ergibt sich eine Leistungsminderung gegenüber dem Einsatz mit dem ursprünglichen Treibstoff, die von den Experten zwischen 5 % und 70 % angegeben wird. Da Holzgas eine hohe Klopffestigkeit von über 100 aufweist, werden Ottomotoren mit hoher Verdichtung von 1:11 und mehr als besonders geeignet angesehen. Auch umgebaute Erdgas-Ottomotoren und Dieselmotoren werden eingesetzt.

Eine Leistungserhöhung kann durch Aufladung des Motors erreicht werden, jedoch wird infolge des noch vorhandenen Staubgehaltes im Gas eine starke Abnutzung des Turboladers befürchtet. Aber auch über das Verschleißverhalten der Motoren unter dem Staubeinfluß ist bisher wenig bekannt. Der Teergehalt des Gases wirkt sich vor allem durch Teerabscheidungen in den Zuleitungen aus. Einmal in den Zylinder gelangt, stört er nicht mehr. [2]

Eine andere Eigenschaft des Holzgases ist seine niedrige Zündgeschwindigkeit, weshalb langsamlaufende Motoren mit großem Hub empfohlen werden. Gegenwärtig werden Serienmotoren bis etwa 1 MW angepaßt. Zukünftig wird mit Leistungen von Holzgas-Ottomotoren bis 5 MW gerechnet, mit denen elektrische Wirkungsgrade bis 30 % und Gesamtwirkungsgrade von 60–80 % erreicht werden können.

Gegenwärtig ist also auch auf dem Sektor Motoren für den Holzgaseinsatz ein ständiger Erkenntnisgewinn festzustellen. Aber das zuverlässige Zusammenwirken aller Elemente des Systems Vergasung-Gasreinigung-Motor im Dauerbetrieb wird noch nicht voll beherrscht.

6. Wirtschaftlichkeitsfragen

Eine allgemeingültige Kosten-Erlös-Rechnung für Holzvergasersysteme und die verschiedenen Formen der Nutzung des Gases kann bisher aus folgenden Gründen nicht vorgenommen werden:

- Die bisherigen Anlagen sind Unikate und kaum im kommerziellen Dauerbetrieb gelaufen, so daß keine verwertbaren ökonomischen Kennwerte vorliegen.
- Die Systeme und ihre Elemente befinden sich zum größten Teil noch in der technischen Entwicklung oder müssen völlig neu geschaffen werden.
- Die Holzbrennstoffpreise hängen stark davon ab, aus welcher Branche sie kommen und wie umfangreich ihr Absatz ist und wie damit ihre mehr oder weniger rationelle Produktion eingeschätzt wird.
- Die entscheidenden Vergleichspreise für fossile Energieträger und die erzielbaren Erlöse für Strom und Wärme von den Holzgas-KWK-Anlagen weichen in den Ländern erheblich voneinander ab, ebenso wie die Energiebesteuerung, z. B. die CO_2-Steuer.

Dennoch lassen sich einige allgemeine Wirtschaftlichkeitsaspekte nennen:

Die Strom- und Wärmegewinnung über die Holzvergasung ist ähnlich wie die ausschließliche Wärmegewinnung aus Biomassen im allgemeinen noch nicht konkurrenzfähig. Insbesondere die voraussichtliche Investition für ein Holzgas-HKW (Gesamtsystem) liegt mit 5000 bis 10 000 DM/kW$_{el}$ sehr hoch. Ein Erdgas-BHKW erfordert dagegen nur etwa 3000 DM/kW$_{el}$. [4] Besonders bei Kleinanlagen sind die Investitionskosten entscheidend. [10] Außerdem sind die für ein Erdgas-BHKW notwendigen Betriebsbedingungen ohnehin schwer erreichbar, nämlich der wärmegeführte Betrieb und die notwendigen >4000 Vollaststunden. [4] Dazu kommt für längere Zeit ein höherer Wartungsaufwand.

Beim Zusammentreffen einiger günstiger Voraussetzungen kann auch heute schon die einfache Wärmegewin-

Tab. 2: Erforderliche Gasreinheit [10, 15].

Anwendung	maximale Gehalte an Partikeln mg/Nm³	Teer mg/Nm³	Alkalien mg/Nm³
Verbrennungsmotor	50 (möglichst 5)	100 (möglichst 50)	
Gasturbine	30		0,24
bisher in verschiedenen Gleichstromvergasern erreichte Werte von-bis	20-8000	10-6000	
Mittelwert	~500	~500	

nung aus Holz für ein Gewerbe oder Gewerbegebiet oder für ein kommunales Nahwärmesystem gegenüber Erdgas oder Öl vorteilhaft sein. Das sind eine hohe zeitliche Auslastung, ausreichend große Leistung der Anlage, hohe Anschlußdichte, Fördermittel, ein geringer Holzpreis.

Diese Bedingungen gelten als vorteilhaft auch für HKW auf Basis der Holzvergasung. Dazu kommen aber noch weitere begünstigende Umstände, die einzeln oder gemeinsam wirken:

- ein geringes Temperaturniveau der benötigten Wärme,
- die Vermeidung von Fremdstrombezug, da eingesparter Strombezug mehr bringt als Einspeisevergütung,
- die Vermeidung eines aufwendigen Elektroanschlußnetzes durch einen Inselbetrieb.

Niedrige Brennstoffkosten sind besonders für die Wirtschaftlichkeit von Großanlagen von Bedeutung [10], so daß hierbei vorwiegend Rest- und Abfallholz zum Einsatz kommen wird. Die betriebswirtschaftliche Tragfähigkeit von Biomasse-Vergasungssystemen wird unter dem gegenwärtigen Energiepreissystem nur außerordentlich schwer erreichbar sein. Sie setzt in jedem Fall eine finanzielle Förderung für die Anfangsinvestitionen voraus. Wenn sie einmal wirksam wird, dann zuerst bei der Altholzentsorgung mit negativen Holzpreisen, sofern nicht halogenorganische oder schwermetallhaltige Kontaminationen enthalten sind, die extrem hohe technische Vorkehrungen gegen Emissionen erfordern.

Neben den umfangreichen weiteren technischen Entwicklungsarbeiten bei der Vergasung, der Gasreinigung und auf dem Sektor der Verbrennungskraftmaschinen sind auch technische und organisatorische Maßnahmen zur Verbilligung der Produktion der Holzbrennstoffe bei ihrer gleichzeitigen Standardisierung erforderlich. Den größten kostensenkenden Einfluß hat darüber hinaus eine massenhafte Produktion des Brennstoffes.

Eine recht tiefgründige Betrachtung der Wirtschaftlichkeit von Energie aus Holz für Schweizer Verhältnisse und ihre allgemeingültige dimensionslose Darstellung mit Relativzahlen haben *Nußbaumer* et al. 1997 vorgenommen. [10]

7. Einige aktuelle Entwicklungsarbeiten

Da eine breite kommerzielle Anwendung von technisch zuverlässigen und ökonomisch tragfähigen Vergasersystemen bisher nicht erreicht wurde, hat die Generaldirektion 12 der Europäischen Kommission ein Förderprojekt zur Entwicklung eines Festbettvergasers kleiner Leistung bis 2 MW_{prim} für einen Standardbrennstoff ausgeschrieben, an dem 10 Partner aus 5 europäischen Ländern mitarbeiten (Laufzeit 1996–1999).

Im Rahmen dieses Projektes wurden bisher u. a. erarbeitet:

- Investitionsentscheidungsmodelle
- eine Methodik zur Durchführung von vergleichbaren Langzeittestes mit Vergasern
- eine Richtlinie zur Probennahme und zur Gasanalyse
- eine Gasreinigungsstudie,

Die Fördergesellschaft Erneuerbarer Energien (FEE), Sitz Berlin, ist einer dieser Partner. Von ihr und ihren unmittelbaren Partnern wurden ferner dazu beigesteuert

- ein Katalog über 106 europäische Holzvergaser kleiner Leistung bis 5 MW [11]
- der Katalog „Forschungs- und Entwicklungsbedarf und -themen zur Vergasung nachwachsender Rohstoffe“
- eine Studie, Untersuchungen zum Holzgasbetrieb von Otto-Gasmotoren im Leistungsbereich 100–2000 kW
- ein präzisiertes Verfahren zur Berechnung des Kaltgaswirkungsgrades von Holzvergasern.

Es wurden erstmalig in diesem Projekt nach einheitlicher Methodik an 4 europäischen Festbettvergasern Tests über 150 Std. ununterbrochenem Betrieb durchgeführt, die einheitlich dokumentiert wurden. Drei davon erwiesen sich als geeignet für die Vergasung von standardisiertem Holzbrennstoff und für eine weitere Entwicklung:

DTU-Vergaser (Dänische Technische Universität) als Zweistufen-Vergaser,

VER-Querstromvergaser (Deutschland), Zuverlässigkeit und Kaltgaswirkungsgrad relativ hoch, aber noch hoher Teer- und Staubgehalt im Gas,

KARA-Vergaser (Niederlande) als komplettes System einschließlich Gasreinigung und Gasmotor.

Die Testberichte sind öffentlich zugänglich.

Zu den allgemeinen Erwartungen, die heute an Biomassevergaser gestellt werden, gehört u. a. die Forderung, daß das System an unterschiedliche Brennstoffzusammensetzung und Brennstoffstückigkeit anpassungsfähig sein muß. Da verschiedene der Probleme beim Betrieb der Vergaser mit der Heterogenität der üblichen Brennstoffe zusammenhängen, ist diese Forderung möglicherweise kontraproduktiv, vor allem bei Anlagen kleinerer und mittlerer Leistung. Deshalb ist auch der andere, im EU-Projekt beschnittene Weg, Vergaser für speziell definierte, sogenannte standardisierte Brennstoffe zu entwickeln weiter zu verfolgen. Gleichzeitig damit muß jedoch mehr Aufmerksamkeit auf die Entwicklung von rationellen Verfahren zur Produktion definierter Vergaserholzbrennstoffe gelegt werden.

In welchem Maß damit eine Verteuerung der Brennstoffe – auch bei ihrer Massenproduktion – eintritt, ist noch nicht klar. Da ähnliche Fragen im Zusammenhang mit der Brennstofflogistik für Holzfeuerungsanlagen im unteren Leistungsbereich auftreten, wird gegenwärtig an der Fachhochschule Eberswalde ein Forschungsprojekt bearbeitet mit dem Thema „Entwicklung eines Brennstoffsortiments zur Erweiterung der Einsatzfelder von Energieholz“.

Mitglieder und Partner der Fördergesellschaft Erneuerbare Energien e. V. haben folgende Innovationen zu Teilproblemen der Biomassevergasung erarbeitet:

- Akustischer Sensor zur Feuchtemessung in Abgasen,
- eine Substanz, die es Mikroorganismen ermöglicht, höhere Kohlenwasserstoffe in Flüssigkeiten abzubauen,
- kontinuierlich arbeitendes on-line-Meßgerät für Staub in Heißgasen,
- System zur Optimierung der Gasanalyse und des Verbrennungs-/Vergasungsprozesses, Brikettierung von Halmgutmaterial ohne Bindemittel.

Es laufen Bemühungen, im Osten Deutschlands ein Internationales Biovergaserzentrum zu errichten mit den Komponenten Forschung und Entwicklung, Erprobung und Zulassung, Entsorgung, Demonstration und Ausbildung sowie Wasserstoff-, Brennstoffzellen- und Methanolforschung.

Seit 1994 existiert die Arbeitsgruppe „Vergasung nachwachsender Rohstoffe“ der Fördergesellschaft Erneuerbare Energien, in die sich 61 Unternehmen, 11 wissenschaftliche Einrichtungen, 4 behördliche Institutionen und 2 Vereine integriert haben. Sie kommt 3–4 mal jährlich zu aktuellen Problemen auf dem Fachgebiet zusammen und hat sich zu einer wirkungsvollen Begegnungsstätte für Experten und Unternehmen entwickelt.

9. Zusammenfassung und Handlungsempfehlungen

■ In zahlreichen Ländern sind große Energiepotentiale vorhanden, deren Nutzung einen Beitrag zur Minderung der CO_2-Emission und zur regionalen Wirtschaft darstellt.
■ Dazu sind vielfältige Verfahren der Energiewandlung nötig.
■ Die Holzvergasung erfordert gegenüber der technisch ausgereiften Holzverbrennung noch umfangreiche Entwicklungsarbeiten, ermöglicht aber über den Einsatz von Verbrennungskraftmaschinen eine Stromerzeugung mit höherem Wirkungsgrad, als er mit der Holzverbrennung und Dampfkraftmaschinen möglich ist.
■ Ständig erreichte Fortschritte in technischen Details lassen eine Marktfähigkeit der Systeme in naher Zukunft erwarten
■ Es wird keinen Universalvergaser für alle Brennstoffe, Leistungsklassen und Zielgruppen geben
■ Das größte Marktpotential besteht bei Festbettvergasersystemen kleiner und mittlerer Leistung.
■ Es sind Varianten von Vergasersystemen mit unterschiedlichen Anforderungen der Länder hinsichtlich Automatisierung der Beschickung, notwendigem Wirkungsgrad u. a. möglich, wodurch unterschiedliche Investitionshöhen erreicht werden können.
■ Die Holzvergasung beinhaltet auch auf längere Sicht ein Innovationspotential (z. B. Methanol, Wasserstoff, Brennstoffzelle, Kohlenstoffprodukte).

Aus der Sicht der Verfasser lassen sich folgende **Handlungsempfehlungen** ableiten:
■ Infolge zahlreicher technischer Probleme ist noch eine intensive Forschungs- und Entwicklungsförderung notwendig.
■ Parallel dazu müssen Demonstrationsanlagen errichtet werden, die entsprechend den erreichten Fortschritten weiterentwickelt, d. h. auf den jeweils aktuellen Stand gebracht werden.
■ Neben der technischen Entwicklung der Vergaser-, Gasreinigungs- und Motorentechnik muß gleichzeitig an der Standardisierung und Verbilligung des Brennstoffes gearbeitet werden.
■ Die Forstwirtschaft der verschiedenen Besitzformen einiger Länder muß ihre waldbaulichen, nutzungstechnischen und betriebswirtschaftlichen Handlungsstrategien gezielt auf die Nutzung der umfangreichen forstlichen Energieholzpotentiale einstellen und eine aktivere Marktpolitik auf diesem Sektor betreiben.
■ Die Energie- und Preispolitik der Staaten muß konsequent auf eine weitgehende Ausnutzung der erneuerbaren Energiequellen ausgerichtet werden.

Quellenverzeichnis

[1] *Autorenkollektiv* „Energie aus Biomasse – Stand und Möglichkeiten der energetischen Nutzung von Biomasse im Land Brandenburg". Hrsg.: Arbeitsgruppe Bioenergie Brandenburg, Ministerium für Ernährung, Landwirtschaft und Forsten des Landes Brandenburg, 1997, 137 S.

[2] *Bludszuweit, S.*, „Eignung von Verbrennungskraftmaschinen für einen geschlossenen CO_2-Zyklus", Vortrag zum ATES-Seminar zum Thema Energieträger Holz am 26. 11. 1996 in Fürstenwalde

[3] *BTG*, „State of small-scale biomass gasification technology", Novem, Netherlands agency for energy and the environment, EWAB-report No. 9622, 1996, 31 S.

[4] *Dieckmann, R.*, „Energetische Nutzung von Holz, Einsatz von Vergasungsanlagen", VDI-Berichte Nr. 1182, 1995, S. 201 ff.

[5] *Haschke, P.*, „Forstliche Energieholzpotentiale in Deutschland sowie ökonomische und technologische Aspekte ihrer gegenwärtigen und zukünftigen Nutzung", Manuskript Jan. 1998, zur Veröff. vorgesehen.

[6] *Haschke, P.*, „Charakterisierung forstwirtschaftlicher Energieholzpotentiale und ihre Gewinnung", Vortrag zur Internationalen Fachtagung Energetische Nutzung nachwachsender Rohstoffe, 21.–22. 9. 1995, TU Bergakademie Freiberg

[7] *Hasler, Ph.*, „Producer gas quality from fixed bed gasifiers before and after gas cleaning", Paper presented at the IEA Seminar IC engines for LCV-gas from biomass gasifiers, October 28, 1997, ETH Zürich.

[8] *Klose, E.*, „Vergasung von Biomasse - Prinzipien und technische Möglichkeiten", Vortrag zur Internationalen Fachtagung Energetische Nutzung nachwachsender Rohstoffe, 21.–22. 9. 1995, TU Bergakademie Freiberg

[9] *Kugeler, K.; Phlippen, P.-W.*, „Energietechnik – Technische, ökonomische und ökologische Grundlagen", Springer-Verlag, 2. Aufl., 1993.

[10] *Nussbaumer, P.; Hasler, Ph.; Jenni, A.; Bühler, R.*, „Energie aus Holz – Vergleich der Verfahren zur Produktion von Wärme, Strom und Treibstoff aus Holz". Im Auftrag des Bundesamtes für Energiewirtschaft (der Schweiz), Juli 1997, Schlußbericht, 153 S. Bezugsquelle: ENET, Postfach 130, CH-3000 Bern 16.

[11] *Oettel, E.; Haschke, P.*, „Katalog Europäischer Holzvergaser kleiner Leistung", Fördergesellschaft Erneuerbare Energien Köpenicker Str. 325, 12555 Berlin.

[12] *Polley, H.; Sasse, V.; Englert, H.*, „Entwicklung des potentiellen Rohholzaufkommens bis zum Jahr 2020 für das Gebiet der Bundesrepublik Deutschland", Mitt. der Bundesforschungsanstalt f. Forst- und Holzwirtschaft Hamburg, Nr. 183, 1996.

[13] *Polley, H., Sasse, V., Englert, H.*, „Das Potentielle Rohholzaufkommen in Deutschland bis zum Jahr 2020 – Ergebnisüberblick", BML, Ref. Öffentlichkeitsarbeit, Juli 1997, Best.Nr. 613–16/96.

[14] *Rösch, Ch.; Wintzer, D.*, „Monitoring Nachwachsende Rohstoffe, Vergasung und Pyrolyse von Biomasse", zweiter Sachstandsbericht; Arbeitsbericht Nr. 49, TAB Büro für Technikfolgeabschätzung beim Deutschen Bundestag, April 1997, 118 S.

[15] *Stassen, H. E.*, "UNDP/WB small-scale biomass gasifier monitoring report", BTG Biomass Technology Group B. V., 1993.

Anschrift der Verfasser

Prof. Dr. sc. Peter Haschke
Eberhard Oettel
Fachhochschule Eberswalde
FB Forstwirtschaft
Alfred-Moeller-Straße 1
D-16225 Eberswalde-Finow

The Impact of Legislation and Policy Instruments on the Utilisation of Wood Fuels

Bengt Hillring

Abstract

The energy system can be monitored in three principal areas: energy consumption, industry structure that affects both the demand and supply of energy, and energy generation. The instruments the government may use to exercise this influence are: support to research and development, support to demonstration, support to information dissemination, administrative policy instruments, and economic incentives. These instruments may be used separately or in combination.

The purpose of this paper is to give some examples of how the energy system has been changed in Sweden and to give general conclusions based on this experience.

Sweden has large resources of biofuels and other renewable energy sources and has based its industry on this supply for centuries. Recently, a commercial industrial market for wood fuels has developed in the district heating sector. This is one result of an energy policy during the 1990s that favoured renewable energy.

Different policy instruments have been used, such as legislation for emission control, investment support for combined heat and power plants, and energy taxation including the introduction of a carbon dioxide tax.

The impacts of this policy are described on a national as well as an international level, and the main conclusion is that there is a very strong need for international harmonisation of energy policies, including the level of taxes.

Keywords: Wood fuels, Policy instruments, Legislation, Energy taxation, Investment support.

Introduction

This paper will present a general description of legislation and policy instruments that can be used to impact the utilisation of wood fuels and that is based on examples from Sweden. The examples will be analysed, and some general conclusions will be given. The paper is based on experience from Sweden, mainly summarised in *Hillring, B., National Strategies to Increase the use of Bioenergy – Policy instruments from Sweden.* Biomass and Bioenergy. In press.

It is the government that institutes the laws that can influence the use of different energy sources. The government may work to effect changes in three principal areas of the energy system: Energy consumption – adaptation of volume, structural change, more efficient use; industry structure, which affects both the demand and supply of energy; energy generation – adaptation of volume, structural change, more efficient generation (*Hillring*, in press).

The instruments the government may use to exercise this influence are: support to research and development, support to demonstration (including technology procurement), support to information dissemination, administrative policy instruments (laws and regulations), and economic incentives. These instruments may be used separately or in combination (*Hillring*, in press).

Wood fuels and other renewable energy can also be promoted by companies on the market. Marketing renewable electricity, i.e. green pricing, is an instrument used by some companies to create an image of being environmentally friendly. Necessary conditions for such an arrangement include a deregulation of the electricity market and recommendations concerning environmentally friendly electricity generation. In Sweden, it is considered a good environmental choice to purchase electricity generated from wood fuels in, for example, combined heat and power plants.

Other solutions on the market are special financial funds financing "green" projects or certification of the production according to environmental quality management systems such as the ISO 14000 (The International Standardisation Organisation, ISO, in Geneva, Switzerland). The Eco Management and Audit Scheme Regulation (EMAS) established by the European Union is another voluntary standard for setting environmental standards.

Tradable emission permits represent another instrument developed co-operatively by the authorities and the market.

On the market, price formation is the most important instrument for stimulating development and efficient resource use. The price of a product or service gives households and businesses information about the costs, securing an economical use of resources. Prices also yield information about consumers' willingness to pay and create a balance between supply and demand. Prices may furthermore be used to influence the distribution of income and consumption within the economy (*Hillring*, in press).

Efficient prices are equilibrium prices that reflect the scarcity on the margin for different goods and services; in this way, prices reflect the value of a resource for the best alternative of use. Completely efficient pricing is rarely achieved in practice, however, which is why society, i. e. the government, has on occasion good reason to intervene in the process of price formation to move it in the desired direction.

As carbon dioxide from the combustion of fossil fuels has long-term effects on climate development, such a case of intervention arises. The non-sustainable use of natural resources such as air, soil and water has far-reaching consequences for the future. A rise in the global temperature may be seen as the result of using a free commodity that is not covered by market prices. Market prices may thus be seen to reflect a scarcity on the market of the day – a market that does not include free goods and future effects.

In recent years, policy instruments of an economic character, such as carbon dioxide taxes, have been debated and subsequently introduced in some countries. These instruments have been designed to give price signals about future environmental impacts and thus to increase the competitive edge of biofuels in relation to fossil fuels, the price of which has gone up with taxes and levies. The policies include an internalisation of external costs of different fuels in today's prices.

Measures such as these give price signals to the market and, provided they are correctly designed, stimulate the development of renewable resources, such as biofuels, in the energy system.

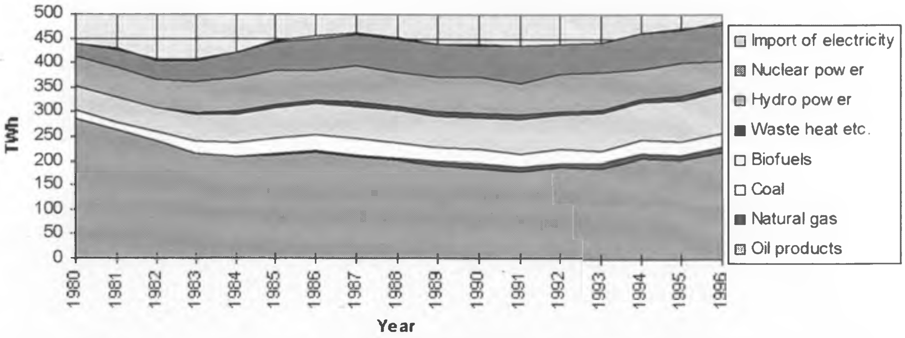


Fig. 1: Total energy supply in Sweden, 1980–1996 (Nutek, 1997), TWh (1 TWh equals 3.6 PJ).

The Swedish Energy System

In the Swedish energy system, there is a significant renewable energy supply, as described in Figure 1. Large scale hydro power is dominant but there is also a quite large amount of biofuel in the supply based on the forest products industry, such as pulp and paper mills and saw mills. The forest products industry represents both users and producers of wood fuels[1].

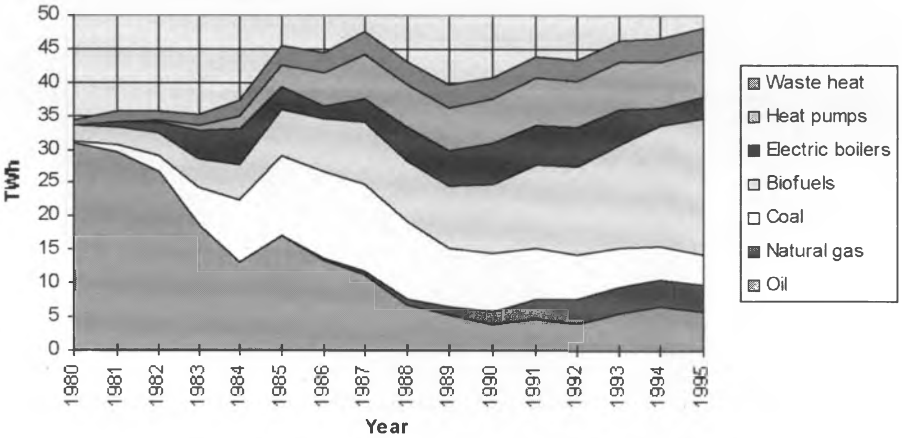


Fig. 2: Energy supplied to district heating, 1980–1996 (Nutek, 1997), TWh.

Especially the district heating sector[2] has faced a very fast increase in the supply of biofuels during the 1990s. Most of the growth has been in wood fuels. The rapid growth mainly owes to the fact that fossil fuels are taxed for heat production while biofuels are untaxed. For the forest products industry and for use in single family houses, there is economic incentive for using wood fuels even without stimulation from taxes etc., since the fuels do not pass the market pricing system, and for many users represent a "free good".

The increase in biofuels is also the result of other factors in the Swedish energy policy, such as investment support, emission control and the repeal of legislation limiting the supply of wood fuels.

Table 1. The aims of and resources for Swedish governmental energy research, 1975-1993 (Ministry of Industry, 1993).

Period, year	Primary goals	Support, million ECU[a], 1990[b]
1975-1978	Energy policy tools	250
1978-1981	Resources for industrial policy and oil replacement	400
1981-1984	Resources for industrial policy	450
1984-1987	Long-term research in natural sciences and technology	300
1987-1990	Phase-out of nuclear power and environmental adjustment	250
1990-1993	Climate-change issues and long-term research	200
Total		1850

[a] 1 ECU = 8.5 SEK, May 1998.

[b] Support includes funding for research and development and for development and demonstration of technology. Support for more efficient energy use, investment support to e.g. wind power, solar power and heating pumps, and support outside of these programs are not included.

[1] Wood fuel: Fuel originating from biological material (biofuel), the origin of which was trees or parts of trees. The term "bioenergy" is superordinate to the terms "biofuel" and "wood fuel". Wood fuels includes the stem wood but more utilised in the Swedish system are other parts of the trees such as needles, leaves, branches and tops and by-products from the forest products industry.

[2] District heating is a public heating system intended for supplying heat in networks to mostly residential buildings but also for industrial use. Heat could be supplied from hot water boiler plants and combined heat and power plant in which heat and electricity is produced simultaneously.

Experience from Legislation and Policy Instruments

Sweden has for historical reasons a very large and important energy intensive industry based on domestic resources such as ore and forests. For several hundreds of years, the government has supported these industries and continues to do so (*Hillring*, in press).

Swedish programs for energy research reflect the history of energy policy in general, as can be seen in Table 1. Policy started back in the 1970s.

In Table 1 it is also possible to identify a mixture of different policies, such as industrial policy including regional policy, environmental policy, financial policy, phase out of nuclear power plants etc. All that can be summed up in one word and called "the Swedish energy policy" in the last 20 years.

Swedish energy policy has given priority to biofuels. The strongest instrument for this development is the 1991 introduction of carbon dioxide taxes on heat production. Electricity is taxed at the consumer, independent of production technology. That means that the producer uses the cheapest fuel, sometimes still a biofuel but usually imported coal.

Investment Support

Swedish energy policy has given rise to a number of forms of investment support. The latest has been support for combined heat and power production based on biofuels. An older investment support was valid for a five-year period between 1991 and 1997, with a total budget of 118 million ECU. The support varied between 175 and 470 ECU per kW of installed electric effect. One requirement has been that biofuels should be used for 85 % of the production during the first five years (*Hillring*, in press). A new investment support program for CHP, similar to the old program, has just been started. The budget is 60 million ECU, and the maximum support is 375 ECU per kW installed electricity.

Legislation and Limits for Different Emissions.

There are several restrictions regulating the utilisation of fuels in heating plants. Below are given two examples: the Environmental Protection Act and the Sulphur Act.

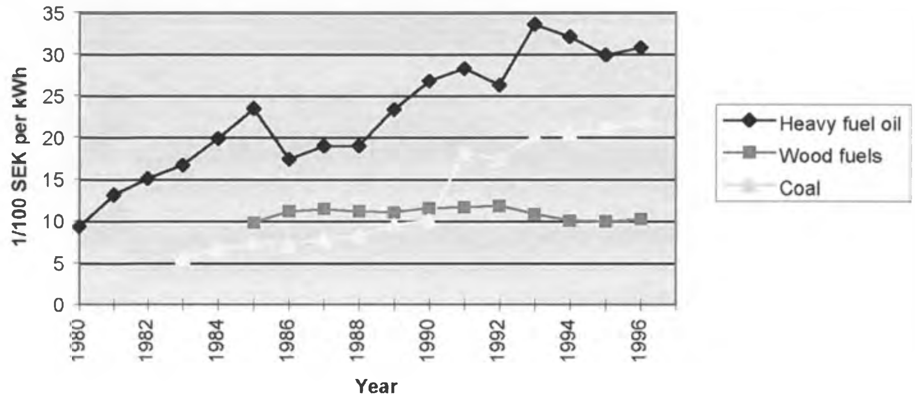


Fig. 3: Fuel prices for heavy fuel oil, wood fuels and coal including taxes for heat production in district heating (Nutek, 1997), 1/100 SEK/MWh.

As a result of the Environmental Protection Act, the builder of a heating plant with a capacity between 0.5 and 10 MW effect must make a report to the regional authorities, who will then set up different monitoring values for emissions of SO_x, NO_x etc.

The same act also forces builders of heating plants with a capacity of 10–300 MW to request permission at the regional authorities. For plants larger than 300 MW, permission is granted by national authorities. The most important issues for the authorities are to stipulate levels for sulphur, nitrogen oxide, dust and certain metals. Noise and transportation intensity are also regulated and must stay within certain limits.

For the larger plants, values are individual and adapted to the local conditions. The Sulphur Act stipulates certain maximum levels for emissions; for sulphur, emissions must be lower than 100 mg per MJ of fuel supplied to the boiler. The level is 50 MG/MJ of fuel for larger plants with emissions of over 400 tons per year

Legislation Influencing the Supply of Wood Fuel

A number of different restrictions influence the utilisation of wood fuels. Sweden had for many years legislative restrictions in the supply of wood fibre and for primary use in the forest products industry (*Hillring*, 1996). At the moment, there is no direct competition between the industry and the use of wood for fuel except in one area. The particle board industry uses the same raw material – sawdust – as the producers of densified wood fuels such as pellets, briquettes, and powder.

For the extraction of biomass from forests, there are currently recommendations from the National Board of Forestry concerning the removal of nutrients from forest areas. Most of the nutrients exist in the leaves, needles and small branches and will be left on the site with the storing and drying system. The typical biomass harvested are dried tops and branches after clear cutting or other logging operations. New recommendations from the authorities to make the harvest of wood fuels from forests sustainable are underway, including ash recycling into the stands.

Taxes

Public energy taxation was introduced in Sweden in the 1950s, for reasons of government finance. After the oil crises of the 1970s, taxation was formed to advance the national energy policy. During the 1970s and 1980s, energy policy profiled the substitution of oil with other fuels and electricity. After 1990, taxation was given an environmental profile, and these taxes can now be said to be the strongest instruments for reducing emissions, particularly in district heating. The general energy tax remains.

A carbon dioxide tax, corresponding to 0.03 ECU/kg CO_2 emission, was introduced in 1991. Today's level is 0.04 ECU/kg CO_2 emission. Industry pays 50 % of the carbon dioxide tax payable for other users.

A sulphur tax, hitting mainly fossil fuels, was also introduced in 1991, equal to 3.5 ECU/kg sulphur. At the same time,

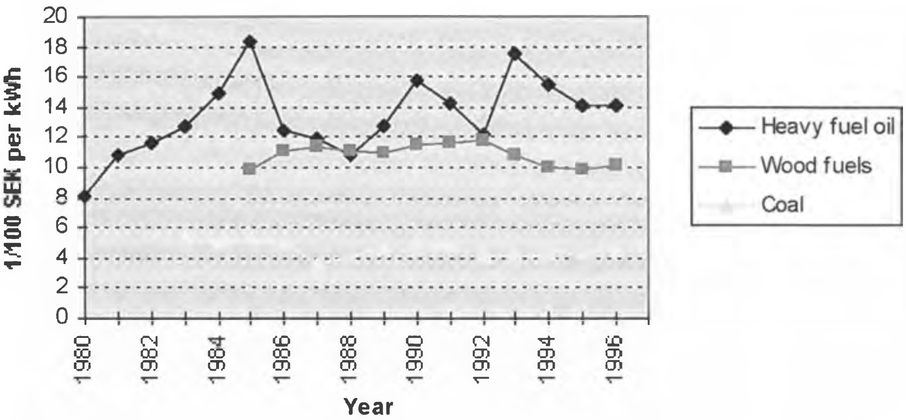


Fig. 4: Fuel prices for heavy fuel oil, wood fuels and coal untaxed for electricity production in combined heat and power production (Nutek, 1997), 1/100 SEK/MWh.

the entire energy sector became subject to business transfer tax as well.

The following figures show the fuel prices for three competing fuels in the district heating sector. For heat production, fossil fuels are since 1991 heavily taxed and wood fuels are untaxed (Figure 3). In electricity production, all fuels are untaxed and taxes are instead placed on the consumer (Figure 4). This means that wood fuels and other biofuels compete very well for heat production while coal is the cheapest untaxed fuel for electricity production.

Biofuel Trade

Recycled wood

Because of the high taxes on fossil fuels in Sweden and new more extensive waste legislation in some European countries, i. e. Germany, the Netherlands etc., the import of recycled wood fuels and other biofuels has increased dramatically during the past few years. This development has been facilitated by the stronger biofuel purchasing power that Swedish heating plants have in relation to foreign competitors whose use of fossil fuels is not taxed.

From a situation in which there was no trade in biofuels in 1991, the import of biofuels has increased very rapidly and was in 1997 some 8–10 TWh (28–35 PJ) or up to 40 % of the supply of biofuels for the district heating sector (*Hillring & Vinterbäck*, unpublished).

Olive stones

Different residues originating from olive oil production have been available to the Swedish heat and power plants since the early 1990s. They are imported from the European countries in the Mediterranean area. The heating potential in Europe of these olive oil solid fuels is estimated at 11 TWh (40 PJ) per year (*Nutek*, 1993). The olive stones may be imported as crushed residues or as pellets.

Olive stones have been burned commercially since 1991 in two Swedish heating plants; in a further two plants, olive stones have been co-fired with coal for testing purposes.

Discussion

During the last two decades there have been many different incentives to promote renewable energy sources in Sweden. The policies have had many different impacts, some expected and some unexpected.

On a **national** level – Sweden has seen an increase in the use of wood fuels and decrease in the levels of emissions, such as sulphur and carbon dioxide. Different evaluations show an increase in emissions for both carbon dioxide and sulphur. The carbon dioxide emissions in heat production have decreased by 8 million tons, or 19 %, from 1987 to 1994. However, an increase of 5.5 million tons occurred during the same period in the area of transportation. About 60 % of the fall in emissions is considered to be a result of the carbon dioxide tax. The district heating sector is most sensitive to the current system of carbon dioxide taxation and accounts for the largest share of the decrease (*Swedish Environmental Protection Agency*, 1995).

The effects with respect to sulphur are similar. Emissions from combustion were halved, decreasing from 71,000 tons of sulphur dioxide in 1989 to 35,000 tons in 1995. About 1/3 of this was a result of the taxation (*Swedish Environmental Protection Agency*, 1997).

Investment support can quickly and temporarily increase the demand to support a market for wood fuels. However, investment support, of the type introduced in Sweden, does not benefit new technology and can skew competition between those who receive support and those who do not. Arguments were advanced to terminate investment support for combined heat and power prior to schedule and to reallocate funds to support research on new technology. Parallel with the investment support, Sweden had a five-year program for new technology amounting to 75 million ECU. There have been some problems finding good projects to support and, as of last year, only 25 % of the funds had been used as compared to 100 % of the investment support (*Hillring*, in press).

On an **international** level – different taxes in different countries give a skewed market for fuels which are reflected in the different energy prices for industrial use.

Conclusions

To this time, energy policy has been national, and it is very important that every country have a policy based on their national conditions. However, if we see exceedingly large differences in, for example, energy taxation or deposition fees, as we do today in Europe, it is possible that, while national policies may be able to solve problems related to global warming in the individual country, they result in an export of the problems to other countries.

If there is an alternative for local biofuel use in the country in which it is produced and that the alternative energy source is fossil fuels, then the use of fossil fuels in total is the same and the global warming problems are simply moving around, for example from Sweden to the Mediterranean area.

To avoid this effects there is a very strong need for international harmonisation of energy policies, including the level of taxes, amongst the European countries and between Europe and other parts of the world.

References

Hillring, B. (1996). Administrativa styrmedel på biobränslemarknaden – Byggnadslag och lag om träfiberråvara. [Administrative policy instruments for the biofuel market: Legislation of natural resource- and wood fibre use]. Uppsala: Swedish University of Agricultural Sciences. Department of Forest-Industry Market Studies (SIMS). Report no 44. 1996. In Swedish with summary in English.

Hillring, B. (In press). National Strategies to Increase the use of Bioenergy – Policy instruments from Sweden. Biomass and Bioenergy.

Hillring, B. & Vinterbäck, J. (Unpublished). Development of International Wood Fuel Trade. Paper to be submitted.

Ministry of Industry. (1993). Energiforskningens mål och medel – Ett perspektiv inför 2000-talet. [Goals and tools for the energy research]. Stockholm: Allmänna förlaget. Ds 1993: 13. In Swedish.

Nutek. (1993). Forecast for Biofuel Trade in Europe – The Swedish Market in 2000. Stockholm: Swedish National Board for Industrial and Technical Development. B 1993: 10.

Nutek. (1997). Energy in Sweden 1997. Stockholm: Swedish National Board for Industrial and Technical Development.

Swedish Environmental Protection Agency. (1995). Utvärdering av koldioxidskatten – har utsläppen minskat? [Evaluation of the carbon dioxide tax: Have emissions decreased?]. Stockholm: Swedish Environmental Protection Agency. report 4512. In Swedish.

Swedish Environmental Protection Agency. (1997). Miljöskatter i Sverige – ekonomiska styrmedel i miljöpolitiken. [Environmental taxes in Sweden -- Economical Policy Instruments in the Environmental Policy]. Stockholm: Swedish Environmental Protection Agency. In Swedish.

Author's address

Bengt Hillring
Swedish University of Agricultural Sciences (SLU),
Department of Forest-Industry-Market Studies (SIMS),
PO Box 7054
SE-750 07 Uppsala. Sweden.
Fax: +46 18 67 35 22
e-mail: bengt.hillring@sims.slu.se

Physical and chemical properties of wood and woodfuels

Prof. Dr. Hermann Hofbauer

Biomass as a renewable energy source can contribute essentially to reduce CO_2 emissions. Therefore it is political demand in a lot of countries all over the world to increase the amount of utilisation of biomass for energy purposes. The most important and most traditional biofuel is wood.

Wood is used for residential heating, district heating as well as in industrial boilers. Depending on the size of the combuster different types of woodfuels can be found. For small combusters (e.g. wood stoves) log wood, wood briquettes or wood chips are frequently utilised whereas in case of industrial boilers waste wood or bark is normally burned. For some of these types of wood fuels standards exists in some countries which specify mainly physical and sometimes chemical properties.

The most important physical and chemical properties of wood and wood fuels will be presented. These properties are mainly piece size, bulk density, water content, calorific value, ash content, elemental analysis, thermal ash behaviour and composition of the ash. A comparison with other biofuels shows that wood is an excellent fuel for combustion as well as gasification. However, there exist some differences between different types of wood especially in nitrogen and chlorine content which are important properties for emission level. Further on essential variations of some properties can even occur within one piece of wood (e.g. wood log).

There exist some problems in connection with wood as fuel. In case of fuel for small combustors the water content can be a serious problem. The water content should be lower then 20 % otherwise the utilisation of heat is insufficient and the emissions of unburned substances are very high. A second problem is the low energy density of all biomass fuels which leads to large fuel volumes. Therefore storage and transportation costs are higher than for fossil fuels. Perhaps pellets can reduce this disadvantage. A third problem is connected to the analytical methods. The methods used were developed for coal and should be adapted for biomass fuels (e.g. ash analysis). Further on an international standardisation effort is needed to be able to compare the results from different analytical laboratories.

Wood waste as fuel is an important option for the future. The problem is that waste wood can be contaminated which can cause problems inside the boiler and/or emission problems. Beside chlorine, nitrogen or sulphur also heavy metals have to be considered. Dependent on the kind of contamination measures referring to construction and/or flue gas cleaning have to be taken into account. To facilitate this decision a classification for waste will be proposed.

Author's address

Prof. Dr. Hermann Hofbauer
University of Technology Vienna
Institute of Chemical Engineering,
Fuel Technology and Environmental Technology
A-1060 Wien, Getreidemarkt 9
Fax.: +43-1-5876384
e-mail: hhofba@fbch.tuwien.ac.at

Resource Potentials and Regional Availability

Timo Karjalainen

Summary

World-wide structural changes in the last 50 years:

- World population doubled
- World energy consumption tripled
- Global economies grew five-fold

... indicating a better overall energy use efficiency

Actual availability of forest biomass:

	Europe average	Nordic Countries average	Central Europe average
growing stock [m^3/ha]	140	291	107
ha per capita	0.35	3.39	0.35
total growing stock [Mio m^3]	22 602	5 641	1 460

Only 59 % of the annual increament in European forests is actually used.

Outlook

- Research needed on nutrients export problems
- Supply of wood for energy supply will increase for all types of biomass
- Biomass consumption statistics are not based on the energy efficiency of the technology applied

Author's address

Dr. Timo Karjalainen
European Forest Institute
Torikatu 34
FIN-80100 Joensuu, Finnland
e-mail: timo.karjalainen@efi.joensuu.fi

Verwertung und Beseitigung von Rückständen der Holzverbrennung

Rainer Marutzky

Kurzfassung

Bei der energetischen Verwertung von Holz und Holzabfällen verbleiben mineralische Rückstände, die entsorgt werden müssen. Die Entsorgungskosten können zu einem entscheidenden Faktor für die Wirtschaftlichkeit der Feuerungen werden. Der Entsorgungsweg wird durch Menge und Zusammensetzung der Aschen bestimmt. Je nach Brennstoff, Verbrennungsbedingungen und Ort der Abscheidung bestehen zwischen den Aschen charakteristische Unterschiede. Verwertungsmöglichkeiten für Aschen sind der Einsatz als Bodenverbesserungs- und Düngemittel in der Land- und Forstwirtschaft. Für diese Art der Verwertung ist eine geeignete Zusammensetzung der Aschen erforderlich, die in der Regel nur bei mit reinen Holzresten und Biomassen betriebenen Feuerungsanlagen erfüllt wird. Weiterhin lassen sich Aschen als Zuschlagstoffe für mineralische Baustoffen nutzen. Auch eine Entsorgung im Bergversatz ist möglich, doch werden die meisten Aschen durch Ablagerung in Deponien beseitigt. Hierbei sind bestimmte Ablagerungskriterien einzuhalten. Kritische Parameter sind bei Holzaschen der Glühverlust, die Wasserlöslichkeit, der PH-Wert des Eluats und der Elutionswert für Chrom-VI. Der Glühverlust ist dabei im wesentlichen auf unverbrannte organische Bestandteile in der Asche zurückzuführen und läßt sich durch Verbesserung des Ausbrandes oder thermische Nachbehandlung der Aschen verringern. Schwieriger ist die Einhaltung der anderen kritischen Parameter, da es sich um vorgegebene Eigenschaften der Aschen handelt. So enthält reine Holzasche zwischen 10 und 30 % wasserlösliche Bestandteile. Der hohe PH-Wert ist auf den Gehalt der Aschen an Calcium-, Kalium- und Natriumhydroxiden und -carbonaten zurückzuführen. Die Alkalität der Aschen ist ein günstiger Parameter, da bei hohen PH-Werten die meisten Schwermetalle immobil vorliegen. Eine Ausnahme ist das Element Chrom, das bei hohen pH-Werten als wasserlösliches Chrom-VI vorliegen kann. Da Chrom ein essentielles Spurenelement des Holzes ist, gilt die Chromproblematik für alle Holz- und Biomassefeuerungen. Besonders stark sind jedoch die Aschen von Rest- und Gebrauchtholzfeuerungen betroffen, da hier oft zusätzliche Chromeinträge durch holzfremde Stoffe erfolgen. Die Elutionswerte für Chrom-VI lassen sich durch feuerungstechnische Maßnahmen oder durch Behandlung der Asche verringern.

Recycling and disposal management of combustion waste is of no relevance for small scale combustion facilities

Mineral compounds content of biofuel ashes:

wood	0,5– 2,0 %
wood products	1,0– 3,0 %
wood waste	1,0– 5,0 %
bark	3,0–10,0 %
annual plants	3,0–12,0 %

Problems

- mix of woody fuels is resulting in changing contents of toxic compounds in the ash
- high content of unburned material
- high content of water-soluble compounds
- high pH value (>pH 13)
- high elution value for chromium VI (cancerous)

Solutions

- ash melting
- extraction with water
- reduction of chromium VI with wet ash collectors

Potential use of ashes

- fertiliser in forestry and agriculture
- filling material for closed-down mines

Recommendation

Special regulations needed for dumping permissions.

Author's address

Prof. Dr. Rainer Marutzky
Wilhelm-Klauditz-Institut
Fraunhofer-Institut für Holzforschung
Bienroder Weg 54E
D-38108 Braunschweig
e-mail: mar@wki.fhg.de

Heat Supply from Woody Biomass

– An Economic Analysis –

Bettina Schneider and Martin Kaltschmitt

Abstract

Due to ecological advantages, wood is a promising source of energy to cover a part of the given heat demand. On this background, the aim of this paper is to give a detailed analysis of the heat provision costs of woody biomass. For different case studies it is shown, which part of the heat provision chain dominates the overall costs and within which range the costs can vary. As the heat provision from wood is only one possibility to cover a given energy demand, these costs are compared to costs for the use of other renewable energy sources and for fossil energy carriers. The use of renewable energies is often promoted by various governmental measures. Therefore, the influence of such governmental incentives which could be applied to promote woody biofuels are discussed and their impact on the heat provision costs are analysed. Based on this, recommendations are given which measures could be applied to make wood a energy source competitive to fossil fuels.

1 Introduction

The total end energy consumption in Germany was 9628 PJ/a in 1996 (*VDI*, 1998). About three fifth of this energy consumption accounts for the provision of heat. In 1996, about 3500 PJ/a have been used for heating rooms and about 2400 PJ/a have been spent to provide heat for industrial purpose. Most of this demand is supplied by fossil fired furnaces. Until now, renewable energies play only a minor role, less than 3 % of the overall given heat demand is covered by non-fossil energies, of which biomass and especially wood makes the biggest contribution. Other possibilities (solar thermal heat production, heat pumps using geothermal energy extracted from the soil, hydrogeothermal heat production) to cover the heat demand play an even smaller role. The almost negligible use of renewable energies to supply heat cannot be justified considering the overall available technical potential. Table 1 gives a survey of the technical potentials of renewable energies and their current use within Germany.

It can be assumed that within the energy system of Germany the limited use of renewable energy sources for heat provision is mainly caused by the higher costs compared to heat production from fossil fuels. Nevertheless, in the public the use of renewable energies is considered as one possibility to reduce the negative environmental effects caused by the use of fossil energy carriers.

Among the various possibilities to provide useful energy based on renewable sources, biomass and especially wood is one of the most promising and already most widely used options. This is particularly true for rural areas. Therefore, the following explanations focus on the heat provision from woody biomass.

Table 1: Potential and use (useful heat) of renewable energies for the heat provision in Germany.

	Energy potential [d] PJ/a	Current energy use PJ/a
Heat from biofuels[a]		
Fuel wood	[c]	77
Residual wood	130	50
Straw	94	2 - 3
Energy crops [b]	380	0
Solar thermal heat production	136 - 718	1 - 2
Heat from soils based on heat	1 316	2 - 3
Hydrogeothermal heat production	1 077	0,5

[a] Only major biomass resources (cf. (Kaltschmitt, 1997a);

[b] An available area of 2 Mio. ha is assumed;

[c] No potential for fuel wood can be given due to the fact that fuel wood is an ordinary product of the conventional wood production;

[d] These potentials could not be summed up because they cover the same heat demand [cf. (Kaltschmitt, 1997b)].

The aim of this paper is to give a detailed analysis of the heat provision costs from woody biomass in comparison to other energy carriers. The costs are determined for different steps within the provision chain for wood (i.e. cultivation, harvesting, transportation and conversion) exemplary for the provision of wood chips from thinning measures and from short rotation forestry. This is done for different conversion technologies being typical applications. As the provision of heat from woody biomass is only one way to cover the given heat demand, the heat provision costs calculated for wood are compared to provision costs based on other renewable sources of energy (like geothermal energy, solar thermal energy) as well as for the use of fossil energy carriers.

Based on these investigations, statements on the economic competitiveness of the heat provision from woody biomass can be given. The extended use of biomass is considered as one of the major options to fulfil the CO_2-reduction aims. In cases where the use of biomass is not economically viable, the influence of subsidies required to make biomass competitive to other possibilities are also discussed. Finally some conclusions are drawn.

2 Frame Conditions for Heat Provision from Wood

To allow a comparison between the investigated heating systems, the same system boundaries have to be defined. The costs are analysed for the place, where the heat is fed into the distribution system of the house (i.e. the costs for the heat distribution system in the case of a large scale heating plant are taken into consideration). The calculation of the heat provision costs for all systems are carried out with a discount rate of 4 %. The depreciation period corresponds to the technical life time of the plant. Taxes, subsidies or tax benefits are not taken into account. Thus, mean costs for the entire economy are given.

2.1 Production

In this study, two different sources of wood are analysed exemplarily in detail. A differentiation is made between wood chips from thinning measures and from short rotation forestry.

Thinning measures. Within the wood log production in conventional forests, thinning measures are necessary. Especially the trees at a breast height diameter (BHD) from 8 to 20 cm of the first and second cuttings are very suitable to be used as a source of energy. The wood chip provision chain is organised as follows:

- Cutting of trees.
- Removing branches and cutting the log into pieces which can be transported easily.
- Transportation of these wood pieces to the forest road.
- Production of wood chips.

To realise a chain like this, different technologies can be applied. The following enumeration shows the most relevant harvesting methods.

- **Motor manual.** The motor manual provision of wood pieces (i.e. felling, cutting) is done with chain saws. The wood is then forwarded by hand to the forwarder which realises the transport to the forest road. Chipping of the wood pieces is done by a chipper with a performance of 10 m³/h on the forest road.
- **Harvester.** A harvester is used to fell the tree, remove the branches, cut the stems in pieces and forward the wood to the forest road. These steps are not very labour intensive, but an expensive harvester is needed. For chipping the wood at the forest road, the same procedure is assumed as for the motor manual method.
- **Whole tree usage.** The harvesting steps are the same as for the harvester method except for cutting the branches and using a forwarder to move the wood to the forest road. Here, the whole tree is chipped with a mobile chipper directly in the forest on the forwarding alley. The transport of the wood chips to the forest road is managed by the chipper itself.

Short rotation plantations. From the current point of view, the wood chip production from poplars as fast growing trees is most promising (*Hartmann*, 1995). For a plantation, about 12000 to 20000 plants per ha are needed. The average yield is around 10 t/(ha + a) of dry matter (*Dreiner*, 1993). In the first year, weed control is necessary. In the following years only fertiliser is needed in most cases. Harvesting time is winter to early spring every third year. Usually, harvest machines which cut and chip the trees in a single operation are used (*Hartmann*, 1997). Two different technologies (i.e. small scale tractor driven system and large scale self driven system) are available so far. After the utilisation period, a recultivation of the used land by removing the roots from the soil is necessary. A technical life time of 22 years is assumed for the plantation (i.e. 7 harvests can be realised).

2.2 Transportation

Thinning measures. After felling and moving the trees to the forest road in the felling time from January to April, the wood is stored in the forest until the end of summer to dry out by respiration and evaporation. In the following heating period, the wood pieces are chipped at the forest road and transported to the combustion plant. Two major possibilities for transportation are available:

- Transport based on a lorry with exchangeable containers. The wood is chipped directly into the container and transported to the plant. No additional storage is realised.
- Transport with agricultural vehicles, like tractors and trailers. The wood is chipped directly on the trailer and transported to the plant. No storage is necessary.

Short rotation plantations. For short rotation plantations, the green chain is most suitable according to the current knowledge. This means, that trees are harvested when a biofuel demand at the plant is given. Thus, the harvested wood chips are transported directly to the plant without any additional storage. Like for wood chips from thinnings, transport can be carried out by a lorry with a changeable container or by a tractor driven trailer.

2.3 Combustion

Wood chips can be used in various types of furnaces. Nevertheless, for the capacity range considered here, only systems with a full automatic operation are of major importance. From the various combustion systems available on the market, the grate firing system is assumed for all heating systems analysed. With this technology it is possible to burn wood chips at a high water content (like wood chips from short rotation plantations) without any additional drying measures. The following system configurations are assumed:

■ **Multiple dwelling house.** The heat and hot water supply of a multiple dwelling house is considered. For this system, a wood chip grate firing furnace with 40 kW thermal capacity is assumed to provide the total energy demand. The full load hours of the heating system are assumed being 1800 h/a.

■ **Small district.** A small district heating system for residential buildings is assumed. This system is equipped with a grate firing furnace providing a thermal capacity of 1000 kW and an additional light oil fired peak load furnace with 1300 kW thermal capacity. For this heating system 2000 full load hours per year are assumed.

■ **Large district.** The third option considered is a large scale district heating system for an extended district. The large system is also equipped with a grate firing furnace. The thermal capacity is in the range of 2500 kW. The additional light oil fired peak load furnace has a thermal capacity of 2500 kW. The full load hours of this heating system sums up to 2000 h/a.

3 Cost Analysis

The heat provision costs from wood chips are determined by the production and transportation costs of the biofuel as well as by the combustion costs. In the following, a detailed cost analysis of the different influencing factors is given. First, the costs of the wood chips at the border of the production site are given. Then the fuel costs at the gate of the combustion plant are analysed. Based on this, the heat production costs at the feed-in point of the houses heat distribution system is given.

3.1 Production costs at the site

Thinning measures. For wood chips from thinning measures, only the harvesting, moving and chipping costs are calculated, because this wood is considered being a by-product from wood log production (i.e. no costs for managing the forest and the forest infrastructure are added). Therefore only the harvesting costs are estimated for three different methods. For each method the costs for breast height diameters (BHD) from 12 to 20 cm are determined (*Dreiner*, 1993; *Kolloch*, 1990). The assumed labour costs for ordinary workers refer to the average wage of forestry workers in Germany (approx. 20 ECU/h (BML, 1997)). For harvester drivers higher wages of about 35 ECU/h are assumed due to their higher necessary qualification.

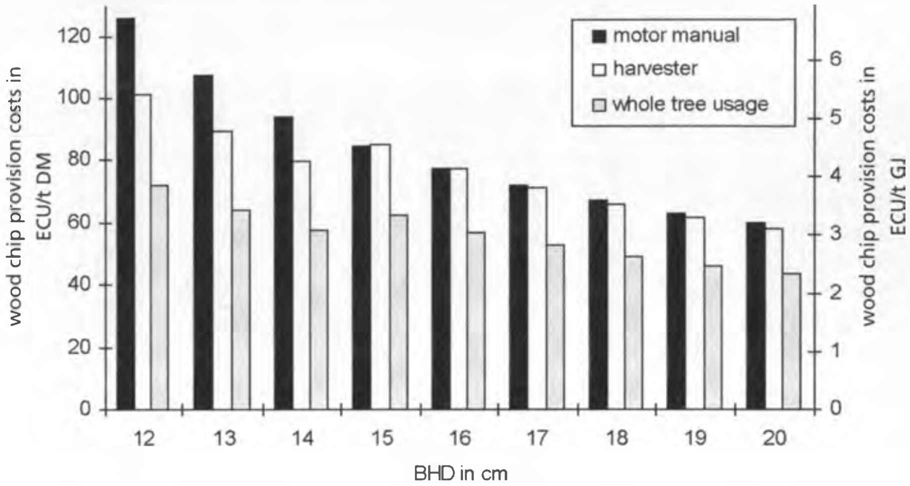


Fig. 1: Wood chip production costs from thinning measures depending on BHD and three different harvesting technologies (DM – dry matter).

Figure 1 shows the calculated wood chips production costs based on the assumptions given above. For all investigated BHDs, the harvester and the whole tree usage are characterised by lower specific production costs compared to the motor manual method. This is mainly caused by the high labour costs necessary to harvest the trees manually. However, above a BHD of 15 cm, the production cost differences of the analysed mechanisation degrees get closer. From 15 to 17 cm BHD, the wood chips production costs for the motor manual and the harvester method are almost the same. This is caused by the higher machinery costs for harvesters, which are needed to harvest trees with a BHD above 14 cm. With an increasing BHD, the harvesting costs for the different methods become more and more similar. It can be stated that the higher the diameter, the lower the costs for harvesting.

The determined costs differ considerably between different locations. Besides the BHD and the different mechanisation degree, factors like the number of trees that can be harvested on a certain area, the working conditions (like the slope, the condition of soil, the surface at the location), the kind of trees, the efficiency and skills of the workers, the labour costs, the organisation and planning of the work, the costs and the reliability of the used machines and the expenditure of extra work like choosing and marking the trees to be harvested can influence the production costs significantly. Most of these influencing factors can not or only hardly be determined for a detailed cost calculation. To give an idea how such parameters can determine the production costs, the influence of varying labour costs is calcu-

Table 2: Influence on wood chip production costs according to the variation of labour costs.

	Wood chip production costs for different harvesting technologies					
	Motor manual		Harvester		Whole tree usage	
Variation of labour costs in %	ECU/GJ	(%)	ECU/GJ	(%)	ECU/GJ	(%)
70	3.22	(78)	3.71	(90)	2.73	(90)
100	4.14	(100)	4.14	(100)	3.04	(110)
130	5.05	(122)	4.57	(110)	3.36	(110)

lated for different harvesting methods exemplarily for a BHD of 16 cm. Table 2 shows the influence on the production costs.

According to Table 2, a reduction or an increase of 30 % of the labour costs has different consequences on the wood chip production costs for the investigated harvesting technologies. As the motor manual method is characterised by a high labour input, a variation of the labour costs has a strong effect on the production costs compared to the harvester or whole tree usage method. In contrast, a variation of the machinery costs would have a stronger influence on the production costs of the two mechanised methods compared to the influence of the labour costs due to the fact that these two processes are very capital intensive and labour extensive.

Short rotation plantations. Unlike the calculations discussed above, the plantation and maintenance costs for the production of poplar trees grown in short rotation plantations have to be taken into account. Except of the planting, which is assumed to be done by a contractor, the establishment of the plantation is carried out by the farm workers. Farm owned machinery is used. Labour costs are based on average wages in agriculture for skilled workers [i.e. 12 ECU/h (*KTBL*, 1996)].

The planting costs mainly result from the use of a forestry planting machine and the price for the cuttings. For 14300 plants per hectare cutting costs of 2145 ECU/ha (0,15 ECU/cutting) and planting costs of 500 ECU/ha are estimated. The costs for preparing the seedbed run up to 101 ECU/ha for the machinery and to 67 ECU/ha for the labour. In the first year, weed control is necessary (two applications of pesticide are assumed which sums up to 100 ECU/(ha + a). Fertiliser is applied in the first year and after each harvest. The needed quantity is based on the nutrients which are bound by the trees [i.e. 3.75 kg N, 0.59 kg P and 2.63 kg K per ton dry matter (Krapfenbauer, 1989)]. For each application, the costs for the fertiliser run up to 92 ECU/ha and the necessary labour and machinery costs sums up to 11 ECU/ha. After the technical life of the plantation, the area has to be recultivated with costs of about 2000 ECU/ha (*Hartmann*, 1995).

It is assumed that harvesting and wood chipping is carried out by contractors. The costs for harvesting and chipping are in the range of 432 ECU/ha for a tractor mounted feller-chipper (i.e. small scale system). For a self driven large scale system (i.e. Claas Jaguar) the costs sum up to about 306 ECU/ha. The given costs are related to one harvest and occur every third year.

To calculate the overall production costs of such a plantation, the fixed costs of the farm have also to be considered. Overhead costs of 260 ECU/(ha a) are assumed according to (*KTBL*, 1997). The leasing rate is fixed to 175 ECU/(ha + a).

Table 3 shows the overall costs. According to this, the production costs of wood chips harvested with a small scale technology are higher than with a large scale technology.

Within the EU, the agricultural overproduction has been reduced by implementing a set aside subsidy. According to the allocation rules, this subsidy is also paid if energy crops are produced instead of food crops. This set aside subsidy varies within different regions between 303 and 482 ECU/(ha + a) (*KTBL*, 1997). For a sensitivity analysis a set aside subsidy of 375 ECU/(ha a) is assumed. According to Table 3 which shows the influence on the total costs, a substantial cost reduction of about 45 % can be achieved by taking advantage of this subsidy.

The costs shown in Table 3 can vary considerably between different sites depending on varying site specific conditions. Exemplarily, the following parameters are analysed in detail:

- Cutting costs. Until now, no market prices for poplar cuttings exist, because there is only a very limited demand (*Küppers*, 1995). Therefore, substantial cost reductions can be expected if short rotation forestry will become more important.
- Yield. The breeding of poplar species for short rotation plantation with high yields started in the beginning of the 80s. Thus, the overall available yield po-

Table 3: Wood chip production costs from short rotation crops considering different harvesting technologies and subsidies.

		Harvesting technology			
		Large scale		Small scale	
		Without subsidy	With subsidy	Without subsidy	With subsidy
Establishment	ECU/(ha a)	262	262	262	262
Treatment costs	ECU/(ha a)	37	37	37	37
Fixed costs	ECU/(ha a)	435	60	435	60
Harvest costs	ECU/(ha a)	110	110	156	156
Total costs	ECU/(ha a)	**845**	**469**	**890**	**515**
Total costs	ECU/GJ	**4.52**	**2.51**	**4.76**	**2.75**

[a] Incl. transfer into farmland at the end of the technical life time.

Table 4: Influence on the wood chip production costs for the self driving harvester method without and with set aside subsidy according to the variation of cutting costs and yield.

	Wood chip production costs			
	Without set aside subsidy		With set aside subsidy	
	ECU/GJ	(%)	ECU/GJ	(%)
Variation of the cutting costs in %				
70	4.26	(94)	2.20	(88)
100	4.52	(100)	2.51	(100)
130	4.90	(108)	2.51	(113)
Variation of the yield in %				
70	6.45	(143)	3.58	(143)
100	4.52	(100)	2.51	(100)
130	3.48	(77)	1.93	(77)

tential could not be realised until now. In addition, it is difficult to find the right poplar species which is adapted to special environmental conditions (*Hofmann*, 1995).

Table 4 illustrates, that the yield has a strong influences on the production costs for both investigated systems. A 30 % increased average yield will reduce the production costs by 23 %. In contrast to this, the variation of the cutting costs has only a minor influence on the wood chip production costs for plantations without a set aside subsidy. However, the cutting costs influence the wood chip production costs much more in the system considering set aside subsidy, because the share of cutting of the total costs is higher than in the system without subsidy. This is true because, referring to Table 3, the fixed costs contribute to a large share of the total costs, if no set aside subsidy is available. To make the production of wood chips from short rotation forestry cheaper, the most important step is a reduction of the relatively high fixed costs.

3.2 Provision costs at the plant gate

To calculate the provision costs at the plant gate, the transportation and the production costs have to be summed up, if no storage and/or special treatment is necessary.

The transportation costs of wood chips from thinning measures and from short rotation plantations can be realised by lorries with changeable containers and with tractor driven trailers. Both possibilities allow a continuous transport from the harvest site to the plant. The transportation costs vary due to the water content of the wood, the transportation distance and the used vehicle. For short distances, the transport with a tractor driven trailer in general is cheaper compared to a lorry transport. For longer distances, the use of a tractor is not advisable due to its low velocity.

Assuming a lorry transportation over a distance of for example 30 km, the occurring costs mount up to 14 ECU/t dry matter or 0.76 ECU/GJ for wood chips from thinning measures based on a water content of 33 %. Due to the higher water content of wood chips from short rotation plantations (i.e. 54 to 61 %), the transportation costs per ton dry matter rise to 18 ECU/t dry matter or 0.95 ECU/GJ.

Based on this, Table 5 shows the provision costs for wood chips at the plant gate for different distances and different production methods.

Table 5 indicates that the provision costs for wood chips at the plant gate vary considerably. The costs for wood chips from thinning measures for example range from 2.6 to 7.9 ECU/GJ (data not shown in Table 5), depending on the different BHDs and the harvesting method. The provision costs from short rotation forestry could vary between 2.8 to 6.2 ECU/GJ (data not shown in Table 5) depending on the harvesting method and subsidy.

Table 5: Provision costs for wood chips at the plant gate for different provision methods, transportation systems and distances.

	Wood chip provision costs in ECU/GJ at plant gate for transport distances of		
	5 km [a]	30 km [b]	60 km [b]
Wood chips from thinning measures (BHD 16 cm)			
motor manual	4.39	4.90	5.27
harvester	4.39	4.90	5.27
whole tree usage	3.29	3.80	4.17
Wood chips from short rotation plantations			
large scale harvesting technology without subsidy	4.83	5.47	5.93
large scale harvesting technology with subsidy	2.82	3.46	3.92
small scale harvesting technology without subsidy	5.07	5.71	6.17
small scale harvesting technology with subsidy	3.06	3.70	4.16

[a] tractor driven trailer
[b] lorry with container

3.3 Heat provision costs

To allow an easy interpretation of the results, the following calculations are based on wood chips provision costs of 4,90 ECU/GJ. These costs at the plant gate are typical for wood chips from thinning measures with a 30 km lorry transport and the motor manual or harvester method (BHD 16 cm). The following calculation of the heat provision costs are carried out for the heating systems described above.

The specific investment costs and the running costs for a wood fired combustion plant depend considerably on the capacity and the technique of the combustion plant. Although plants over 1000 kW thermal capacity have to be equipped with instruments to guarantee the observance of the emission limits, the specific investment costs are lower compared to plants in the capacity range below 100 kW. However, the running costs in large scale plants are higher than in small plants. Here the owner normally realises the operation and maintenance without charging this duty. Thus, only 5 ECU/h for the owners working hour are assumed. In opposite to this, people have to be employed by the plant owner to run a heating plant for the heat provision within a district heating system; in addition to this, considerable costs for emission measurements, electricity etc. have to be taken into account. Table 6 shows the costs for the three different plants investigated here.

Table 6 indicates that the heat provision costs vary between the different heat provision systems investigated here. According to this, the heat provision for the small scale system ("multiple dwelling house") is more expensive compared to the other investigated systems. The "large district heating system" provides heat at lowest costs. This results from the fact that the specific investment costs for smaller plants are considerably higher compared to large scale plants.

These results are influenced by a broad variety of assumptions and defined frame conditions. Figure 2 shows the influence of the investment costs, the depreciation period, the interest rate, the costs of the wood chips and the running costs exemplary for the "multiple dwelling house system".

According to Figure 2, mainly the high investment costs determine the heat provision costs. A subsidy for the plant of 30 % of the investment costs would lead to a decrease of the heat provision costs of approx. 15 %. The biofuel costs also have a high influence on the heat provision costs. A 30 % reduction of the wood chips costs leads to approx. 12 % lower heat provision costs. Such a reduction can be obtained if the set aside subsidy is paid. The technical lifetime of the plant is also an important influencing factor. An increase of the technical availability of the furnace from 15 to 19.5 years leads to 6 % lower heat provision costs. In opposite to this, the interest rate influences the heat provision costs only slightly. Also the running costs play only a minor role because the owner realises the operation and maintenance himself at only very little costs.

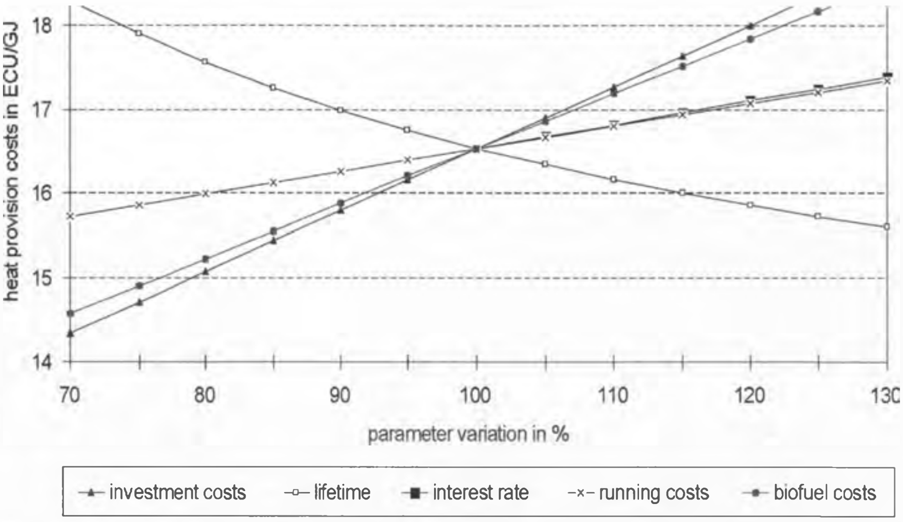


Fig. 2: Variation of parameter for a 40 kW wood chip plant and resulting influence on the heat provision costs.

4 Cost Comparison

Within an energy system as it currently exists in Europe, biomass has to compete with other options for the heat provision. Therefore, in the following explanations, the heat provision costs calculated above based on wood chips are compared to other heat provision options. Beside fossil energy carriers, other renewable energies like solar or geothermal energy could be used to provide heat for the analysed case studies. The following possibilities are investigated in more detail:

- Multiple dwelling house system. Here the energy supply from woody biomass is compared to a fossil fired furnace (i. e. light oil), a solar thermal heat collector system in combination with a fossil fired backup system and geothermal energy extracted from the soil based on a heat pump.
- Small district heating system. Here, the heat provision from wood chips is compared to a solar collector system with a fossil fired backup system and a seasonal heat storage system as well as a fossil fired furnace (i. e. light oil).
- Large district heating system. For this system, the heat provision based on wood chips is compared to a hydro-geothermal heat provision system and a fossil fired furnace (i. e. light oil).

Figure 3 shows the results of these calculations.

- For the multiple dwelling house heating system the heat supply from fossil fuels is considerably cheaper compared to all other options investigated here. This is true because of the low specific investment costs and the low fuel costs. The heat provision from the soil with the help of heat pumps is only a little more expensive. Compared to these two options, the use of wood chips for the provision of heat is characterised by higher costs. This is mainly caused by the high investment costs for the combustion plant and the relatively high biofuel costs. But this possibility is cheaper than a heat provision from solar energy with collectors.
- For the small district heating system, the heat supply from fossil energy is again the cheapest option. Compared to

Table 6:Technical parameters and heat provision costs from wood chips for different heating systems.

	Heating systems		
	multiple dwelling house	Small district	Large district
Technical parameters:			
Fuel	wood chips	wood chips + light oil	wood chips + light oil
Thermal capacity of biofuel furnace in kW	40	1 000	2 500
Thermal capacity of peak load furnace in kW		1 300	2 500
Utilisation ratio of biofuel furnace in %	75	80	80
Utilisation ratio of peak load furnace in %		85	85
Coverage with biofuel in %	100	80	80
Costs:			
Investment costs in ECU/kW			
Biofuel plant	397	284	174
Peak load plant		161	127
Distribution system		235	213
Building/storage room	250	120	108
Costs per supplied GJ heat			
Investment costs in ECU/GJ	7.32	5.43	4.26
Running costs in ECU/GJ	2.70	3.44	3.42
Fuel costs in ECU/GJ [a]	6.55		6.17
Heat provision costs in ECU/GJ	**16.57**	**15,04**	**13,85**

[a] for wood chips costs of 4.90 ECU/GJ and a light oil price of 4.08 ECU/GJ

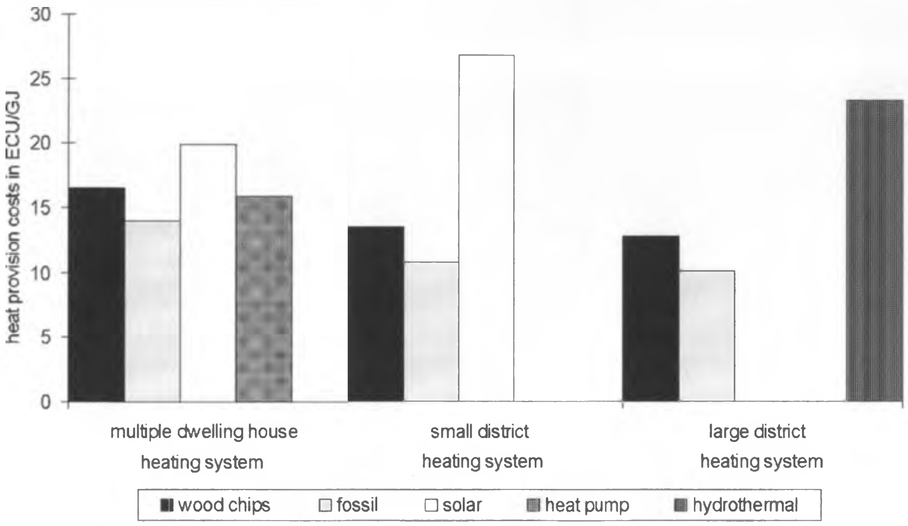


Fig. 3: Heat provision costs of the analysed heat supply options [cf. (LUX, 1997)].

this, the heat provision from woody biomass is considerably more expensive. The use of solar energy via solar collectors is even more expensive because of the very high investment costs for the collectors and the seasonal heat storage system which is assumed here.

■ For the large district heating system, the use of fossil fuels is the cheapest heat provision option. Like for small district heating systems, the biomass option is noticeable more expensive. Due to very high drilling costs to develop the geothermal reservoir, the heat provision costs of the investigated hydrothermal heat supply system is more as twice as high than the fossil option.

To summarise these results, wood chips as a fuel for the provision of heat are more or less competitive compared to other renewable energies for the cases analysed here. Nevertheless, the use of fossil fuels is unrivalled the cheapest option to supply heat under the given circumstances.

Since the utilisation of biomass for heat provision is bound up with a couple of environmental advantages (*Kaltschmitt*, 1997c), governmental support for an increased market introduction of biofuels is often claimed. Such administrative incentives should result in cheaper heat provision costs for biomass fired heating plants compared to fossil fuel fired ones. In the following, different governmental measures to promote the use of biomass are discussed:

■ One realised possibility is the already discussed set aside subsidy. However, this measure on its own cannot provide an economically competitive heat production as shown in Table 7.

■ Investment grants for combustion plants are given in some countries. Such incentives lead to a cheaper heat provision from biomass compared to fossil fuels. Table 7 shows that a grant to the investment costs of a biomass fired plant should be between 30 and 50 % to make the provision of heat from wood competitive to heat from fossil fuels.

■ Often these two measures are combined. Table 7 shows that the set aside subsidy plus a 15 % investment cost subsidy makes the woody biomass competitive to the fossil fuel for the "multiple dwelling house system". For the two district heating systems a 30 % investment subsidy plus the set aside subsidy is necessary to achieve the same result. Because the furnace used in the "multiple dwelling house system" has high specific investment costs, a reduction of these costs by means of administrative measures has a stronger influence on the heat provision costs than for the other two systems.

In addition to the investigated governmental measures so far, fossil fuels could be burdened with an adequate tax for the negative environmental effects of their utilisation. This is the reason why in some countries a CO_2- or an energy-tax was introduced in the past. Finland for example introduced a CO_2-tax already in 1990, charging 11.5 ECU/t CO_2 (*Wuppertal-Forum*, 1997). Due to this governmental incentive, the price for light oil and natural gas increased by 0.85 and 0.63 ECU/GJ resp. For the three heat provision systems assumed here, this measure is not sufficient to make wood as a fuel competitive compared to fossil fuels. This is one of the reasons, why Sweden introduced a higher CO_2-tax which amounts to 42 ECU/t CO_2 for households and 21 ECU/t CO_2 for the industry (*ROOS*, 1998). Since the wood fired district heat-

Table 7: Comparison of heat provision costs from woody biomass compared to fossil energy for different heating systems under alternative policy frameworks.

Heat based on	Heat provision costs in ECU/GJ for different heating systems		
	multiple dwelling house	small district	large district
fossil fuels	14.0	10.8	10.1
wood chips without subsidies	16.5	13.5	12.8
wood chips + set aside subsidy	14.6	12.0	11.3
wood chips + 15 % investment subsidy	15.4	12.6	12.1
wood chips + 30 % investment subsidy	14.3	11.7	11.3
wood chips + 50 % investment subsidy	12.9	10.6	10.4
wood chips + set aside sub. + 15 % invest. sub.	13.5	11.1	10.5
wood chips + set aside sub. + 30 % invest. sub	12.4	10.2	9.8
fossil fuel + CO_2-tax [a]	17.5	12.2	11.6
wood chips + CO_2-tax [a]	16.5	13.9	13.2
wood chips + CO_2-tax [a] + set aside subsidy	14.6	12.4	11.6
wood chips + CO_2-tax [a] + set aside sub. + 15 % invest. sub.	13.5	11.5	10.9

[a] refers on the CO_2 tax of Sweden

ing systems have a fossil fired peak load furnace, for these systems, the higher fossil fuel prices have to be taken into consideration as for the exclusively fossil fired heating systems. Therefore, the heat provision costs for the two biomass fired district heating systems are slightly higher than without a CO_2-tax. This governmental measure results in a cheaper heat provision using biomass in the "multiple dwelling house system" than using fossil fuels. This is not true for the two district heating systems due to the lower tax and the higher costs for the peak load provision from fossil fuels (Table 7). To make such systems competitive, a CO_2-tax like in Sweden combined with the set aside subsidy and an investment cost reduction up to 30 % is needed.

5 Conclusions

Wood as a source of energy is a promising fuel to cover the given heat demand due to ecological advantages (*Kaltschmitt*, 1997 c). On this background, the aim of this paper is to give a detailed analysis of the provision costs for heat from woody biomass. The costs are determined for different steps within the provision chain for wood chips from thinning measures and from short rotation forestry. This is done for three different heating systems ("multiple dwelling house", "small district", "large district"). These costs are compared to the heat provision costs from other renewable and fossil energy sources used in all three supply systems. The influence of governmental incentives to bring biomass closer to the market are also analysed.

The main results of the cost analysis for the heat provision from biomass can be summarised as follows:

- The costs for the production of wood chips from thinnings are mainly influenced by the share of man power or machinery use and the mechanisation degree. For wood chips from short rotation forestry, mainly the overhead costs and the given plantation costs determine the wood chip production costs.
- The production costs of the wood chips contribute most to the biofuel provision costs at the plant gate; the transport of the fuel between the production site and the plant site plays only a minor role even for longer distances.
- The costs for the heat provision are mainly determined by the investment costs for the plant and the biofuel costs. All other cost items make only minor contributions to the heat provision costs.

When the heat provision costs from wood chips for the supply tasks investigated here are compared to the heat costs based on other renewable sources of energy and fossil fuels, it becomes obvious that the heat provision based on biomass is more expensive compared to fossil fuels and some other renewable sources of energy. It is likely that this is one of the main reasons that biomass plays only a minor role within the energy system in Germany.

Since the utilisation of biomass for heat provision is bound up with a couple of environmental advantages, governmental support for an increased use of this source of energy is often available. Such measures aim to allow an economic operation of a plant for a potential operator. By analysing different administrative measures which are already available or could be available in the future, the following statements can be made:

- The use of the set aside subsidy is not sufficient to make a heat provision from biomass competitive to a heat production from fossil energy carriers.
- Governmental grants for a biomass fired furnace are available in a range of up to 50 % of the investment costs in some European countries. Only at the upper end of this bandwidth, the heat production from biomass becomes partly competitive compared to fossil fuels.
- A combination of a set aside subsidy and a relatively high investment grant could lead to a competitive heat provision from wood chips compared to fossil fuels in most cases.
- This is also true for a CO_2-tax as it was introduced in countries like Sweden (i.e. 42 ECU/t CO_2 for households and 21 ECU/t CO_2 for the industry). If such a governmental measure is introduced, a heat production from biomass in the small capacity range will be economic compared to all other possibilities to provide heat. For large scale systems, additional incentives are necessary.

Summing up, biomass will be only competitive to fossil fuels if governmental incentives are set into force. Among all possibilities, the implementation of a CO_2-tax like it is already realised in Sweden, is the most promising option to allow a fast market introduction of biomass for covering a part of the given heat demand. Based on such measures, this renewable source of energy could make a substantial contribution to an environmental more sound energy system in the future.

Literature

BML (1997): Agrarbericht 1997: Agrar- und ernährungspolitischer Bericht der Bundesregierung. Bundesministerium für Ernährung, Landwirtschaft und Forsten, Bonn, S. 69.

Dreiner, K., Frühwald, A., Küppers, J.-G., et. al. (1993): Verwertung von Holz als umweltfreundlicher Energieträger – Eine Kosten-Nutzen-Untersuchung. Bundesforschungsanstalt für Forst- und Holzwirtschaft, Hamburg.

Hartmann, H., Strehler, A. (1995): Die Stellung der Biomasse im Vergleich zu anderen erneuerbaren Energieträgern aus ökologischer, ökonomischer und technischer Sicht. Schriftenreihe "Nachwachsende Rohstoffe" der Fachagentur Nachwachsende Rohstoffe e.V. (FNR), Band 3, Landwirtschaftsverlag, Münster-Hiltrup.

Hartmann, H., Thuneke, K. (1997): Ernteverfahren für Kurzumtriebsplantagen – Maschinenerprobung und Modellbetrachtung –. Bayerische Landesanstalt für Landtechnik, Weihenstephan.

Hofmann, M. (1995): Schnellwachsende Baumarten für den Kurzumtrieb- Aspekte der Pflanzenzüchtung und Ergebnisse zur Kloneignung auf verschiedenen Standorten. In: Statusseminar Schnellwachsende Baumarten am 23. und 24. 10. 1995 in Kassel, Tagungsband. Fachagentur Nachwachsende Rohstoffe e.V. (FNR), Gülzow, S. 17–26.

Kaltschmitt, M. (1997 a): Biogene Festbrennstoffe: Was können sie zur Treibhausgasminderung leisten? In: Jahresbericht 1996/97, "Luftreinhaltung in Baden-Württemberg", "Das Treibhausgas CO_2 – Wirkung und Minderung –". Arbeitsgruppe Luftreinhaltung der Universität Stuttgart, Stuttgart, S. 122–138.

Kaltschmitt, M., Wiese, A. (Hrsg.) (1997b):

Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. 2. Auflage, Springer, Berlin, Heidelberg.

Kaltschmitt, M., Reinhardt, G. (Hrsg.) (1997 c): Nachwachsende Energieträger: Grundlagen, Verfahren, ökologische Bilanzierung. Vieweg, Wiesbaden.

Kolloch, H.-P. (1990): Ökonomische Untersuchungen zur Ernte und zum Einsatz von Stroh und Schwachholz als Energieträger in Großfeuerungsanlagen, TU Weihenstephan, Weihenstephan.

Krapfenbauer, A. (1989): Forstliche Biomasse-Energiegewinnung-Nähstoffkreisläufe. Holz-Zbl. 115, Nr. 45, S. 682.

KTBL (1996): KTBL-Taschenbuch Landwirtschaft, Daten für die Betriebskalkulation in der Landwirtschaft. 18. Auflage. Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V.(KTBL), Darmstadt.

KTBL (1997): Betriebsplanung 1997/98 – Daten für die Betriebsplanung in der Landwirtschaft –. 15. Auflage, Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL), Darmstadt.

Küppers, J.-G. (1995): Ökonomische Aspekte der Kurzumtriebswirtschaft. In: Statusseminar Schnellwachsende Baumarten am 23. und 24. 10. 1995 in Kassel, Tagungsband. Fachagentur Nachwachsende Rohstoffe e.V. (FNR), Gülzow, S. 83–93.

Lux, R., Kaltschmitt, M. (1998): Regenerative Energien zur Niedertemperaturwärmebereitstellung – Eine vergleichende energiewirtschaftliche Analyse. Erdöl – Erdgas - Kohle, 114. Jahrgang, Heft 1.

Roos, A. (1998): Swedish University of Agricultural Sciences, Uppsala, Sweden, personal communication at march 26th 1998.

VDI (Hrsg.) (1998): Jahrbuch 98. Verein Deutscher Ingenieure (VDI), VDI-Verlag, Düsseldorf.

Wuppertal-Forum (1997). Finnland: Reform der Energiesteuer. In: Wuppertal Bulletin zur ökologischen Steuerreform. Jahrgang 3, Nr.3.

Authors' address

Dipl. Ing. agr. Bettina Schneider
Dr.-Ing. Martin Kaltschmitt
Institute for Energy Economics and the Rational Use of Energy (IER)
University of Stuttgart
Hessbruehlstraße 49 a
D-70565 Stuttgart – Germany
Fax +49 711 780 6177
e-mail: mk@ier.uni-stuttgart.de

Technologies of Wood-Combustion

Arno Strehler

1. Introduction

The critical greenhouse effect caused by greenhouse gases, mainly CO_2, and the limited availability of fossil energy sources call for increased efforts in energy saving and utilisation of renewable energy systems. Due to this large potential and many positive side effects biomass has a high priority in replacing fossil energy. Biomass resources, caused from solar radiation, have a theoretical potential which is 10 times higher, than the total world consumption of primary energy, with around 7 billions tonnes of oil equivalent (OE) per year. If we evaluate all growing biomass on land worldwide we get an energy equivalent of 70 bill t OE. The limitation of availability of fossil energy is in the range of 50 to 70 years for crude oil and natural gas and of about 200 years of coal. Climate experts tell us that we are not allowed to use fossil energy over such a long period. We have to face a climatic catastrophe, if we continue using fossil energy at this high rate. There is a need to save energy, our largest potential and to replace fossil fuels soon by using renewable systems like biomass.

2. Potential of renewable energy systems

Figure 1 shows in column 1 the total energy consumption, in column 2 the consumption of fossil energy. Column 3 offers the total energy in biomass fixed on land per year. The next columns are ideas, how much land would be necessary to cover a part of the demand of energy via energy plantations. As there is a very high need to fight against growing deserts, energy plantations would be an appropriate procedure. Many people discuss the competition between energy plantation and nutrition of mankind. Regionally there is some competition, no doubt about that, but not in global points of view. As figures from FAO Rome show, by the year 2000 about 50% of the arable land will not be in use

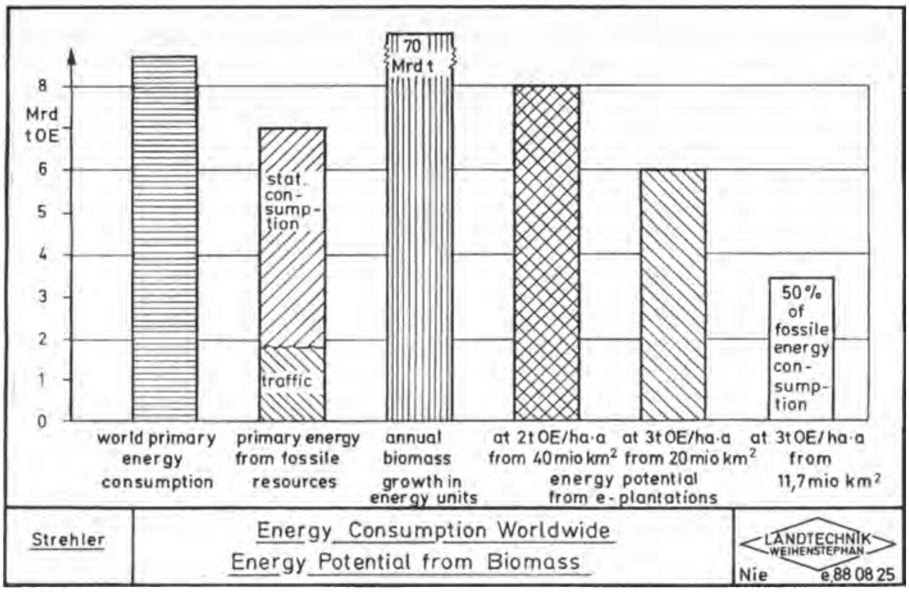


Fig. 1: Energy Consumption World-Wide Energy Potential Biomass.

for crop production anymore. This area alone would cover the energy demand shown in column 6 in Figure 1.

It seems very sensible to utilise land for energy crop production, because it would be endangered otherwise by water- and wind erosion as a result of the greenhouse effect.

In Germany we have a relatively high energy demand. The primary energy consumption is in the range of 340 mill. t OE, covered mainly by fossil resources. They have to be replaced. In case of an ecological tax reform a saving of 50 % seems to be possible. The rest has to be replaced mainly by renewable energy systems. There are the cheap resources such as by-products (straw, wood waste) and more expensive energy crops. When grown on 5 million ha of so called "surplus areas" in agriculture, the potential could reach 20 to 36 million t OE. The low value is for a high share of oil crops, the high value reflects on a high share of high yielding energy crops as solid fuel, as shown in Figure 2.

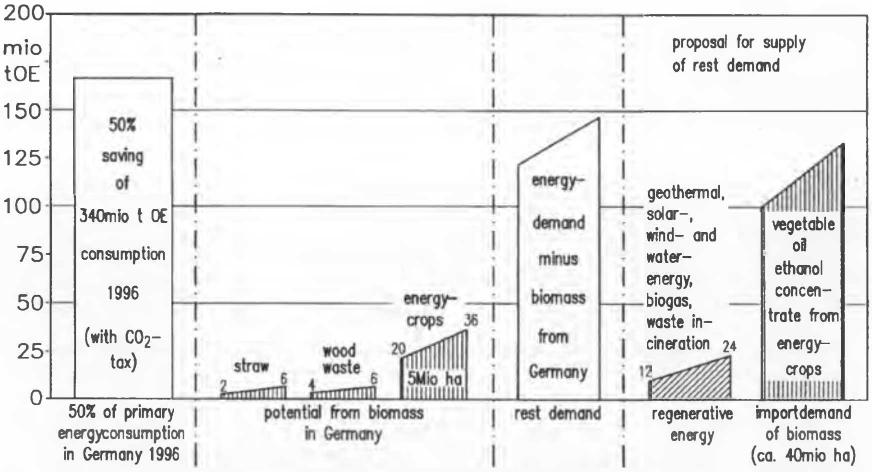


Fig. 2: Substitution of fossil energy in Germany via saving and use of regenerative energy.

3. The fuel

3.1 Energetical value of biomass fuels

Different types of biomass fuels have a calorific value in the range of 15500 to 16500 kJ/kg, with 15 % water content. Apart from the calorific value the ash content is very important. Pure wood has only 0.5 %, wheat straw up to 6 % ash content. The difference in ash content leads to different calorific values. The most important chemical elements delivering the energy are carbon, hydrogen sulphur and phosphorus. Table 1 shows these important values characterising biomass fuel including a comparison to coal and fuel oil.

Just some figures for practise: 10 t of straw harvested from 2.5 ha arable land or 30 m³ of wood (stacked rolls or logs) deliver as much heat as necessary to supply a medium sized house in Central Europe for 3–4 months during wintertime. The fuel demand of a middle sized farm could be covered by straw from 5 to 10 ha or by using 60 to 120 m³ fuel wood. Special energy saving dwellings have a much lower demand in the range of 6 to 8 m³/year.

3.2 Biomass fuel properties

The combustion characteristics of straw, wood and other biomass sources depend basically on their moisture content and chemical characteristics. Table 2 shows the specific weight and calorific value in relation to its moisture content. Fuel should be air dry in order to have a storage without losses. Especially in small furnaces a low moisture content is the basis of a high combustion quality. Wood and straw should be stored rain-protected and with aeration systems (forced or natural draft).

The high content of volatiles causes problems in straw and wood combustion. Therefore, it is necessary to control the power when using discontinuous charging. Burning systems with separate chamber for gasification and secondary combustion chamber to burn the gas perfectly are necessary. Wood furnaces do not work properly in the range below 50% of performance. To cover a lower heat demand a heat store is necessary. This can be a big water tank, the size should reach 100 litter per 1 kW heating performance. This combination allows to run the furnace in the optimal range with low emission and to utilise as much heat as necessary without influence on the boiler efficiency. Surplus heat will be stored in the water tank. As soon as the water tank is heated up,

Table 1: Fuel characteristics.

Fuel	Volatiles %	Calorific Value MJ/kg	Ash %	C %	O %	H %	N %	S %
Straw	80.3	14.2	4.3	44.0	35.0	5.0	0.5	0.1
Wood	85.0	15.3	0.5	43.0	37.0	5.0	0.1	-
Charcoal	23.0	30.1	0.7	71.0	11.0	3.0	0.1	-
Peat	70.0	13.5	1.8	47.0	32.0	5.0	0.8	0.3
Brown coal	57.0	13.6	1-15	58.0	18.0	5.0	1.4	2.0
Mineral Coal	26.0	29.5	1-15	73.0	5.0	4.0	1.4	1.0
Coke	4.0	25.9	9-17	80.0	2.0	2.0	0.5	0.8

Table 2: Specific weight and calorific value of wood and selected biomass fuels.

Biomass Fuels	Moisture content	Calorific Value		Bulk Density kg/ m³	
	%	kcal/kg	kJ/kg	Spruce	Beech
Meter logs	0	4 420	18 560	310	400
(Spruce & Beech)	10	3 910	16 400	330	420
	20	3 400	14 280	350	450
	30	2 900	12 180	370	480
	40	2 410	10 100	390	510
	50	1 920	8 100	410	530
Wood chips	10	3 910	16 400	160	180
(Spruce)	20	3 400	14 280	180	200
	30	2 900	12 180	200	220
	40	2 410	10 100	215	235
Plant Residues				High Density Bales	
- Cereal straw	10	3 700		15 500	120
- Corn stalk	10	3 440		14 400	100
- Flax stive	10	4 040		16 900	140

charging of the furnace has to be stopped. When the heat store starts to reduce its temperature even in the upper layer, charging of furnace has to be started again. There is also a possibility of burning vegetable oil to gain energy from biomass. But this possibility will not be discussed in this paper.

4. Harvesting, storing and processing of wood for combustion

The combustion behaviour of the biomass fuels depends on the one hand on their chemical properties and on the other hand on the physical structure of the organic materials. The physical structure can be influenced by different processing techniques like milling, cutting, compaction, baling or pelleting.

4.1 Wood harvesting and storage

Wood is available in different forms of processing, from saw-dust to big voluminous wood pieces. The different types of processing are shown in Figure 3. Saw-dust is mainly available in wood processing industries and sawmills. It can be utilised in special small stoves with discontinuous charging, in units with automatic fuel charging or in large injection units. Wood chips are produced from soft wood, mainly in the forest where wood should be pre-dried naturally to diminish the technical drying costs. To prevent moulding, the moisture content of the pre-dried wood chips should be below 20 %. Drying of wood chips increases its calorific value and makes handling easier.

The most conventional way of wood processing for small voluminous hand charged stoves is the preparation of short rolls or logs and split logs with lengths up to 1 m for large sized combustion units. Briquettes and pellets are mainly produced from saw-dust and bark. Briquetting and pelleting is the basis of utilising this fuel in small combustion units outside the agricultural and forestry sectors. The energy demand of compaction ranges from 40 to 80 kWh/t.

	saw dust	wood chips	wood log 30-50cm length not piledup - piledup	wood logs 100cm length piled up	pellets from saw dust or wood chip
specific weight kg/m³	120 - 180	160 - 250	250 – 500	300 – 500	400 - 600
weight per unit kg	—	- 0,2	0,4 - 2,5	3 - 25	0,03 - 0,2
yearly storage room demand average dwelling m³	105 – 140	70 - 105	40 – 105	40 – 70	35 - 50
aptitude for transporting short-distance	+ +	+ +	+	+	+ +
aptitude for transporting long-distance	+	+	0	+	+ +
charging of combustion chamber	mechanical and by hand	mechanical and by hand	by hand	by hand	mechanical and by hand
possibility of charging by hand	0	0	+	++	+
automatic control of charging	+	++	—	—	+
possibility for power regulation	++	(0 under b.) ++	0	0	+ (++)
usual charging- and recommendable combustion systems	interm. special stoves contin. in wood chip comb.	coarse wood chips, underburn., all wood chip combustions with cont. charging, most prefurnace	interm. under-burning	intermitt. underburning or through burning	intermittently underburning or cont. wood chip comb.

notice : ++ = very suitable + = suitable 0 = possible - = less suitable

Fig. 3: Technical characteristics of wood for combustion.

4.2 Technical routes of wood processing, storage and charging for different types of combustion units

Many forms of biofuels are available. Depending on its origin, wood is processed and stored in different ways. Sawmill and saw-dust from wood processing and saw industry can be utilised directly in special injection furnaces or it can be calibrated to different sized pieces via pelleting and briquetting. Pellets can be utilised in small units with automatic charging. Briquettes replace mainly wood logs. The briquettes with up to 60 mm diameter can also be charged automatically to big boilers. Wood waste from thinning in the forest and from sawmill residues are most often chipped to pieces from 5 till 50 mm diameter. For all this forms of fuels special furnaces have been developed. The possible routes from processing to charging in furnaces are shown in Figure 4. The most important are wood log and wood chip combustion.

5. Technical characteristics of wood stoves and wood boilers

5.1 Furnaces with discontinuous fuel charging

5.1.1 Stoves and boilers for short logs, briquettes and coarse wood chips

Many manufacturers produce stoves and boilers for short wood logs and most of them are also appropriate for briquettes and coarse wood chips. Figure 5 shows a common single stove working with through-burning system.

Simple through-burning stoves require short charging intervals for good combustion quality. When buying a single stove, people should pay attention to the possibilities in heat control, movable grate and big sized ash-box. Regarding the combustion system, most of the warm air tiled stoves are similar to this construction. In order to reach higher efficiency, the primary combustion chamber is connected to a heat exchanger which is leading the heat to the surrounding air. The heated air leaves the tiled stove through openings which can be adjusted to the heat demand required. The cold air enters the tiled stove at the bottom is heated inside and leaves the unit at the top using the thermal effect. The stoves used only for wood should have a big sized combustion chamber.

Recently, tiled stoves have also been produced with an underburning system. This type of combustion unit has the advantage of longer intervals in charging while maintaining a high combustion quality. More common are systems with top burning systems in connection with a secondary combustion chamber. This type is shown in Figure 6.

The so called "tiled ground stoves" having a very good heat storage property, are sold mostly for wood combustion. These stoves are produced by local specialists and are usually very expensive especially when using high value parts requiring a specific work of art.

This basic stove delivers the energy mainly through radiation. Here the main disadvantage is the long delay (at least two hours) from ignition to the delivery of heat. However, the advantage of this type of stove is providing heat for up to 10 hours after the combustion has stopped.

Combined furnaces. There are many varieties of wood stoves, from open chimney to tiled stoves. There are chimneys with the possibility of closing the combustion chamber. They are manufactured either from glass or metal. This type is a compromise between fun and heat efficiency. Even open chimneys are delivered with parts of boilers to be able to circulate the heat of the chimney in the central heating system. So called

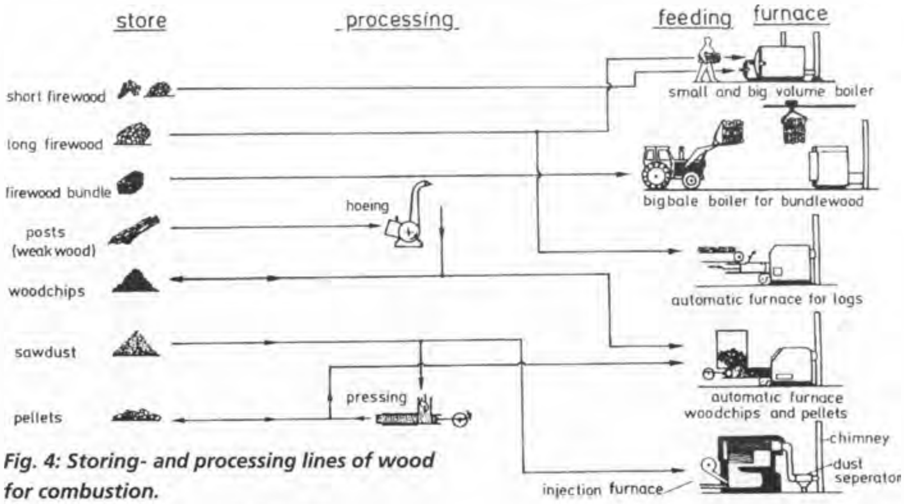


Fig. 4: Storing- and processing lines of wood for combustion.

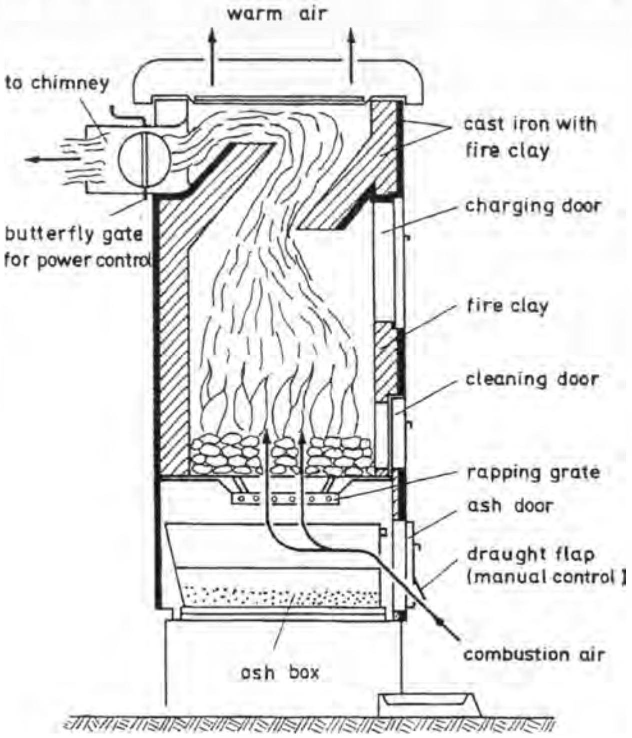


Fig. 5: Through-burning stove for short wood logs, briquettes and coarse wood chips.

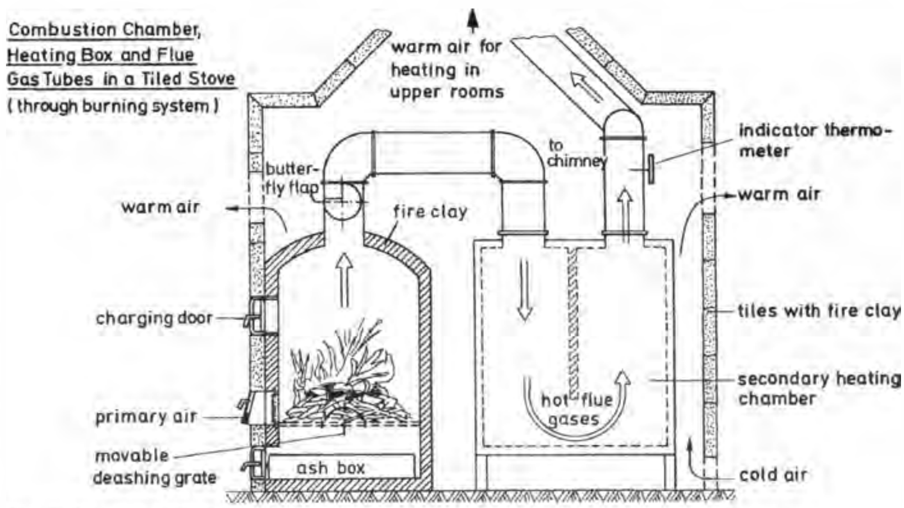


Fig. 6: Warm-air tiled stove with heatbox.

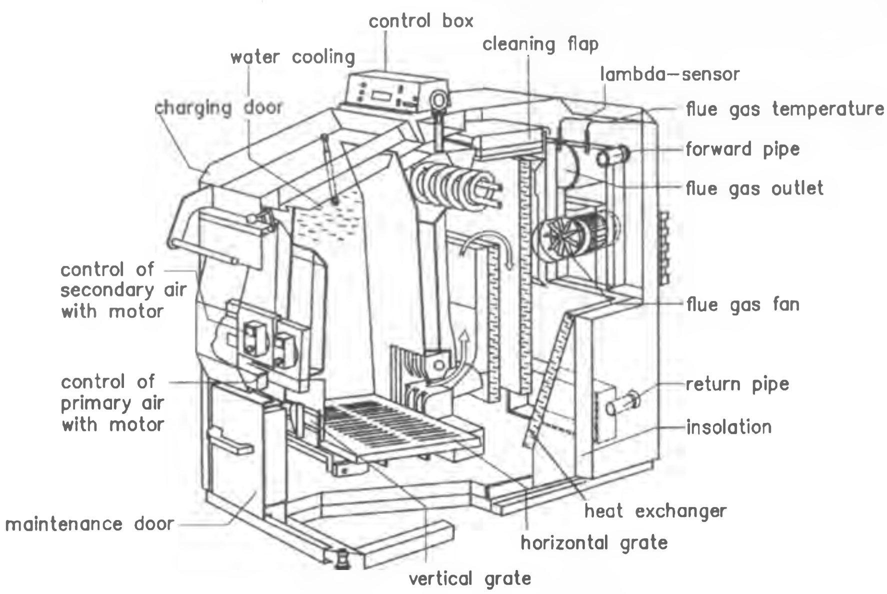


Fig. 7: Bottom burning boiler with flue gas fan and top charging.

chimney stores have a glass charging door in front of the combustion chamber. They are very popular as additional heater.

Heat-herd. Another variety is the so called heat-herd-system. This furnace is used mainly in small or medium size agricultural dwellings in forestry regions. New types include a movable grate (with adjustable height) for optimal adaptation to the type of fuel and to summer and winter situation. The power regulation is satisfactory. The high frequented charging is less favourable. To save labour, due to the work load with ash removal and charging it becomes more and more common to install a central boiler in a special room.

Central boiler. In contrast to the single stoves, central boiler systems deliver the heat in a radiator grid all over the dwelling. Heat circulation pumps distribute the hot water to the radiators and thermostats regulate the heating power in the rooms to be heated. A boiler thermostat switches on the circulating pump as soon as the boiler temperature reaches 70–80 °C, in order to avoid corrosion in the boiler.

The boilers are sold mainly with under-burning systems, in order to save labour. Figure 7 shows the system of a boiler for short wood pieces. All manufacturers deliver bottom-burning systems for short wood pieces, coarse wood chips an briquettes from bark, straw and saw-dust. The most important points are the proper connection to a secondary combustion chamber of high temperatures and the satisfactory retention time for the flue gases for oxidation. The secondary combustion air has to be adjustable, and it should be pre-heated. Modern furnaces adjust the secondary combustion air additionally via flue gas quality using O_2- or CH-sensors.

Many manufacturers produce highly efficient wood boilers with low emissions. Since the last ten years CO-emissions were reduced at least ten times from 2000 mg CO to 150 mg CO/m³ flue gas.

5.1.2 Boilers for coarse wood chips and long wood-logs

In order to save labour for charging of biomass boilers, large volume furnaces for whole bale burning and wood-logs are often used in agriculture. In this case there are through-burning and under-burning systems in practice.

Through-burning systems. The first small-bale boilers came from Denmark and originally they were relatively simple in construction to keep costs low. The combustion chambers were cylindrical, in a horizontal position with a length of 1.2 m and a diameter of 0.8–1.2 m. In front was a big charging door and inside of this door a small charging door to avoid flue gas entering the heating room during charging operations. The combustion air entered the boiler through two flaps controlled by a thermostat. With too low suction of chimney it was difficult to run these boilers, because critical flue gases left during charging and even up to 20 min after charging via chimney with high pollution. The low combustion quality, especially with straw and wet wood, led to improvements of this boiler by many manufacturers. For utilisation of hot air, additional heat exchangers and gas cleaning units were applied.

Wood ash has to be removed every two months and straw ash every 1 to 3 weeks. To avoid low combustion quality when the furnace is not operated at full

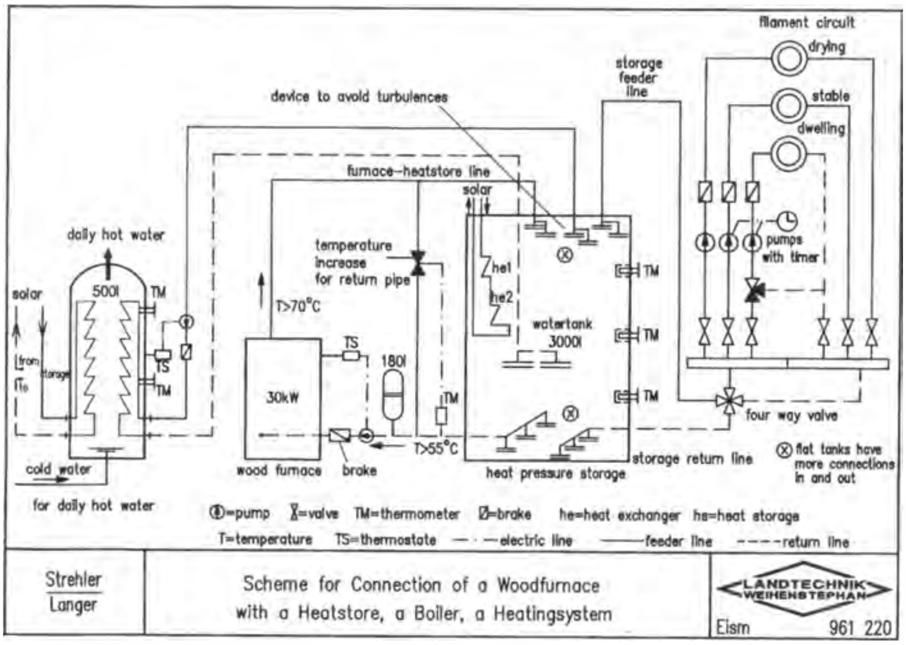


Fig. 8. Connection of a woodfurnace with other devices.

power, the boiler has to be combined with heat stores. The minimum size of the store is a water tank of 100 litres for each kW heating power. In this case, the stored heat is sufficient to cover the night heat demand even in the cold season. During the day, when the furnace runs at full power, it covers both the day heat demand and the heat necessary for the night. In summer, it is enough to heat up the store once a week or less often, depending on the hot water requirement. Many manufacturers of boilers deliver their own heat store system.

One example of a well proved heat store system is shown in Figure 8.

The specific prices of biomass boilers are between 200–300 DM/kW in Germany. Including costs of heat-store, the total investment cost becomes 300–400 DM/kW (thermal). Including the installation and heat distribution devices, the specific investment cost of straw and wood heating systems are in the range of 400–600 DM/kW.

Meanwhile, there are bottom burning boilers for meterlogs on the market. A water-cooled fuel chamber of at least 1.10 m length, 0.5 m broad and 0.8–2 m high can store fuel for 3 to 10 hours. The charging door can be placed on the sidewall (good for wood log feeding) or on the top (for wood, but mainly for straw bales). All modern furnaces for wood and straw are equipped with a flue gas fan to ensure proper function and low emission.

5.2 Furnaces with automatic fuel charging for wood chips and pellets

Soft wood, produced in the forest or wood residues from forests and saw mills have to be chopped to make them suitable for efficient combustion with low labour demand.

5.2.1 Pre-furnace system

The main advantage of the so called pre-furnaces is that the old oil boiler can be used as a heat exchanger. Replacing the oil-burner the pre-furnace can be directly adapted to the system. Pre-furnaces are usually fed through automatically controlled augers or hydraulic cylinders. The feeding rate of biomass fuel follows the actual heat demand automatically. The combustion air is provided by a fan. Some furnaces are

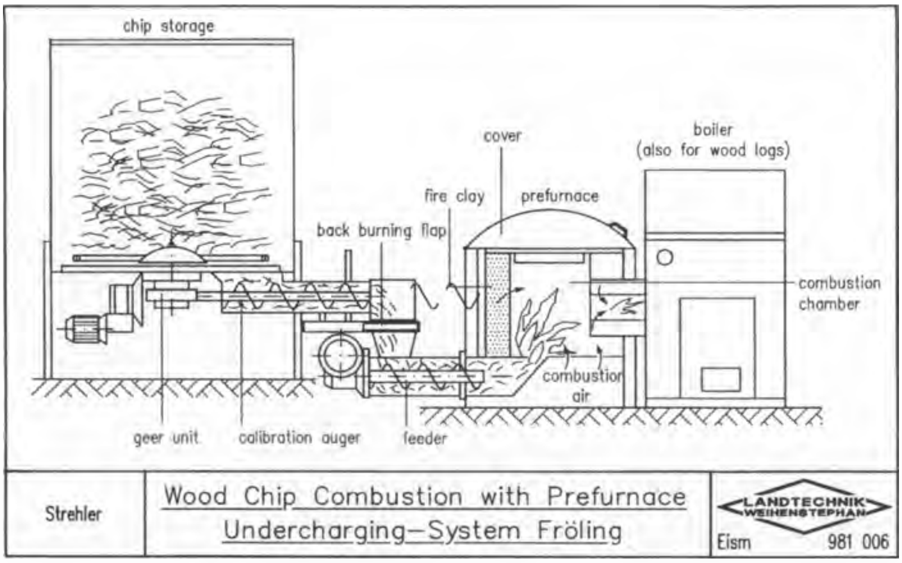


Fig. 9: Arrangement of a pre-furnace system.

divided into primary and secondary combustion chambers. The combustion air flows through different sections. The newest pre-furnaces are equipped with an automatic electrical ignition system.

The flames produced in the pre-furnaces reach the boiler together with the hot gases, which are not completely burned in the pre-furnace. The boiler is used as a secondary combustion chamber and heat exchanger. The fuel is charged automatically from a feeding box which contains the fuel for half a day up to two months. Between the feeding box and combustion unit, there is security equipment to protect the unit against return burning. The feeding box can be charged automatically from a large pre-container (long-time fuel store) or has a big size directly.

Some pre-furnaces are relatively cheap, therefore they can already be proposed for wide-scale practical applications. A simple pre-furnace including fuel supply, one-day fuel container and feeding box costs about 20000 DM, having a power output of 50 kW, that means approximately 400 DM/kW. One example is shown in Figure 9. If there is a higher heat demand of 150 kW the price of the low-tech pre-furnaces is only 30 000 DM, which is equal to a specific price of 200 DM/kW. Daily function control is necessary with these pure units. But there are many high tech pre-furnaces on the market, the price is higher. Undercharging and movable grate systems are engaged. The performance is in the range of 12 kW up to some megawatts.

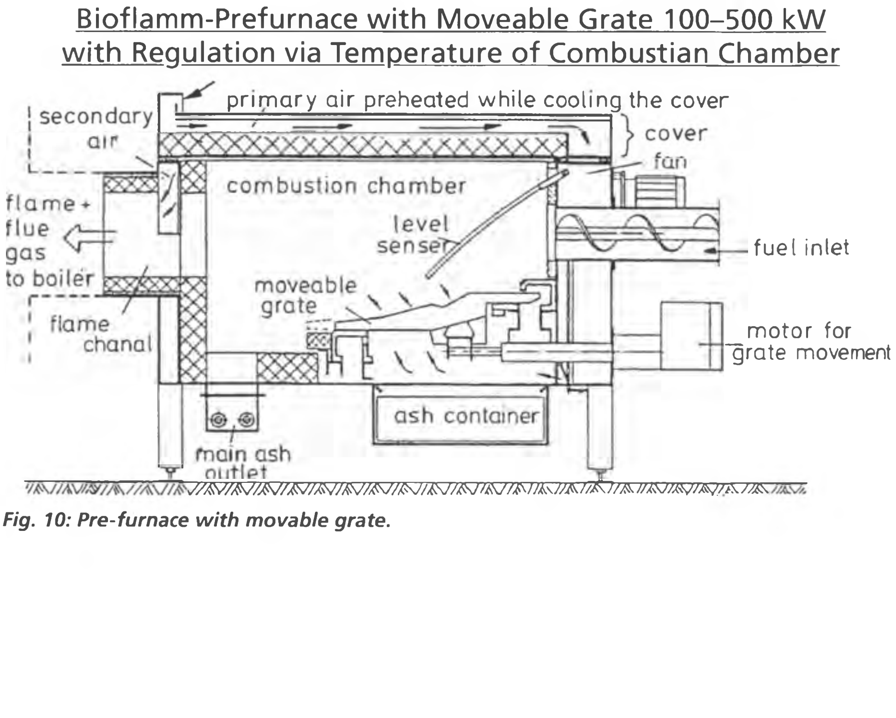


Fig. 10: Pre-furnace with movable grate.

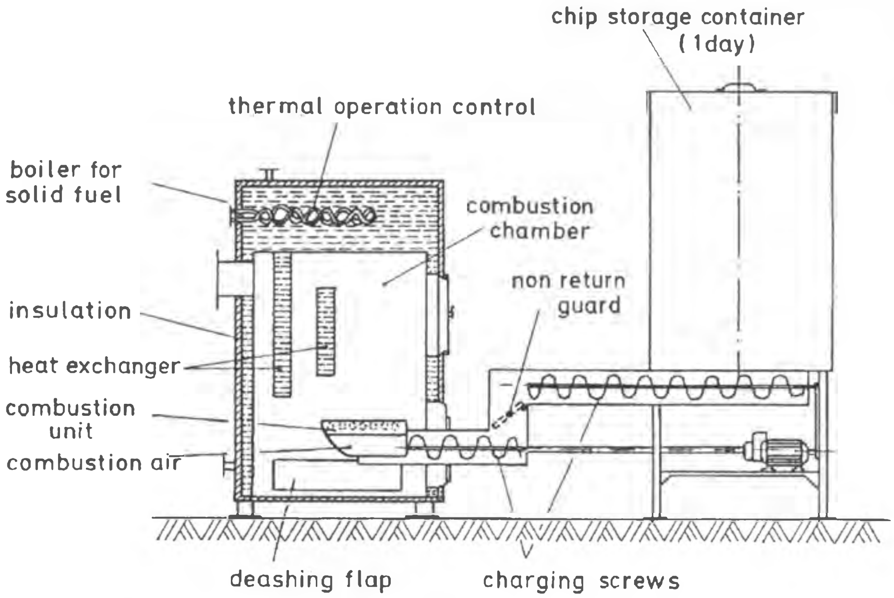


Fig. 11: Stoker as under charging system

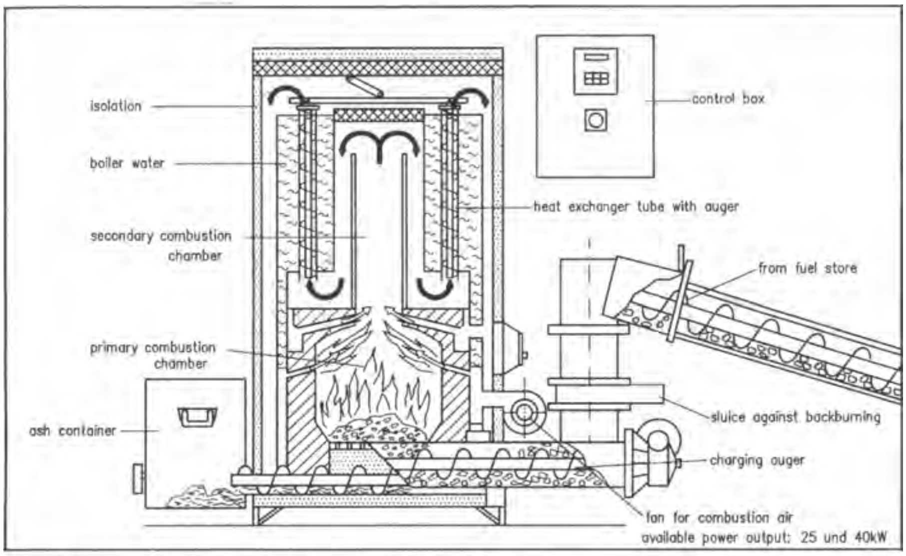


Fig. 12: Undercharging system in a small boiler (Fröling).

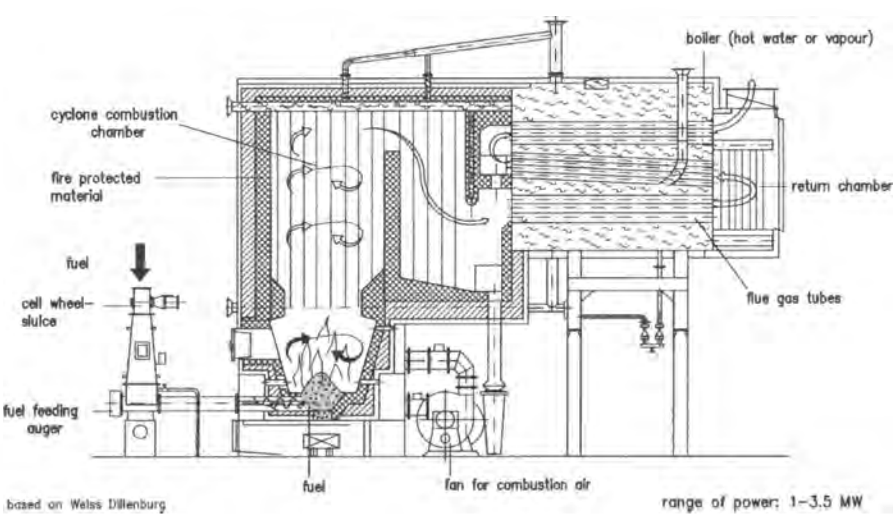


Fig. 13: Undercharging system for high performance with a steam boiler.

In the case of a higher demand in combustion quality (urban area) more expensive pre-furnaces have to be applied. If fuel is to be fed directly into the combustion chamber, and ash removal has to be done automatically, then movable grates or ash bars should be applied.

The pre-furnace with sloping grate can also be charged by auger conveyors. A level control system protects the furnace from overcharging. The primary and secondary combustion air supply results in a higher combustion quality. The WVT manufacturer produces this type of pre-furnaces with fixed and movable grates

The undercharging combustion systems have been applied with great success in big and even small furnaces as well as in pre-furnaces and directly in boilers. In these furnaces, the reliable removal of ash from the combustion area is liable. Many manufacturers install too small ash containers, which leads to an additional workload.

If an almost fully-automatic biomass combustion system is requested with wood chip burning, a furnace with movable grate should be applied, however, these combustion units are much more expensive than the simple pre-furnaces with stepped movable grates. The pre-furnace can also be operated efficiently with chopped straw, sawdust, cereals processing waste and other biofuel.

Stoker systems. If a large sized boiler is available which can be used as a heat exchanger, the oil-burner can be replaced by a so called stoker-system instead of a pre-furnace. In this case, the combustion takes place in the boiler (Figure 11), which probably leads to a lower combustion quality, but on the other hand the heat losses and costs are much lower. In the case of a low power demand (below 50 kW) the stoker-system is relatively economic. Electrical ignition is also available for stokers. The cost of this type of furnace are 13000–15000 DM for 20–40 kW units.

5.2.2 Boiler integrated wood chips furnaces

In the case of a new investment, boiler integrated furnaces are more reasonable than pre-furnace types. They need less space. The combustion systems are the same. Very common are undercharging types with low performance, shown in Figure 12 and with high performance in Figure 13, the last one with the possibility of vapour production and power generation.

Wood chip district heating plants. In the beginning, the district heating plants installed furnace systems which were similar to the ones used in the wood processing industries long before. Now they have been modified to meet the requirements of whole-tree chips, especially as regards the conveyor systems and combustion chamber. The furnace system for fuel chips must cope with a relatively high moisture content, i. e. in the range of 55–60 % moisture of the total weight. Special heat exchangers allow recondensation of water in the flue gas in order to improve the heat efficiency.

Figure 14 shows the layout of a chip-fuelled district heating plant. Today's operational experiences with such plants show that great interruptions in operations belong to the past. Smaller disturbances do occur, whereas larger breakdowns are rare for the latest plants. When problems occur, the reason is often the feeding system where oversized wood fragments cause interruptions. All in all, the operational stability of most modern chip-fuelled heating plants is close to the operation stability of coal-fired heating of the same size. Also critical flue gas emissions could be reduced drastically in the last decade. The heat distribution costs nearly as much as the boiler including the charging system with 800 till 1000 DM/kW.

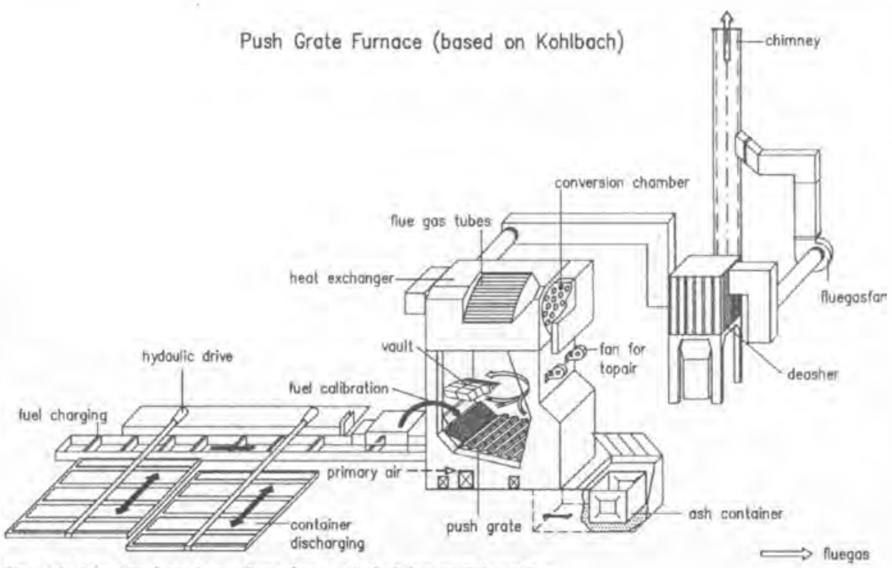


Fig. 14: District heating plant for wood chips combustion.

6. Economic aspects of wood combustion

The market prices of different heat generators can be compared if their so called specific prices measured e. g. in DM/kW are calculated. These specific prices are shown in Figure 15 for various energy sources and different types of heat generators on the left side. The specific price ranges for some types of biomass heating plants from 200 till 1000 DM/kW, having automatic charging facilities and high efficient burning systems. The annual costs result from interest and depreciation with 15 % from investment.

Furnaces with low heating performance have, in general, a higher specific price, especially when expensive technology is adapted for automatic charging. Hence furnaces with high power output show a comparatively low specific price.

The economy of biomass combustion depends basically on fuel prices, while the net usable heat, which can be generated from the different fuels, has to be evaluated in relation to the costs of the combustion unit. Fuel prices for wood lead to heat costs from 0.03 till 0.06 DM/kWh, as shown in Figure 15 on the right side. Labour costs are in the range of 0.01–0.04 DM/kWh heat. The capital cost result form annual costs divided through heating hours per year (2000). The capital costs (basic line Fig. 15) plus labour costs + fuel costs are the main components for total costs, ranging from 0.05 DM/kWh up to 0.20 DM/kWh under less favourite conditions. Figure 15 shows the total costs for oil combustion with 0.08 till 0.11 DM/kWh when fuel oil costs only 0.40 DM/litre. All 0.10 DM/litre price lift lead to a cost increase from 0.01 DM/kWh. Fuel oil prices from 1.10 DM/litre, as given in Sweden and Denmark, would improve the wood combustion in Germany to a high competition.

7. Environmental aspects

The environmental aspects of using biomass for heat generation can be summarised as follows:

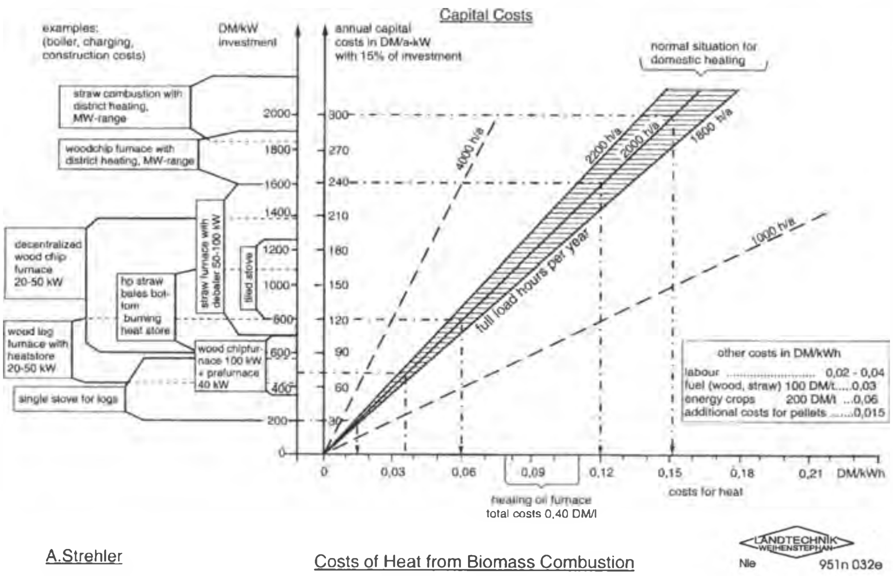


Fig. 15: Cost calculation.

- when using biomass as energy carrier, there is always a closed CO_2 circle. That means, that in the case of energy generation from biomass, there is no growing CO_2-content in the atmosphere, when crops will be planted continuously.
- The heavy metal content in biomass raw material is close to zero, and therefore, there is no heavy metal emission during combustion.
- The sulphur content in biomass is very low. Even in the case of straw, the sulphur content of flue gas is much smaller than that of the light heating oil combustion.
- The nitrogen content in biomass is also low, except for some crops of high protein content. In this case there must be a NO_x-control when burning the material.

Unfortunately there are also negative environmental effects of biomass combustion which should always be kept at low level:

- particularly in straw combustion there is a high dust emission, therefore the filters have to be used for partition of the flue-gas. Hydrocarbons will also be emitted when wet fuel is used.
- Smell and carbon-monoxide (CO) are also developed in a higher degree when the solid biomass fuel has too high moisture content or the combustion chamber is not constructed and adjusted properly. In general, the hot secondary combustion area should be applied, the gas retention time should be at least 0.5 seconds and the combustion temperature should be kept around 1000 °C.
- Slag problems occur with straw combustion and with wood and high bark content when the primary combustion area in the regio of the fuel has a too high temperature, i. e. more than 1000 °C in the ash.
- It is very important to avoid the smell of biomass combustion, which is caused by CH at low temperature levels. This is possible when the secondary combustion area is well designed. Temperature has to be more than 1000 °C, gas retention time should be at least 0.5 seconds. Two-step combustion should be standard when a discontinuous charging is applied.

Parameters	Instruments	Computerised Analysis
CO_2	Brigon Indicators with Liquids	x
CO	Brigon Indicators with Liquids	x
CH	Special Gas Indicator Devices	x
O_2	Liquid Indicator	x
No_x	Fuel Gas Analysis	x
Dust	Pump, Filters, Compact Instrument	-

The above parameters are usually measured and evaluated when the environmental effects of biomass are analysed.

New results of the Weihenstephan test unit show, that the combustion of non polluted wood leads to unimportant low emission of dioxin, polycyclic aromates and other poisonous gases when furnaces are of adequate design and well used.

Author's address

Dr. Arno Strehler
Bavarian Research Station
for Agricultural Engineering
Weihenstephan-Freising
Technical University Munich
Vöttinger Straße 36
D-85354 Freising
e-mail:
str_sek@ban.tec.agrar.tu-muenchen.de

Poster Presentations and Additional Contributions

Biomass Energy in a Small-Scale Region of a Developed Country – The Case of the District of Göttingen

Christian Ahl

Introduction

Innumerable studies describe the theoretical, technical, economical and forecasted potential of energy resulting from renewable energy sources of biomass for the total world, (*Hall*, 1997; *Wood* & *Hall*, 1994), for Europe (*Ahl*, 1993; *Wrixon* et al., 1993), for a country (*Kaltschmitt* & *Wiese*, 1993) or for a region (*Ahl* & *Eulenstein*, 1994). For the individual citizen, living in a town or a small village of a developed country, these results, either in percentages or Joules, etc. are not very easily grasped or reflected in relation to his or her own situation.

For the regional and municipal planning authorities, the potential of RES of the area under consideration is either not known or the various resources are not brought together in any figure concerning their energy potential. Waste departments, agricultural departments, forest departments and nature-resource caring authorities do often elaborate energy studies relying on their particular resources, either wastes, sewage-sludge, wood, agricultural by-products, landscape raw materials, etc. only.

Methodology

To calculate the several accessible sources of RES on a district level and scale, specific conditions and frameworks have to be established by questioning the private and administrative authorities about the quantity and quality of possible RES (of which they are mostly not aware of).

The current framework of agricultural production in the district of Göttingen is, of course, the Common Agricultural Policy (CAP) of the European Union (EU); in the case of forestry production it is the Waldgesetz (Federal Forestry Law), which sets boundary conditions.

Other sources of forestry or agricultural production are garden and landscape by-products of the public sector (the private organic waste is not included). In the past, the acreage of nature protection was enlarged and the biomass resulting from managing the nature conservation areas will contribute in future to the total resources.

Energy consumption, in terms of the private sector, is split into thermal energy, electricity and transportation. As no statistics are available on a district level, the average usage of energy on the federal level was scaled down on the 260 000 inhabitants of the district of Göttingen. The household sector, total transportation and the industrial sector count for 11 700 kg CO_2 per capita. Heating sums up to 2300 kg CO_2 which is about 8000 kWh per year and inhabitant in Germany (*German Bundestag*, 1990). The mean emission factor for heating resources (gas, oil, coal, steam) is about 0.08 kg CO_2 per MJ (*Hartmann & Strehler*, 1995).

To calculate the calorific value of the different biomass sources, the assumption was made, that dry matter would be delivered to the thermal district heating station. Of course, the moisture content reduces the heating value MJ/kg material, but it is strongly dependent on the production chain, pre-treatment and climatic conditions. Therefore, the dry matter yield of each production system concerned was taken as a basic for a calculation method.

Results

Agricultural Production of Biomass in the District of Göttingen

The total utilised agricultural area (UAA) in the district of Göttingen is about 56 000 hectares. In the year 1995, 6000 hectares were set-aside under the respected CAP-scheme, while 28 000 hectares were cultivated with cereals (*LWK*, 1996).

On 730 hectares of the set-aside land, rapeseed was the preferred crop under the current subsidy-system with an average yield of 3600 kg rapeseed/ha, or, 1.2 t of biodiesel. The remaining 5900 hectares were up to now fallow, either green- or bare-fallow, but could be cultivated with a cereal-variety with high mass-yield. Under extensive biomass-production, 13 t of dry matter (inc. straw and grain) would be a realistic figure.

Of the average cereal production, 50 % of the straw could be probably assumed to be available for energy purposes, 50 % remained on the fields or was used as foodstuff or was not collectable.

Table 1 summarises the results of arable biomass production in the district of Göttingen.

In fact, the potential could be raised by implementing more efficient energy crops into the crop rotation or including short rotation forestry on long-term set-aside land (*Dimitri*, 1988). The Biodiesel option is currently well accepted by the

Table 1: Biomass-Production in the Arable Sector of the District of Göttingen (only plant production), 1995.

Land-use in ha	yield t dm/ha	total t dm	in GJ
6 600 set-aside 730 rapeseed 5 900 cereals	 3.6 t rapeseed 13 t straw & grain	2 628 or biodiesel: 870 t 76 700	32 000 (for biodiesel)[a] 1 342 250
28 000 cereal-prod.	5 t straw	50%: 70 000 t	1 225 000
total: 2 599 250 GJ			

[a] 37.5 GJ/t Biodiesel

Table 2: CO_2-Credits from agricultural sources in the district of Göttingen.

Product	GJ	t CO_2/GJ	total replaced CO_2 in t
Biodiesel	32 000	0.063	2 016
Energy cereals	1 342 250	0.074	99 327
Straw	1 225 000	0.074	90 650
in total: 191 993 t CO_2			

Table 3: Forestry production in the district of Göttingen.

		in total			just thinnings		
Forest	m^3/ha *year	m^3	t	TJ	m^3	t	TJ
27 500 ha broad-leaved trees	5	137 500	89 400	1 564	82 500	49 500	866
10 170 ha conifers	7	71 190	28 500	500	42 700	17 000	300
		in total: 2 064 TJ			**in total: 1 166 TJ**		

farmers although from the energy point of view solid biomass production would result in a higher input/output ratio for energy. Therefore, the Biodiesel production and its energy content equalise a net substitution for fossil fuels in CO_2 credits 0.063 t CO_2/GJ[1] replaced end used-energy. For the solid matter, the replacement factor is about 0.074 t CO_2/GJ of end used-energy (*Hartmann* & *Strehler*, 1995).

Forestry Production of Biomass in the District of Göttingen

37690 hectares of the district of Göttingen are covered by forests. 66 % of the tree varieties are broad-leaved trees, of which beech hold 73 %, and conifers count for 34 % with a 76 % majority of spruce. The annual dry matter growth for broad-leaved trees is 5 m^3/ha and year, for conifers it is about 7 m^3 /ha and year. Different options might be possible: all growth might be assigned to energy purposes or, rather, 60 % of the growth used as thinnings for energy consumption.

Usually, the woodfuel replaces the fossil energy of the various heating-systems in private houses or in buildings such as public swimming pools, schools, or hotels etc. District heating based on wood chips or pellets from wood residues diminishes the CO_2-burden of the atmosphere with a net-effect of 0.079 t CO_2/GJ.

For the two options considered, the overall-use of forest wood in the district of Göttingen for energy purposes would result in a net-depletion of CO_2 of 163000 t, for the 60 % option in 97900 t of CO_2.

Biomass from Landscaping and Gardening

Landscape features such as hedges, bushes, semi-natural grasslands have been used in the past by the rural population itself as bee-keeping areas, as rough-grazing ground or as basic timber for craftsmen. Today, the countryside has to be managed in order to preserve the resource and to protect habitats of rare flora and fauna. This requires regular cutting and cleaning of the growth of the bushes etc.

This also applies to alley-trees along the roads in the district of Göttingen. Until now the cut wooden material is burnt at the place or redistributed as chips into the slope of routes and motorways.

Results of municipal gardening are grasscuts, small branches, stubs and entire trees, which are rarely marketable. Composting would be one possibility for the fresh organic matter, but for the chipped branches and trees, which are collected during wintertime, the thermal option would be fitting best.

The following compilation (Table 4) takes into account the possible resources of woody biomass other than from the forest and agricultural production.

Roughly 133 TJ of energy could be offered by resources from landscape activities in the district of Göttingen for local energy supply.

Thermal Energy Supply by Biofuels for the Single Citizen in the Local Area

For the district of Göttingen, it totals as follows inTable 5.

3000 to 4000 kWh for a single person will more than satisfy the total energy for heating in future, if newly constructed houses and renovated older buildings fulfil the so-called Wärmeschutzverordnung (1994, insulation regulation). This regulation sets an upper boundary of heating-expenditure of 100 kWh/m^2. The foreseen consumption will be in the range of 70 kWh/m^2 for average houses with a ratio of outer walls to inner volume of 0.5.

[1] Biodiesel incl. rapecake as foodstuff, without the energy value of straw, but using slurry as N-source.

Table 4: Landscaping and gardening biomass yields in the district of Göttingen.

Matter	Size	Yield t dm/year	total GJ[b]	CO_2 - net effect in t
Hedges & windbreak	50 km length	1 500 t	26 250	2 074
Orchard-meadows	250 ha	175 t	3 063	242
Basket-willow-meadows	25 ha	20 t	350	28
Alley-trees	1 000 km	5 000 t	87 500	6 913
Municipal-gardening	900 ha	900 t	15 750	1 244
	in total:	**7 595 t**	**132 913 GJ**	**10 501 t CO_2**

[b] 17.5 MJ/kg

Table 5: Thermal energy supply for the single citizen and net Carbon dioxide-effect.

Area	Population	a) incl. total forest growth b) thinnings	generated thermal energy per capita (80% efficiency)	saved net CO_2 per capita
District of Göttingen	260 000 inhabitants	a) 4 796 163 GJ b) 3 898 163 GJ	a) 4 088 kWh b) 3 326 kWh	a) 1 406 kg CO_2 b) 1 155 kg CO_2

Kyoto, Rio and the State's Commitment to Carbon Dioxide Reduction

If the Rio commitment of the German Federal State, which was revitalised at the Kyoto meeting in December 1997, still concerns the government and the population, the reduction of the CO_2-level on the basis of the 1990 figures by 25 % is only feasible by combined measures. The amount of 1406 kg or 1155 kg CO_2 which could be saved by each citizen of the district of Göttingen, is about 10 to 11 % of the sum of 11700 kg CO_2 output per capita. Therefore, the use of renewable energy sources in the thermal energy sector for heat-supply alone has the potential of nearly 50 % of the forecasted reduction. If the other measures, as higher energy efficiency, improved building insulation, reductions of transportation by strengthening the regional market, intelligent energy usage etc., would be inserted as a whole in the society, the focus on the reduction of 25 % should be feasible.

The saying "Think globally – act locally!" will help removing the still existing barriers obstructing politicians, administrative authorities and of course the public if the possible benefits of local resources are presented to each individual in a local district as, e.g., in this study for the district of Göttingen.

References

Ahl, C. (1993): Energy & Biomass: Potential for cultivation and prospects for utilisation from the European Community's Perspective. – European Parliament, STOA, Luxembourg.

Ahl, C. & F. Eulenstein (1995): Energie und Biomasse – von EU-Potentialabschätzungen zur realen Regionalbilanz. – Plenarvortrag auf der Terra-Tec-Messe, Leipzig, 1. März 1995, Sektion 11 "Energie" publ. in: Volker U. Hoffmann (ed.): Energie – BG Teubner Verlagsgesellschaft, Leipzig, pp 22–36.

Dimitri, L. (1988): Bewirtschaftung schnellwachsender Baumarten im Kurzumtrieb zur Energiegewinnung. – Forschungsinstitut für schnellwachsende Baumarten in Hannoversch-Münden (Hrsg.), Nr. 4.

German Bundestag (1990): Protecting the earth. A status report with recommendations for a new energy policy. – German Bundestag 1990

Hall, D. O. (1997): Biomass Energy 'Forever' in Non-OECD Countries? Why it is important to know what is going on and how this can be determined. – Biomass Energy: Keys Issues & Priority Needs. OECD/IEA, Paris, pp. 57–77.

Hartmann, H. & A. Strehler (1995): Die Stellung der Biomasse. – Landwirtschaftsverlag GmbH, Münster.

Kaltschmitt, M. & A. Wiese (1993): Erneuerbare Energieträger in Deutschland. – Springer-Verlag, 1993.

LWK (1996): Statistik der Landwirtschaftskammer Hannover, Aussenstelle Göttingen.

Wärmeschutzverordnung (1994): Verordnung über einen energiesparenden Wärmeschutz bei Gebäuden. – Gesetz vom 16. August 1994, gültig ab 1. 1. 1995.

Wood, J. & D. O. Hall (1994): Bioenergy for development. – FAO Environment and Energy Paper 13, Rome, 1994.

Wrixon, G. T., A. M. E. Rooney & W. Palz (1993): Renewable Energy 2000. – Springer Verlag, 1993.

Author's address

Dr. Christian Ahl
Institute of Soil Science
University of Göttingen
von-Siebold-Straße 4
D-37075 Göttingen
e-mail: cahl@gwdg.de

Cascade Utilisation of Biomass: Strategies for a More Efficient Use of a Scarce Resource

Helmut Haberl

Abstract

Biomass use tends to increase the socioeconomic appropriation of net primary production (NPP) and thus leads to major disturbances of the natural energy flow of ecosystems. The appropriation of aboveground NPP in Austria amounts to 41 % which is higher than the estimates for global NPP appropriation (25 to 39 %). There is evidence that NPP appropriation contributes to biodiversity reduction. Biomass thus should be regarded as a scarce resource and used sparingly. If biomass should play a major role for CO_2 reduction, the efficiency of biomass use has to be increased. A suitable strategy is the development of biomass utilisation plans with a focus on a "cascade utilisation of biomass". The use of biomass as a raw material and as an energy carrier should be optimised in an integrated manner: If biomass is used for energy generation which had been previously used for some other purpose this will not contribute to NPP appropriation. The development of optimal biomass utilisation cascades requires that conflicts of interest, e. g. between waste management, economic, energy and environmental policy, and target conflicts between different ecological goals (e. g. reduction of NPP appropriation vs. CO_2 reduction) are overcome.

Introduction

The utilisation of biomass is encouraged for several purposes: It is used instead of fossil energy carriers in order to reduce CO_2 emissions, the anticipated resource scarcity of fossil fuels and the need to import fuels. Moreover, materials made of biomass are used to substitute for many environmentally detrimental materials. For example, wood is used instead of other materials for furniture or as construction material and paper instead of synthetic materials.

There are important arguments in favour of these recommendations: Biomass is indeed a "renewable" resource as long as agriculture does not deplete soil fertility and forests are allowed to regrow after logging. Its use thus contributes to a "closed cycle" economy. In many cases the amount of energy needed for production will be lower if biomass is used instead of minerals which lowers emissions. Moreover, biomass combustion does not contribute to the CO_2 enrichment of the atmosphere. If all biomass for combustion is taken from ecosystems where the plants are allowed to regrow after biomass harvest, biomass combustion should not contribute to the build-up of CO_2 in the atmosphere and is often called "CO_2-neutral".

These arguments may be questioned in detail. For example, when calculating energy balances of biomass use, the fossil energy modern agriculture uses (fertilisers, pesticides, tractors etc.) must not be neglected. Corn production in the USA, for example, yielded 12,4 MJ.m^{-2}.yr^{-1} with a total energy input (fossil fuels and labour input of people and draft animals) of 4,3 MJ.m^{-2}.yr^{-1} in 1985 (*Pimentel* et al. 1990). According to *Smil* (1991), world-wide agricultural harvests amounted to 35 EJ.yr^{-1} in 1985 and required a fossil fuel subsidy of 12 EJ.yr^{-1}. Thus agriculturally produced biomass contributes to CO_2 emissions if the process chain is taken into account. Furthermore, if biomass harvest contributes to a loss of organic material in the soil, this may also contribute to a net CO_2 release into the atmosphere.

These problems notwithstanding I want to discuss another important environmental aspect of biomass utilisation. Biomass use contributes to significant changes of the natural energy flow of ecosystems. The chemically stored energy which plants produce in the process of photosynthesis is the main energetic basis of all food chains. By using biomass, societies alter the amount of energy available for ecological energy flows and also change the quality of the available biomass. As I will show, this intervention is likely to contribute to species loss and is highly relevant with respect to many important ecosystem properties. Thus biomass must not be considered a readily available resource, but is indeed a very scarce resource.

Biomass utilisation and the energy flow of ecosystems

The measure most widely used to characterise the overall energy flow of ecosystems is net primary production (NPP). NPP is the biomass production of green plants in a certain region within one year. Societies greatly influence the amount of NPP actually available for ecosystem processes on their territory: (1) They influence the productivity, i.e. the NPP per m^2 and year of ecosystems, for example by constructing buildings, roads etc., and thus preventing NPP altogether, but also by agriculture and forestry, and (2) they harvest a significant proportion of the biomass which annually grows on their territory. These two processes can be appraised with a single indicator called "appropriation of NPP" (*Vitousek* et al. 1986, *Wright* 1990, *Haberl* 1997). Of course, other properties of ecological energy flows are also influenced by society, e.g. food chains are altered by hunting. Until now, however, the only indicator for societal interventions into ecological energy flows, for which we have sound empirical data which may be quantitatively related to natural processes, is NPP appropriation.

Empirical studies show that the current level of NPP appropriation is significant. *Vitousek* et al. (1986) and *Wright* (1990) have estimated the world wide appropriation of NPP to fall within the interval of 25 to 40 percent. I have estimated the appropriation of the aboveground NPP in Austria in 1990 to be 41 percent (*Haberl* 1997). Data are restricted to aboveground NPP, because there are few reliable data on subterranean NPP of forests. The calculations rely on land-use, agricultural, and forestry statistics as well as meteorological data and harvest factors from the literature. Elevation was considered on the basis of data from a geographical information system. Harvest was calculated from Austrian agricultural and forestry statistics. My results show that the prevention of ANPP contributes 17 % to the ANPP appropriation in Austria, of which about one half is caused by construction, and the other half by an agriculturally induced reduction of productivity compared to natural ecosystems. Agricultural harvest accounts for 49 % of ANPP appropriation, logging for 34 %. Taken together, construction accounts for 8 %, agriculture for 58 % and forestry for 34 % of ANPP appropriation (Table 1).

Calculations based on remote sensing data which are currently under way in our department indicate that NPP appropriation may be even higher. It is very likely that values for many other industrialised European countries are higher. They typically have less than the Austrian 45 percent of forests with rather low NPP appropriation per unit area. Furthermore, 12.6 percent of the Austrian territory are above 1800 m elevation where no NPP appropriation can be assumed to occur. In other countries agricultural areas, roads and buildings are likely to cover a higher percentage of the surface.

Table 1: Socio-economic appropriation of aboveground net primary production in Austria 1990 (Source: Haberl 1995).

	ANPP / biomass [PJ.yr^{-1}]	Percent of potential vegetation
ANPP of the potential vegetation	1 501	100.0%
ANPP of actual vegetation	1 396	92.3%
Harvest	512	34.1%
– of this agriculture	308	20.5%
– of this logging	204	13.6%
ANPP remaining in nature	884	58.9%

Ecological consequences of NPP appropriation

NPP appropriation significantly alters the energy flow of natural ecosystems and may be seen as an indicator for the intensity of human interventions into natural ecosystem processes (*Haberl* 1997). But what do we know about its likely effects on the structure and functioning of ecosystems? NPP is the main energy input for all heterotrophic food chains. Obviously, then, the harvest of 100 percent of the NPP is unsustainable, since this would leave no room for any wildlife species (which in turn would result in the extinction of most heterotrophic organisms as for example animals and fungi).

There is evidence that NPP appropriation has an effect on the structure and length of food chains and on species diversity. If we follow the arguments of *Hutchinson* (1959), we may suspect that a reduction of energy flow is likely to cause a reduction of the length of food chains. Until now, empirical studies failed to produce unequivocal results on this matter. However, a recent study by *Oksanen* (1990) showed that the amount of energy available per unit area greatly influences food chain structure, as far as vertebrates are concerned (for a more thorough discussion of this issue see *Haberl* 1995).

If a reduction of energy flow reduces the length of food chains, then a second assertion of *Hutchinson* (1959) may also prove correct. He postulated that the amount of available energy exerts an important influence on species diversity. In the last two decades this idea experienced a renaissance as the so-called species-energy theory of biodiversity (*Brown* 1991, *Wright* 1987, 1990). In short, the species-energy theory predicts that the number of species which can inhabit a certain environment increases with the amount of energy available; conversely, the number of species will decrease if energy flow is reduced (Fig. 1).

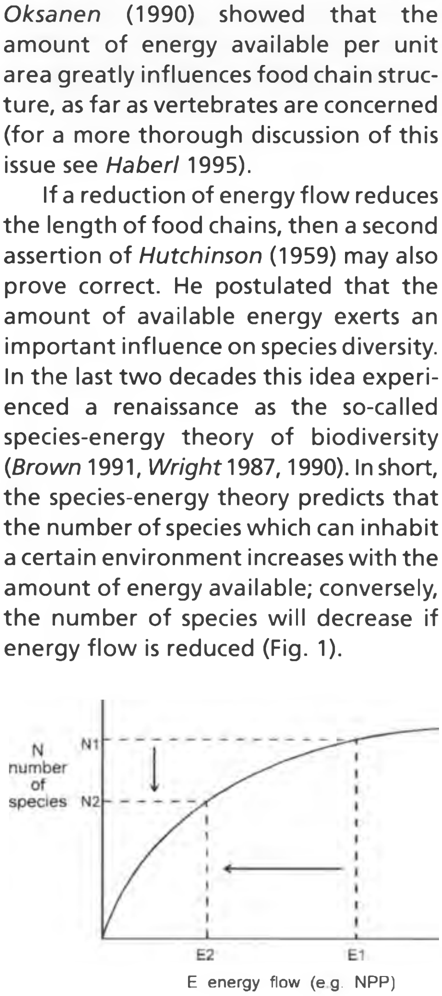


Fig. 1: Species-energy curves demonstrate the relation between energy flow (E) and species richness (N). If energy flow is reduced, species-energy theory predicts a reduction of species richness (after Wright 1990).

This theory predicts that in habitats with abundant resources rivalling species will be able to specialise with respect to more gradients and thus can avoid extinction due to Gauses' principle of competition exclusion (*Brown* 1991). While in poor habitats there are few, generalistic species, in resource-rich habitats many specialists prevail. One reason for this are the "costs of commonness", i.e. negative effects of high population densities (e.g. parasitism, pests, specialised predators) (*Wright* 1987). The species-energy theory is not only able to explain the gradient of species diversity from the poles to the equator, but has also been empirically tested and verified (*Currie* and *Paquin* 1987, *Turner* et al. 1987, *Wright* 1987).

Unfortunately, the formulation of a sound "sustainable level" of NPP appropriation has not been possible until now. To my knowledge there is only one publication on this issue. *Weterings* and *Opschoor* (1992) argue that anthropogenic interference should be "small" compared to natural fluxes. On the basis of this consideration and the current level of global NPP appropriation, they argue for a level of 20 % NPP appropriation as a sustainability criterion. This limit, however, is based on an ad-hoc assumption, not grounded on theoretical or empirical evidence. On the other hand, the current level of NPP appropriation in industrial countries is already considerable. Following the precautionary principle, the proportion of NPP appropriation should not be increased significantly as long as there is no sound understanding of the ecological consequences such a strategy would have.

Biomass utilisation cascades

From the previous discussion we may conclude that significant increases of the biomass harvest of industrialised countries should not be considered a sustainable option for alleviating other environmental problems as for example resource scarcity or global warming. Thus if biomass utilisation should play a major role in environmental policy, its efficiency has to be increased: The biomass harvested should be used as effectively as possible in order to contribute to as much as possible to the substitution of environmentally detrimental materials and fuels.

This could be possible by a strategy of integrated optimisation of material and energy uses of biomass which may be called "cascade utilisation of biomass". The use of biomass as an energy carrier and as a raw material are usually treated separately, and the potential for either are also often estimated independently of each other. Biomass use is often "optimised" only over parts of its supply chain of applications instead of an optimisation over the whole "cascade" of applications. Optimising biomass use to reflect the different characteristics of different biomass sources and of the different sectors of the economy's requirements for biomass of particular physical characteristics would offer significant efficiency gains. For this it is essential to take into account the quality of the biomass required. For example, if biomass (wood) is used for the production of press-boards, the properties of the fibres will be decisive. Other properties, e.g. calorific value, are important, if biomass is used for energetic purposes.

The rationale behind this strategy is that if biomass is used which had been previously used for some other purpose then this biomass use will not contribute to an increase of NPP appropriation. If, however, biomass is harvested additionally, then this biomass use will increase NPP appropriation and is thus ecologically less desirable (it must not necessarily be disadvantageous, though). Integrated biomass development plans which consider the broader implications of biomass production and use could be an appropriate instrument for such a policy. Until now, only first steps in this direction have been made (*Müller* et al. 1995, *Geißler* et al. 1997).

First analyses in Austria suggest that there are significant potentials for the utilisation of biomass residues and/or wastes. Tentative calculations of *Geißler* et al. (1997) show that in Austria there may be a potential of up to 50 $PJ.yr^{-1}$ of currently unused biomass materials which are potentially usable for energetic purposes. This is 36 % of the currently used amount of biomass (138 $PJ.yr^{-1}$) in Austria. This means that without increasing NPP appropriation, biomass utilisation as an energy carrier could possibly be increased by 30 to 40 % with a strategy of cascade utilisation of biomass.

In developing a "cascade model" of the range of sources and applications of biomass, it becomes clear that there are a number of areas where conflicts of interest arise. For example, policies to avoid waste arising will impact on recycling levels and use of materials, and clearly reduce the potential energetic uses of waste. Such conflicts of interests may include among others:

- The aim of contributing to a net CO_2 reduction through the increased use of biomass in general, and in particular through the increased use of biomass in the various sectors of the economy – energy, construction, feedstocks, agriculture.
- The need to keep the appropriation of NPP and thus the primary biomass harvest within the ecological constraints.
- The interests of the waste sector and the raw material cycle, and re-use of biomass (e.g. paper products, chip boards etc.).
- The economic value of each of the biomass use options, and the support for and potential creation of employment on a local and regional level.

Conflicts of interest may be solved within the framework of a multi criteria decision analysis. This is a tool which may be used to support decision making processes in a situation, where a limited amount of criteria must be taken into account, which can not be reduced to one single measure or parameter (*Munda* 1995, *Strassert* 1995). For example, competing options may have economic, social, and environmental aspects. The monetary aspects may be measured by some indicator of economic profitability (e.g. net present value). The environmental impacts may be measured by some environmental indicators or an environmental index. And the social aspects may be only described as some "desirability order" of the three options. Instead of computing some valuation index on the basis of ad-hoc assumptions on the weighing of different criteria, multi criteria decision analysis aids the decision maker to weigh different incommensurable criteria and make explicit his or her preferences.

Conclusions

Instead of viewing biomass as an "ace in the hole" of environmental policy, we should accept the fact that biomass is a scarce resource which should be used sparingly from an ecological point of view. A simple look at the orders of magnitude reveals that a substitution of fossil fuels with biomass would not work: The upper limit for biomass utilisation must be well below the actual above-ground NPP which totals 1.396 $PJ.yr^{-1}$ in Austria. The total energy input of the Austrian society – including nutrition and fodder for animals – amounts to 1.680 $PJ.yr^{-1}$. If we additionally consider that NPP appropriation should not be increased to ecologically disadvantageous levels, then the possible role of biomass combustion for energy policy may be put in a realistic perspective.

A strategy to cope with such limitations is based on the observation that the current environmental problems are a consequence of the quantity and quality of man-made material and energy flows. From this perspective, a reduction of the overall energy and materials throughput of industrial societies should be the core of sustainable development. Rather than replacing one material with another, this concept focuses on the delinking of material and energy flows from economic performance and the quality of life (*Fischer-Kowalski* et al. 1997). On the operational level, then, energy conservation should have priority over an increase of biomass use as a climate protection strategy. A cascade use of biomass could contribute to such a strategy. Of course, it would be valuable to develop such methods and instruments for a broad range of scarce natural resources – as an attempt to delink material and energy flows from economic development and the quality of life.

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References

Brown, J. H. (1991): Species Diversity. In: Analytical Biogeography, A. A. Myers and P. S. Giller (eds.). Chapman & Hall: London (3rd. edition), 57–89.

Currie, D. J. and V. Paquin (1987): Large-scale biogeographical patterns of species richness of trees. Nature 329, 326–327.

Fischer-Kowalski, H. Haberl, W. Hüttler, H. Payer, H. Schandl, V. Winiwarter, H. Zangerl-Weisz (1997): Stoffwechsel der Gesellschaft und Kolonisierung von Natur, Ein Versuch in sozialer Ökologie. Gordon & Breach Fakultas : Amsterdam.

Geißler, S., T. Jorde, H. Gupfinger, H. Adensam, H. Haberl (1997): Grundlagen für die Erstellung von Biomassebewirtschaftungskonzepten auf der Basis einer Nutzungsoptimierung. Unpublished interim report to the Federal Ministry of Science and Transport, Austrian Institute of Applied Ecology, Vienna.

Haberl, H. (1995): Menschliche Eingriffe in den natürlichen Energiefluß von Ökosystemen, Schriftenreihe Soziale Ökologie No. 43, IFF-Social Ecology: Vienna.

Haberl, H. (1997): Human Appropriation of Net Primary Production as An Environmental Indicator: Implications for Sustainable Development. Ambio 26 (3), 143–146.

Hutchinson, G. E. (1959): Homage to Santa Rosalia, or why are there so many kinds of animals? American Naturalist 93, 145–159.

Müller, D., D. Oehler, P. Baccini (1995): Regionale Bewirtschaftung von Biomasse: eine stoffliche und energetische Beurteilung der Nutzung von Agrarflächen mit Energiepflanzen. ETH Hochschulverlag: Zürich.

Munda, G. (1995): Multicriteria Evaluation in a Fuzzy Environment. Physica: Heidelberg.

Oksanen, L. (1990): Predation, Herbivory, and Plant Strategies Along Gradients of Primary Productivity. In: Perspectives on Plant Competition, Grace, J. B. & D. Tilman (eds.), Academic Press: San Diego. 445–473.

Pimentel, D., W. Dazhong, M. Giampietro (1991): Technological Changes in Energy Use in U.S. Agricultural Production. In: Agroecology, Researching the Ecological Basis for Sustainable Agriculture, S. R. Gliessman (ed.), Springer Ecological Studies 78 : New York, 305–321.

Smil, V. (1991): General Energetics, Energy in the Biosphere and Civilization, Wiley : New York.

Strassert, G. (1995): Das Abwägungsproblem bei multikriteriellen Entscheidungen. Lang : Frankfurt/Main.

Turner, J. R. G., C. M. Gatehouse, C. A. Corey (1987): Does solar energy control organic diversity? Butterflies, moths and the British climate. Oikos 48, 195–205.

Vitousek, P. M., P. R. Ehrlich, A. H. Ehrlich, P. A. Matson (1986): Human Appropriaton of the Products of Photosynthesis. BioScience 36 (6), 368–373.

Weterings, R. A. P. M. & J. B. Opschoor (1992): The Ecocapacity as a Challenge to Technological Development. Advisory Council for Research on Nature and Environment. Publication RMNO Nr. 74a, 1992.

Wright, D. H. (1987): Estimating Human Effects on Global Extinction. International Journal of Biometeorology 31 (4), 293–299.

Wright, D. H. (1990): Human Impacts on Energy Flow Through Natural Ecosystems, and Implications for Species Endangerment. Ambio 19 (4), 189–194.

Author's address

Dr. Helmut Haberl
Interdisciplinary Institute for Research and Continuing Education of the Universities Innsbruck, Klagenfurt and Vienna (IFF)
Dept. of Social Ecology
Seidengasse 13
A-1070 Vienna, Austria
e-mail: helmut.haberl@univie.ac.at

Renewable Resources and their Energetical Use

Kurt Häge

Summary

On a recultivated area of the Jänschwalde opencast mine, the company Lausitzer Braunkohle Aktiengesellschaft performs a large-scale test for the production of biomass by alley-cropping in co-operation with the Technical University of Brandenburg, Cottbus, and the Institute for Energy Resources, Cottbus.

Alley cropping is a method for planting fast-growing tree species in alleys with field strips lying in between the tree rows for the use of energy wood and biomass. This aims at providing alternatives for the land use and the energetical use of renewable resources. The project alley cropping shall link agricultural and silvicultural utilisation and test it under the climatic conditions of Lower Lusatia.

In parallel to the field test, combustion processes for the energetical use of wood and biomass are investigated at the Institute for Energy Resources. The target of these investigations is to essentially improve the efficiency of the energetical use of renewable resources by means of innovative combustion processes, for example cycloid firing. It is intended to prove the efficiency by which renewable resources can be converted into thermal energy under Lusatian conditions. In this way, alley cropping contributes to saving resources and to developing innovative technologies for heat production.

Author's address

Prof. Dr. Kurt Häge
LAUBAG
Knappenstraße 1
D-01968 Senftenberg, Germany

State Energy Policy and Utilisation of Biomass in Slovakia

Ján Ilavský and Milan Oravec

1. Introduction

The economic transformation in Slovakia, accompanied by the considerable decrease in production within the most parts of the national economy, has caused decrease in the energy and fuel consumption. Compared to the year 1989, the total annual energy consumption during the year 1994 decreased by 20 %. Since the year 1995, as a result of gradual increase in economic production, the consumption of energy and fuel has been increasing and the level of the consumption already reached in the year 1989 will to be reached again around the year 2000, when the total annual consumption of energy and fuel will be about 950 up to 1000 PJ.

During the current decade, the gradual change in the structure of fuel consumption is expected. In particular, there is a considerable increase in natural gas consumption. The electric energy produced on the basis of nuclear fuel will exceed more than 50 % of the total production. More than 25 % of the electricity has been produced by coal combustion in thermal power stations equipped with desulphurisation systems. It is assumed, that the construction of steam-gaseous equipment and plants based on the natural gas will be used as well as there will be more use of the renewable sources of energy.

Slovakia has to import approximately 90 % of the primary sources of energy and reserves for the domestic sector, non-renewable sources of energy are very limited. Therefore, increased demand of energy has been forcing us to a more rationalised use of non-renewable sources of energy, together with the expansion of the use of renewable sources of energy as well as the creation of ecologically and economically acceptable combinations, too.

Only very small attention has been paid to the use of renewable sources of energy until the year 1991. Main reasons for this situation were the centralisation of the sources of energy as well as the considerable financial support and the subsidies towards the classical fuels and produced energy. Potentially, apart from hydro-energy, the most important renewable source of energy, which is ready almost for immediate use, is biomass from forestry and agriculture.

The main producers of biomass suitable for energetic use are mostly the various branches within forestry, woodworking industry as well as within agriculture. At present, the only use of biomass for energy purposes is the production of heat. The forestry sector produces annually, on average, 400 000 tons of fuelwood with an energy value of 3800 TJ, more than 90 % of it being sold to inhabitants. Only a very small quantity, which means approximately the amount of 10 000 tons, is used for the purposes of energy production from forest biomass in form of chips, which corresponds to an energy value of 180 TJ annually. The organisations of the forestry sector have their own consumption which represents a quantity of 2000 tons annually.

Within the wood-working industry, an amount of 250 000 tons of waste wood is used annually for the purposes of energy production. Within the agricultural sector, biomass for energy has practically not been used. The exception is one straw incinerator with an output of 230 kW. A small amount of straw is occasionally exported to Austria.

The total quantity of biomass, which is used annually for energy production amounts to 660 000 tons with an energy equivalent of 6270 TJ, which represents 0.6 % of the total fuels and energy consumption for the whole of Slovakia.

The majority of the boilers used for biomass combustion do not meet the requirements from the point of view of environmental and energy parameters. The main obstacle to the development and modernisation of the conversion technology for energy from biomass is lack of financial means.

2. State energy policy and utilisation of renewable energy sources

The strategic target of the Energy Policy is to supply energy to all consumers, at the same time, energy has to be:

- produced at the lowest cost and the minimum environmental impact
- transported to the consumer safely and reliably
- used in the sphere of energy sources with transport and consumption as effectively as possible.

The main goal is to achieve

- the necessary level of certainty in obtaining energy resources and the orientation of the energy economy of the Slovak Republic towards efficient and environmentally acceptable technology for electric power generation
- increased use of renewable and secondary energy sources
- introduction of energy efficient manufacturing technology processes and appliances that would help to achieve gradual lowering of both energy intensity and absolute energy consumption.

The creation of the energy policy is based on

- an economic development revival strategy
- forecasts of the gross domestic products (GDP) development
- a strategy for providing of primary energy resources (diversification of imports, transit, storage capacities)
- analyses of economic results of Slovakia
- a strategy for supplying fuel and energy to the residential sector
- international conventions, declarations and documents (e. g. Energy Charter)
- opportunities and forms of foreign capital input.

One of the goals of the energy policy is to achieve a sufficient level of security in obtaining of energy resources. In the field of providing the fuel resources and the use of fuels, satisfying of following strategic interests will be crucial:

- to secure by means of long-term contracts imports of strategically important raw materials and fuels (crude oil, natural gas, coal, nuclear fuel)
- to search for options of diversification of natural gas and crude oil imports, with the aim to decrease the vulnerability of the economy of the SR
- to provide for sufficient stock of solid fuel for both residential and power sectors
- to preserve domestic extraction of brown coal and lignite on deposits being exploited
- to change gradually the structure in fuel consumption in favour of an increased share of environmentally preferable fuel types, particularly by the use of dendromass
- to provide for the development of domestic extraction of hydrocarbons in accordance with discovered natural potentials of their sources
- in the field of natural gas storing, to solve purposefully the conversion of petroleum-gas bearing deposits so that it would be possible to built up sufficient storage capacities for the needs of the SPP, and consequently for foreign customers, and to establish strategic reserves of natural gas
- to increase transmission capacities of the transit system of the SR
- to establish legislation-type and economic conditions for increased use of renewable and secondary energy sources
- by means of a further development of the transit system and increased transportation of natural gas, to provide for an increased foreign currency income which is necessary for purchasing natural gas from other countries
- to search new possibilities for realisation of integration-type activities in the Russian Federation with the aim to secure the supplies of natural gas in return for exports of investment complexes
- to build up transit power links with Austria and Poland.

To fulfil these intentions is very demanding from the investment point of view. It will require flexibility in the investment policy, in the use of combined capital sources and in obtaining suitable loans.

The overall review of the current energy production and energy consumption in Slovakia is illustrated in the best way by the Energy Balance conceived for the period 1990–1994, in order to provide the history of the development within this sector since the foundation of SR.

It has to be mentioned that electricity generated from nuclear fuel is included in domestic production. Nevertheless, the nuclear fuel is 100 % imported. So the nuclear fuel should be included in the imported energy carriers

Table 1: Structure and Development of Domestic Energy Carriers.

Carrier / year	1990		1991		1993		1994	
	PJ	%	PJ	%	PJ	%	PJ	%
Brown Coal	54.0	49.1	47.0	56.6	47.7	65.5	48.8	62.9
Crude Oil	3.0	2.7	2.9	3.5	2.8	3.8	2.8	3.6
Natural Gas	24.0	21.8	10.0	12.1	8.3	11.4	9.5	12.2
Hydro-Energy	11.0	10	8.0	9.6	13.9	19.2	16.4	21.2
Others	18.0	16.4	15.1	18.2	0.1	0.1	0.1	0.1
Total	**110**	**100**	**83**	**100**	**72.8**	**100**	**77.6**	**100**

Table 2. Structure and Development of Energy Carriers Import.

Carrier / year	1990		1991		1993		1994	
	PJ	%	PJ	%	PJ	%	PJ	%
Coal	279.1	29.3	247.4	30.7	213.3	29.7	193.4	27.1
Crude Oil	269.3	28.2	207.4	25.7	187.5	26.1	198.1	27.8
Natural Gas	249.6	26.1	202.7	25.1	180.1	25.0	185.6	26.0
Nuclear	131.0	13.7	127.0	15.8	120.1	16.7	132.3	18.5
Electricity	26.2	2.7	21.8	2.7	14.4	2.0	3	0.4
Others	0	0	0	0	3.7	0.5	1.3	0.2
Total	**955.2**	**100**	**806.3**	**100**	**719.1**	**100**	**713.7**	**100**

what means the real domestic production is 10.8 % and import 89.2 %. The only possibility to decrease the import is the increased utilisation of domestic renewable energy sources and further implementation of rational use of energy measures.

3. Renewable energy sources

The use of renewable energy sources in Slovakia is not very high. The share of renewable energy sources in the overall primary energy consumption is slightly higher than 2 %. However, Slovakia has quite a substantial potential, which is expected to be used mostly at regional level. Data on the theoretical and technically feasible potential vary in different sources not only in terms of numeric data, but also in their structure. Potential of renewable energy sources as described in the Slovak energy policy is listed in the following Table 3:

Table 3: Potentials of renewable energy sources.

Source	Energy potential (PJ)
Geothermal	7.160
Biomass - (forest and waste)	15.714
Small hydro	2.574
Solar	4.9
Wind	1.1
Industry and municipal waste	3.6
Waste heat	4.5
Total	39.548

4. Utilisation of biomass for energy

Biomass is one of the most important primary energy sources in Slovakia. The main utilisation is expected on regional level and depends on the development of each region.

The most suitable biomass types for energy generation in Slovakia are

- forest biomass: wood and wood processing waste
- agricultural biomass: straw and manure for biogas.

The expected amount of forest biomass in the year 2010 is about 1 260 000 tons which is an equivalent of 11.4 PJ of annually generated energy. The development of the annually usable amounts of biomass by 2010, suitable for energy generation, will depend on the annual output of wood, the orientation of the forest industry and the price changes for wood.

Currently, straw from the production of cereals is not used for energy generation, only some portion is exported to Austria. The potential of straw depends on the production of cereals, which has decreased currently. The production of cereals in 1993 was around 3000 × 103 tons, which means some 3200 × 103 tons of straw with an energy potential of about 46 PJ. Supposed that ⅓ of the straw could be used for energy production, the overall potential annually could be approximately 15 PJ.

Biogas generated mainly from animal manure, household waste, food industry and sewage plants, represents a theoretically potential of approximately 15 PJ, which means that the realistic usable potential could be some 5 PJ.

This is, of course, an estimation based on the current situation. Potential

Table 4: Biomass resources in Slovakia for energetic purposes.

Type of fuel	Average annual usable amount [t.year⁻¹]	Energetic equivalent	[1]Energy consumption		[2]Outputs of fuels and energy (3–5) [TJ.year⁻¹]	[3]Produced energy [TJ.year⁻¹]
			Specific consumption [GJ.t⁻¹]	Total consumption [TJ.year⁻¹]		
1	2	3	4	5	6	7
A. Sources from forest						
– small wood+harvest losses	250 000	2 375	0.23	58	2.317	1 912
– waste at forest landings	40 000	380	0.19	8	372	307
– waste at central landings	50 000	475	0.15	8	467	385
– precommercial thinnings	13 000	124	0.23	3	121	100
– stumps	20 000	190	0.31	6	184	152
– fuelwood	440 000	4 180	0.09	40	4.140	3 416
B.Small wood-processing plants						
– piece waste	100 000	950	0.23	58	2 317	1 912
– sawdust, shavings	50 000	475	0.14	8	372	307
C.Fast-growing tree species	300 000	5 100	0.23	58	2 317	1 912
Together: A		7.724	—	123	7.601	6.271
B		1.425	—	11	1.414	1.167
C		5.100	—	96	5.004	4.128
TOTAL			—	**230**	**14.019**	**11.566**

[1] – Energy production of consumption in working operations: skidding – chipping – biomass transport and consumption of energetic sources

[2] – Difference between energetic value and energy consumption

[3] – Calculated on basis of an average energetic efficiency of 82.5%

sources of forest biomass for energy are listed in following Table 4:

According to the conditions in Slovakia there are following prospective forms of energy production:

a) Direct combustion of raw material
- hot-water heating of buildings,
- production of technological steam,
- production of technological heat,
- production of electricity (steam turbine, gas turbine) and utilisation of waste heat,
- hot-air drying,
- forest biomass as main fuel in combustion of communal and industrial wastes.

b) Energetic gasification of dried out raw material
- production of electricity (gas motor + generator),
- production of electricity and utilisation of waste heat,
- pyrolytic combustion for heating,
- combination of the mentioned forms with charcoal production.

c) Briquetting of dried-out fine grained waste
- heating of houses, recreational buildings, hot-air heating, etc.

Other forms of energetical biomass utilisation could be implemented with difficulties considering economically reachable concentrations of raw material and present state of technology development.

Significant factors influencing the method of energetical utilisation and installed capacity (output) of energetical equipment are as follows:
- biomass parameters of quality, mainly moisture and grain size,
- biomass concentration,
- energy consumption.

The moisture of forest biomass after short-term storage varies in the interval 40–45 % and after long-term approx. 1 year storage in the covered stockyard −20 %. The raw material with a moisture content over 20 % can be used effectively in direct combustion. Raw material with a moisture content below 20 % can be gasified and for briquetting material moisture content has to be 10–15 %. The moisture problem can be solved by artificial drying which has to be calculated in the energetical balance and the cost of the energy production.

In Slovakia, an average theoretical concentration of raw material per one region is 15500 t.year^{-1} with respect to an economical maximal transportation distance of 25 km. Actually a concentration of fuel dendromass in consumption localities will be in the range from 300–5000 tons. Regarding the energetical properties of biomass, brown coal and heating oils can be substituted by biomass. In regions where gas is not available for heating, biomass can be an alternative of natural gas.

Combined heat and electric power production can be applied at outputs of more than 500 resp. 1000 kW in operations or in district heating systems.

For direct biomass consumption it is necessary to have suitable heating equipment with a capacity of 25–1000 kW. The need of higher outputs will be solved by a design of equipment with greater capacity according to the users conditions or by installation of series of heating equipment. Special technologies will be used for biomass combustion with various waste.

Energetical gasification of dried and raw material:
- Production of electricity in combination with using waste heat in localities where raw material with a corresponding moisture content is supplied. According to the energy consumption, power stations work on a capacity of

40–80 kW, occasionally their combination will be used. It will be used mainly in small wood processing plants.

■ Production of electricity with utilisation of waste heat in localities which are not connected to the public networks of energy production. Waste heat will be used partially for drying of wood for gasification.

Pyrolytic combustion of fuelwood in form of bolts will be used for the heating of family houses and small objects as well in situations where a thermal output of 20–80 kW is needed. It will be especially applied for users who have direct access to fuelwood (workers in forestry, forest owners).

Briquettes are an ecologically advantageous substitution of coal in classic combustion chambers without necessity to treat them.

In 1993 and 1995, the Forest Research Institute in Zvolen proposed the Conception of energetic utilisation of forest biomass in Slovakia. The Ministry of Agriculture and the Ministry of Economy of the Slovak Republic have accepted the submitted Conception and it was consequently included in the State Energy Policy of the Slovak Republic by the year 2005 approved by the Government of the Slovak Republic.

5. Literature

Ilavský, J., Majer, E., Oravec, M.: Utilisation of the forest biomass for energetic purposes in the Slovak Republic. In: Zemìdìlská technika, 41, 1995, No 2, pp. 79–82.

Oravec, M., Ilavský, J., Majer, E., Hollingdale, A.: Concept of utilisation of the forest biomass for energy in the Slovak Republic. World Energy Congress, Copenhagen, June 1996, 6 pp.

Anon.: The Energy Sector of Slovakia. EC Energy Centre, Bratislava, June 1996, 52 pp.

Authors' address

Dr. Ján Ilavský
Dr. Milan Oravec
Forest Research Institute
Masarykova 22
96092 Zvolen, Slovak Republic
e-mail: ilavsky@fris.sk

Utilisation of Biomass in Slovakia[1]

Ján Ilavský and Milan Oravec

Technology for production of fuel-biomass

Technologies have been designed for utilisation of dendromass from precommercial thinnings as well as from final fellings depending on the place of performance of the individual working operations, the composition of the machinery sets according to users´ subjects (large state enterprises, private firms etc.). Data were calculated on the basis of the annual efficiency of the respective machinery sets. The calculations were made on the level of direct production costs which provide a better possibility of comparison thus eliminating the influences of the other costs, especially of overhead costs which distort the resulting values.

Chipping or crushing of wood waste is a prominent technological operation during its processing. The choice of kind and type of equipment for the size adjustment depends on the locality of occurrence, kind and concentration of raw material and on the method of its utilisation: technological or energetical (direct combustion, gasification, briquetting, etc.). The chipper S-800 was developed and constructed at the Forest Research Institute and is determined for the processing of less valuable wood occurring in low quantities. It has an annual efficiency of 2000 to 3000 t of chips. The waste wood chipper D-1000 was developed for the processing of larger wood quantities.

Chipper S-800

S-800 is a disk chipper intended for processing of wood up to 15 cm diameter. It operates as a mobile equipment mounted to the three-point tractor suspension or it is stationary driven by an electric motor. It has either two knives for chips with a length of 12–25 mm, suitable for direct combustion or in case of raw material of better quality for technological purposes, or it has three knives in a disk and produces chips of a length of 4–8 mm, suitable e. g. for production of fuel briquettes.

Basic technical specifications:	
diameter of chipping disk	830 mm
number of chipping knives/ counter knives	2 (3)/1 ps
admission aperture	265 x 285 mm
max. diameter of chipped wood	150 mm
chips length adjustable	5–25 mm
drive – electric motor	40 kW
– three point tractor suspension	50 kW
chipping dis speed	
– stationary	750 turns.min^{-1}
– mobile	950 turns.min^{-1}
weight of chipper	900 kg

Waste wood chipper D-1000

The waste wood chipper is intended for the dimensional homogenisation of wood raw material which is not workable at all or only with great problems. In forestry, this is the case with short tail cuts-off (waste wood) resulting from round wood handling, branches of coniferous trees from branch-trimming machines, stems, roots, brushes, etc. In agriculture mainly branches from fruit tree cuttings, shrubs from pasture lands clearings and from recultivation, switches from vineyards cutting, etc. are considered. The waste wood chipper will also have a more extensive use for liquidation of various kinds of wood wastes in building trade and industry, for instance sheeting units, pallets, rafters, etc. In the long run these equipments will be needed for biomass utilisation from forests with a very short rotation period (so-called energetic forests).

Basic technical specifications:	
diameter of chipping drum	600 mm
number of drum turns (speed)	1000 min^{-1}
number of knives	20 pieces
admission aperture	
– width	1000 mm
– height	350 mm
average size of chipped material	20–40 mm
max. diameter of wood	300 mm
capacity	18 m^3.h^{-1}
weight	8000 kg

[1] Extract of a poster presentation. Information which is already included in the previous presentation is not repeated.

Production of energy from forest biomass

Forest biomass is characterised by considerable dimensional diversity. For better transport, handling and in order to increase energy production efficiency it is necessary to adjust the raw material dimensions by chipping (branches, trees) and crushing (manipulation and processing of waste, stems).

At present, direct combustion of forest biomass is energetically and economically the most efficient method of its energetic use in woody regions for heating of buildings (central heating plants or individually) as well as the combined production of energy and heat in case of larger concentrations of fuelwood.

Energetic gasification including the production of electric power is suitable in wood-working plants or as suppliers for the public electricity grid.

Briquettes are an environmentally friendly substitution of coal in classical furnaces without necessity of adjustment where the continuos supply of woodfuel is not available.

The realisation of intentions to expand the energy production from biomass depends on available technologies at acceptable prices and a technical level on European standard.

The price policy in fuel and energy applied by the year 1990 in former socialist countries did not stimulate a development of renewable energy sources utilisation. Renewal of interest in utilisation of renewable energy sources due to liberalisation of prices has elicited the need of technological development.

In 1991 the Forest Research Institute designed the scientific and technical project *The Utilisation of Forest Biomass for Energy*, included in the programme *The Utilisation of the Secondary and Renewable Energy Sources* by the former Federal Ministry of Economy in Prague. During 1991–1992, the Forest Research Institute in Zvolen completed the above-mentioned project within the framework of the whole Czechoslovak Federal Republic. Since the year 1993 the Forest Research Institute has been co-ordinating and investigating working place for the project *The Utilisation of Forest Biomass for Energy* on the basis of the requirements of the Ministry of Economy of the Slovak Republic.

The mentioned projects are intended to solve the following problems:

- design and development of technologies and machinery for harvest, collection, transport and dimensional homogenisation of biomass suitable for energy utilisation,
- development of combustion equipment for moist biomass adjusted dimensionally within the range of capacity from 100 to 3000 kW,
- development of internal combustion engines for wood gas with generator of electricity in the range of capacity from 23 to 50 kW,
- development of gasification generators for wood gas production for gas engines in a capacity up to 88 kW,
- development of a briquetting press, capacity 500 kg per hour.

Currently, proposed solutions are in the realisation and pre-realisation phase, respectively. In 1993 the Forest Research Institute Zvolen proposed the Conception of energy utilisation of forest biomass in Slovakia. The Ministries of Agriculture and Economy of the Slovak Republic have accepted the submitted Conception and it was consequently included in the State Energy Conception of the Slovak Republic by the year 2005 approved by the Government of the Slovak Republic in July, 1993.

Energetical benefits

6250 TJ energy can be produced using 400000 t of forest biomass unused till the present time and by more effective utilisation of fuelwood. 115.2 TJ of energy, i.e. 1.84 % of the amount produced, is consumed for preparation and energy production.

By managing energy forests and utilising their production it is possible to produce 4200 TJ in the year 2005. For managing, felling and own production of energy 3.8 % of the given amount are used. Thus, the average annual energetic profit is 4040 TJ.

Ecological benefits

600 960 t of brown coal with a heating value of 13 $MJ.kg^{-1}$ and an energy production efficiency of 80 % will be substituted by the production of 6250 TJ of energy from forest dendromass. The pollution load to the environment will be reduced by 3.08 mil. t of CO_2, 93300 t of SO_2, 7810 t of No_x, 30400 t of fly ash and 120000 t of slag and ash. The production of CO_2 during the combustion of biomass is part of the natural cycle of substances and it does not increase its share in the air.

In the case of implementation of energy forests projects 401000 t of brown coal graded can be substituted in 2005. This will prevent the production of 2.06 mil. t of CO_2, 62300 t of SO_2, 5210 t of No_x, 20300 t of fly ash and 80000 t of slag and ash.

Economical benefits

The costs of obtaining raw material in suitable quality from the point of view of grain size and moisture are one of the decisive economic criteria for profitability valuation of energy production from wood.

According to the grain size the assortment is classified as follows: fuelwood assortment, piece and fine-grained waste from processing and wood hand-

Table 1: Direct production costs for preparation of forest dendromass.

Raw material	Direct production costs (DPC) ($Sk.t^{-1}$)	Price per 1 GJ (Sk)/US$ (1 US$ = 32 Sk)
Dendromass from clearings	415 - 600	43.70-63.20/1.0-2.0
Dendromass from thinnings	156 - 619	16.40-65.29/0,5-2.0
Dendromass from regeneration felling	268 - 489	28.20-51.50/0.9-1.6
Underground dendromass	410 - 610	43.20-64.20/1.4-2.0
Sawdust from forest depots and small wood-working plants	100 - 200	10.50-21.10/0.3-0.7
Cut-offs from forest depots and small wood-working plants	150 - 300	15.80-36.80/0.5-1.2

Table 2: Price of heat produced in a boiler house with installed capacity of 0.5 to 1.6 MW (Results of the study of reconstruction possibilities of coal municipal boiler houses elaborated by the Forest Research Institute in Zvolen).

Fuel	Price for 1 GJ	
	$Sk.GJ^{-1}$	$US\$.GJ^{-1}$
Brown coal	216 - 268	6.8 - 8.4
Natural gas	188 - 222	5.9 - 6.9
Forest chips	150 - 181	4.7 - 5.7

ling, respectively, chips and chipped material. Dimensional homogenisation of wood by splitting or chipping often increases the cost of fuel, however, a direct combustion enables utilisation of simpler and cheaper furnaces and better control of the combustion process and by this way a higher efficiency of energy production. Energy gasification and briquetting require utilisation of raw material homogenised dimensionally.

Production costs of preparation of wood as a fuel depend on the number and quality of work invested in performances which have to be executed. The least costs are for waste originating during processing or wood handling when the considerable part of cost is included in the price of the main product. Direct costs of preparation of fuel consist only of potential dimensional homogenisation and necessary transport.

Preparation of fuel from cutting residues from stands includes all working operations from skidding to transportation to the place of consumption. Counting the economic profitability it is necessary to consider the savings from the removal of the raw material from the felling area. The savings resulting from stand hygiene improvement are difficult to calculate in advance.

The direct production costs for preparation of forest dendromass, including transportation, are as follows:

The present price of forest chips in Slovakia is 600 to 750 $Sk.t^{-1}$ (18.8–23.4 $US\$.t^{-1}$) which represents 63.20–78.90 Sk (2.0-2.5 US$) per 1 GJ.

The price of fuelwood is approximately 350 $SK.m^{-3}$ (10.9 $US\$.t^{-1}$) and it represents 38.90 Sk (1.2 US$) per 1 GJ.

For evaluation of the competitiveness of fuel dendromass it is necessary to consider two basic situations:

- fuel consumed by producer (forestry, forest owners),
- fuel sold to other consumers.

In the first case a producer can add only the necessary overheads to the direct production costs. The price of the fuel sold to other consumers includes overheads and profit.

The price of heat produced in a boiler house with installed capacity of 0.5 to 1.6 MW using various kinds of fuel is listed in Table 2:

The production costs for 1 kWh of electric power by a power plant with a capacity of 40 kW with natural gas engine range from 1.96 to 2.55 $Sk.kWh^{-1}$ according to the capacity utilisation level of the equipment.

By 2000, the time of project realisation of energy utilisation of forest biomass being prepared in Slovakia, the average annual savings of costs of energy production are predicted to be 61 mil. Sk.

Conclusion

Approximately 1 % of the total consumption of fuels and energy in Slovakia will be covered by production of energy from usable amount of less-valued dendromass. The potential of domestic fuel-energy sources used for the time being will increase by 6.7 %.

By utilisation of fuel dendromass the import of brown coal graded will be reduced by 500 000 t . $year^{-1}$ or of natural gas by 200 mil. m^3.

In Slovakia a direct combustion, energetical gasification and adjustment of fine-grained waste by briquetting are the most prospective methods of energetical utilisation of dendromass.

A wider and more efficient utilisation of that fuel will lead to results in ecology as well as in economy. Dendromass as an ecological less-damaging fuel enables a considerable reduction of local pollution load of environment. Relatively equable occurrence of that raw material will enable a supply of fuel from local sources resulting in savings in coal transportation especially to remote regions.

Further advantages of biomass energetical utilisation:

- more flexibility of reaction on local changes in amount and structure of energy consumption,
- reduction of negative impacts caused by fluctuation of prices of basic fuels,
- possibility of integration of investments in local and regional level, respectively, and by reduction of state budget load,
- creation of new job opportunities,
- improvement of self-sufficiency of the state in the sphere of fuels.

Measures for utilisation extenuation:

- reduction of state subsidies for heat and energy or their provision for renewable sources as well,
- preferring of ecologically convenient domestic energy sources,
- support of regional projects including local renewable energy sources,
- credit and tax policy supporting utilisation of renewable sources,
- charges and increase of air pollution by fossil fuel combustion.

Authors' address

Dr. Ján Ilavský, Dr. Milan Oravec
Forest Research Institute
Masarykova 22
96092 Zvolen, Slovak Republic
e-mail: ilavsky@fris.sk

Fuelwood Production in Agroforestry Systems for Sustainable Land Use and CO_2-Mitigation

Ernst Kürsten

Abstract

The existence of a fuelwood market is a basic precondition for attempts to develop sustainable landuse systems which integrate trees on arable or pasture land (agroforestry). The Kyoto protocol to the United Nations Framework Convention on Climate Change has opened new chances to finance wood energy and agroforestry projects by the instrument of joint implementation in the next years.

Keywords

agroforestry, climate change, joint implementation, fuelwood, biomass energy, carbon dioxide

1. Introduction

There are two basic reasons for an increased production of fuelwood:

- On a local level especially in many tropical regions there is an acute scarcity of this form of energy which is a daily need fore more than half of the global population.
- Globally we need a reduction of CO_2-emissions due to the global warming problem. The substitution of renewable energy sources – of which fuelwood actually is the most important one – for fossil fuels is a main strategy in this context. It is closely connected with the possibility of using additional trees as carbon sinks.

In spite of this facts is often very difficult to get more trees on the ground. In Central America e. g. one common argument for not planting trees is the small size of landholding and the long wait until production. This is true for small farms, especially when the production of trees in blocks and with species of long rotation is recommended. In this case agroforestry is a solution. As to be shown here its introduction should be connected with the energy sector and may be funded by greenhouse reduction measures as joint implementation.

2. Agroforestry and fuelwood – two sides of a medal

Agroforestry covers land use systems in which trees and shrubs are grown in association with herbaceous crops, either in a spatial arrangement or a rotation. It has productive functions, such as the capacity of the tree component to produce fuelwood, fodder and fruit, and service functions, chief among which is that of soil conservation. The high potential of agroforestry as a means of achieving sustainable land use – especially in the tropics – has been investigated and promoted since the early 1980s. Its now becoming progressively translated into practice, through the design of sound, appropriate, agroforestry systems and their inclusion in the process of land-use planning (*Young*, 1989).

In Central America it was experienced that even under the restriction of size it is possible to incorporate a forestry component within small farms by using living fences with fast growing species. The living fence is an agroforestry system and is the advantageous for farm delimitation, protection from soil erosion, prevention of trespassing, and keeping animals away from crops. Also it has low cost of establishment and maintenance, and additional products such as fuelwood, post and materials for construction can be obtained. The introduction of living fences was shown to have a significant positive impact on small farm incomes with an estimated internal rate of return of 28.80 % (*Reiche*, 1991).

Another example for the financial benefits of agroforestry systems can be seen in Table 1. The combination of agricultural crops with trees for fuelwood production can bring a higher profit than pure plantings of either. The same is true for the ecological benefits.

The basic precondition for the economic success of fuelwood production systems naturally is the existence of a local fuelwood market. As it was shown in Costa Rica this can be stimulated by the switch from fossil fuel (bunker) to fuelwood in small industries (e.g. saline) (*Portilla* and *McKenzie*, 1991). Markets generally have been proven to provide important incentives to tree planting. Thereby the possibility to sell small diameter logs is especially essential, because they are an unavoidable by-product even if high quality lumber shall be produced (*Current* and *Scherr*, 1995). So an active fuelwood market turns out to be a valuable tool for any attempts to propagate soil conserving and sustainable agroforestry systems. This aspect has to be kept in mind if an energy system is being planned.

3. Establishing agroforestry and bioenergy systems by "joint implementation"

This headline is meant ambiguous: First of all it shall repeat, that landuse planning and energy policy should be designed in close cooperation. But secondly it refers to the actual political efforts to reduce greenhouse gas emissions.

At the Third Conference of the Parties (COP III) held in Kyoto, Japan, December 1–10, 1997, a protocol to the United Nations Framework Convention on Climate Change (UNFCC) was signed, which made "joint implementation" (JI) to a generally accepted political instrument. This mechanism allows companies from the industrialised nations to generate emission credits by investing in projects to reduce, avoid or sequester greenhouse gas emissions in developing countries in a cost-effective manner. In a pilot phase, internationally referred as "Activities Implemented Jointly" (AIJ) several countries already started projects some of which dealt with forestry, agroforestry and biomass energy. Australia e. g. just in November 1997 created its "International Greenhouse Partnerships" (IGP) Program in order to find ways to use JI for a cost-effective fulfilment of its greenhouse gas emission target. Another objective of the program is to enhance Australian trade and investment links in environmental technology and services areas in the energy and other relevant sectors, mainly focused Asia-Pacific region.

Table 1: Costs and proceeds for different types of cultivation in El Salvador (values in Colones/ha for 1989) (Juarez, McKenzie, 1991).

Type of Cultivation		First Year	Second Year	Third Year	Fourth Year	Total Profit in 4 Years
Maize, traditionally						
Costs	*- Labour*	2104.78	2104.78	2104.78	2104.78	
	- Material	808.02	808.02	808.02	808.02	
Proceeds		5916.00	5916.00	5916.00	5916.00	
Profit		3003.20	3003.20	3003.20	3003.20	12012.80
Maize with Eucalyptus						
Costs	*- Labour*	3083.73	1914.94	390.84	3843.89	
	- Material	2275.31	766.31	120.85	120.85	
Proceeds		4102.80	4102.80	0.00	24869.09	
Profit		-1256.24	1421.53	-511.69	20904.31	20557.92
Eucalyptus Plantation						
Costs	*- Labour*	1837.38	469.208	413.508	3431.61	
	- Material	1012.21	58.21	58.21	58.21	
Proceeds		0.00	0.00	0.00	25145.03	
Profit		-2849.59	-527.41	-471.71	21655.21	17806.50

Table 2: Estimated CO_2-mitigation effects of agroforestry systems (in $Mg \cdot C \cdot ha^{-1}$ agroforestry land) (Kürsten, Burschel, 1993).

Accumulation and Conservation of Carbon Stores	
Trees in Agroforestry Systems	3... 60
Wooden Products	1... 100
Soil Organic Matter	10... 50
Protection of Existing Forests	0...1000
Sum	***(14...1210)***
Reduction of CO_2-Emissions within 50 Yrs	
Energy-Substitution	5... 360
Material-Substitution	0... 100
Reduction of Fertilizer-Input	1... 5
Sum	***(6...465)***
Total	**20...1675**

Host countries will benefit by gaining access to technology that will build the infrastructure needed to meet their development needs while also benefiting the global climate. Accordingly a big German company decided in spring 1998 to invest DM 30 million in a forestry CO_2-mitigation project. This demonstrates well that after Kyoto there are much better chances to receive funds for agroforestry and fuelwood projects by the mechanism of JI. As it has been demonstrated by scientific calculations (see Table 2; *Swisher*, 1991) and practical experiences from many pilot projects since 1989 there is a big potential for greenhouse gas mitigation by agroforestry. The increasing use of biomass and its conversion efficiency for producing heat, electricity, and liquid fuels can become a significant factor in the global management of atmospheric CO_2 over the next century (*Sampson* et al., 1993). Consequently this chances should be used intensively in the interest of a sustainable development especially in tropical countries.

References

Current, D., S. J. Scherr, 1995. Farmer costs and benefits from agroforestry and farm forestry projects in Central America and the Caribbean: implications for policy. Agroforestry Systems, 30: 87–103.

Juarez, M., T. A. McKenzie, 1991. Sistema agroforestal maiz-eucalipto en El Salvador: analisis financiero. Silvoenergia No. 45, CATIE, Turrialba, Costa Rica, p. 4.

Kürsten, E., P. Burschel, 1993. CO_2-mitigation by agroforestry. Water, Air and Soil Pollution, 70: 533–544.

Portilla, W., T. A. McKenzie, T. A., 1991. Un caso de evolution en el desarollo de proyectos forestales. Silvoenergia No. 40, CATIE, Turrialba, Costa Rica, p. 4.

Reiche, C., 1991. Economic analysis of a living fence case in Central America – Development of a methodology for the collection and analysis of data with an illustrative example. Invited paper presented at the Economics of Agroforestry Systems Workshop, Honolulu, Hawaii, July 22–26, 1991. CATIE, Terrible, Costa Rica, p. 22.

Sampson, R. N., L. L Wright, J. K. Winjum, J. D. Kinsman, J. Benneman, E. Kürsten, J. Scurlock, 1993. Biomass management and energy. Water, Air and Soil Pollution, 70 (1–4): 139–159.
Swisher, J. N., 1991. Cost and performance of CO_2 storage in forestry projects- Biomass and Bioenergy, 1 (6): 317–328.
Young, A., 1989. Agroforestry for soil conservation. CAB International, Wallingford. pp. 246.

Author's address

Dr. Ernst Kürsten
Consultation – Forestry
and Woodworking Industry
An den Papenstücken 2
D-30455 Hannover
fax: (49)511-499076
e-mail: E.Kuersten@t-online.de

Determination of an Economic Energy Supply Structure Based on Biomass Using a Mixed-Integer Linear Optimization Model

Janet Nagel

Abstract

Biomass can be used for generating heat and power or for a combined heat and power generation in order to substitute fossil fuels. As a result of the low fossil fuel prices and the higher investment and operating costs of biomass-fired plants, the energetic use of biomass has to be checked for every case in each application area. The preferred field of application is the rural area because of the reasonable relation between the potential of biomass and the transportation distances that have a great influence on the economic viability. The knowledge about the location of consumers as well as of the energy plants and the possible laying of a district heating pipe is important for the clarification of an optimal heat supply structure in an isolated area. A mixed-integer linear optimization model based on the dynamical evaluation of economic efficiency can help to find the most economical and ecological supply structure. The model has to be developed for three different types of operating companies. The influences of different parameters on the target function can be analyzed by defining scenarios and by running sensitivity analyses. The results show, that the energy prices have the highest influence on the economy.

Keywords

energy model, mixed-integer linear optimization, scenarios, sensitivity analysis, operating companies, dynamical evaluation of economic efficiency, yes-no variables

1 Introduction

Since most heating systems in the New Federal States of Germany, especially in Brandenburg, are out-dated (*Viele veraltete Wärmeerzeuger in deutschen Heizungskellern*, 1997), the municipalities have the historically unique opportunity of re-organizing the heating supply and improving the energy utilization (*Ministerium für Wirtschaft, Mittelstand und Technologie des Landes Brandenburg*, 1994). The amount of biomass and the rural structures of Brandenburg where biomass can primarily be used facilitates an integration of biomass into energy supply. More than 84 % of the useful area in Brandenburg is cultivated by agriculture and forestry (*Landesumweltamt Brandenburg*, 1994). The biomass potential of wood, energy plants (rotational fallow, long-term fallow), straw, grass and animal excrements available amounts to 30.2 and 46 PJ/a (*Haschke* et al., 1994). The biomass potential could cover approx. 12 % to 19 % of the total energy consumption of Brandenburg households, which in 1994 amounted to 247.64 PJ (*Landesamt für Datenverarbeitung und Statistik Brandenburg*, 1996). Up to 5.6 % of the CO_2-emissions could be reduced (*Hartmann*, 1994). However, the questions:

- if the economic potential of biomass is sufficient,
- what kind of technology and service can stand the economic comparison,
- what kind of general political, economical and ecological conditions are required, and
- which influences on the supply structures are caused by the use of bionic fuels

have not yet been satisfactorily answered.

To answer these questions a computer based method can be used as an instrument of decision-making.

2 Description of the optimization model

The computer program is based on the mixed-integer linear optimization using the dynamical evaluation of economic efficiency. Because of the 1-0-condition of the mixed-integer linear formulation, it is possible to pinpoint the location and therefore to answer the question of whether to build or not to build a heating system, a heating plant or a co-generation plant.

Different operating companies have to be taken into account for analyzing the energetic use of biomass in rural areas in competition with fossil fuels. In the rural area three types of operating companies are typical (Fig. 1). First of all, the municipality can amalgamate to an operating company to provide itself with heat (and electricity) (municipality that uses its heat production for itself – municipality TH). Secondly, an investor, a farm for example, can produce biomass for energy generation to cover his own demands (investor PA). Additionally, he can sell surplus energy to surrounding consumers if it is economically viable. Finally, an investor, like a power supply company, can generate and sell energy with a profit motive (investor SE). The three types of operating companies have different aims using the produced energy and therefore different ways of looking at the arising costs.

Different balance boundaries have to be defined for these three operating companies before a mathematical transformation can be done. For the operating company "municipality TH" the boundaries have to be drawn around the total supply area (Fig. 2). However, for the operating company "investor PA" and "investor SE" the boundaries have to be drawn just around their own area (Fig. 3).

The operating companies "investor PA" and "investor SE" can sell heat and electricity to other consumers. The question, whether an individual energy supply (heating systems) is more economical for other consumers is not relevant for them. The different balances cause different mathematical formulations.

Before the mathematical model can be built the problem has to be abstracted and a model of the municipality has to be developed. In the mathematical formulation the number of mixed-integer variables has to be limited to ensure the mathematical solubility. On the other hand a precise solution can only be achieved if the costs for each technology in the supply area are exactly determined. In order to realize both solubility and precision, a special model is developed starting with the demand for heat of each inhabitant (consumer) in the municipality. Corresponding to the spatial structure the supply area is divided into grid squares [groups of consumers (VG)]. At the same time these are locations for energy conversion plants. Based on this, heat supply can be reproduced by numerous variants of supply types using heating systems (HA) or heating/co-generation plants (HW) (Fig. 4). Different technologies are available for the components HW and HA. They can be operated with the corresponding fuels.

District heating systems start from four locations (ST1 to ST4) of heating plants (HW). At the junctions (KN) the district heating systems are split up into

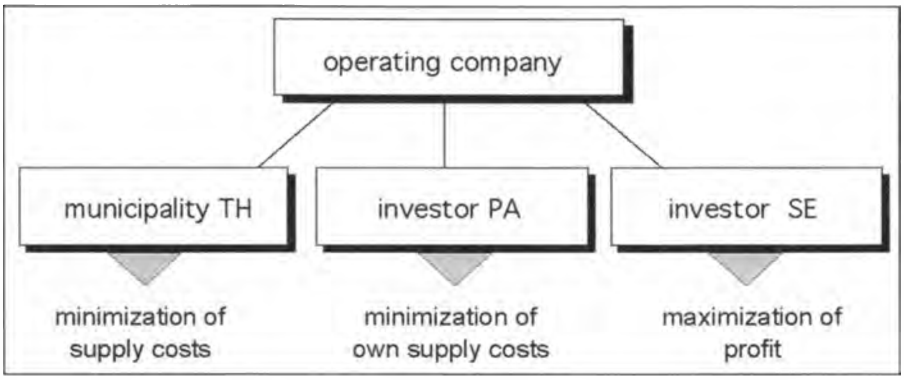

Fig. 1: Operating companies.

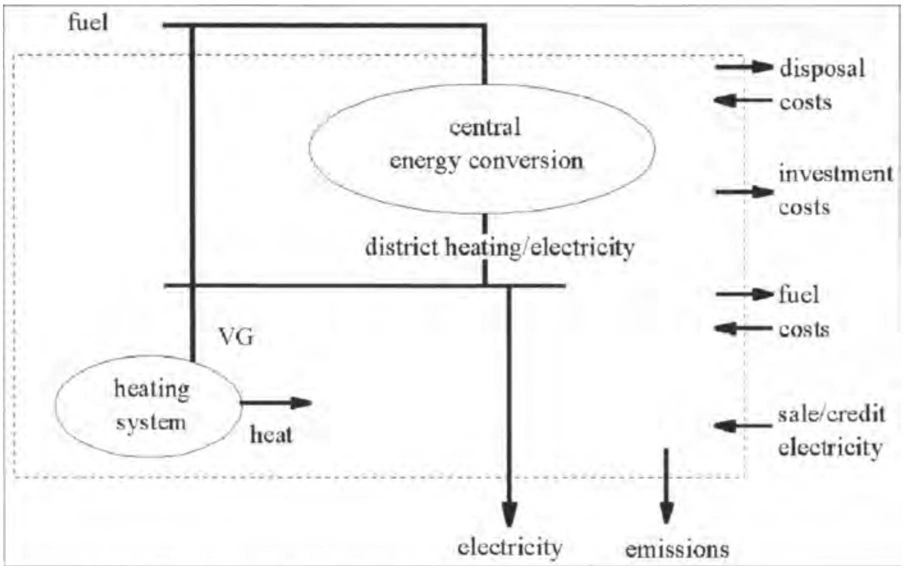

Fig. 2: Balance boundary for "municipality TH".

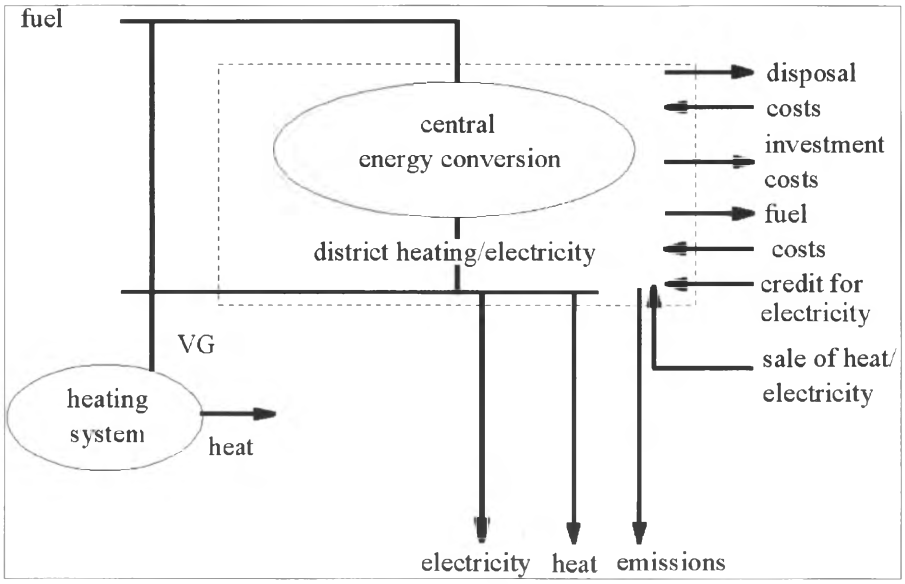

Fig. 3: Balance boundary for "investor PA" and "investor SE".

two streams with one going to a group of consumers (HU) and one to the next junction (NKN). The complete heat supply of one grid square is described by the stream NKN. Within the distribution system the stream HU leads to each building. These systems are designed for the heat consumption of each single consumer and cause corresponding costs. Costs have to be calculated separately for each group of consumers, such as households, trade, farms or buildings such as multiple-unit dwellings. For simplification of the model, similar types of consumers for example households or restaurants within the grid square can be united if the demand for heat is the same. In this way the inspection of the total heat consumption of VG is transferred into a single inspection of each consumer. As a result, an exact calculation of the costs that are caused by the heat consumption is possible. The same conditions are valid for decentralized supply structure using heating systems. The costs must be calculated for each consumer as well.

In order to determine the costs of district heating systems, their length in the grid squares (VG) has to be registered. In view of the change of diameter of district heating systems proceeding with the reduction of heat consumption, an average diameter within each VG is used for calculations.

This energy supply model facilitates a spatial relation of consumers, energy conversion plants and distribution systems. In addition, the heat flow within the supply area can be shown as well.

For analyzing a concrete municipality the extensive data base of the model is specified by information about the consumer, the size of the buildings determining their total energy consumption, the spatial location and the structure of the district heating system in the grid squares (Fig. 5). The formation of typical seasonal structures of daily demand is based on the total energy consumption of each group of consumer types. Over a day the energy consumption is divided into four time zones over a day (morning, day, evening, night). Using this structure of the daily energy consumption the model is able to split the plants into base and peak load range plants and to determine the model of running the plants within the four time zones.

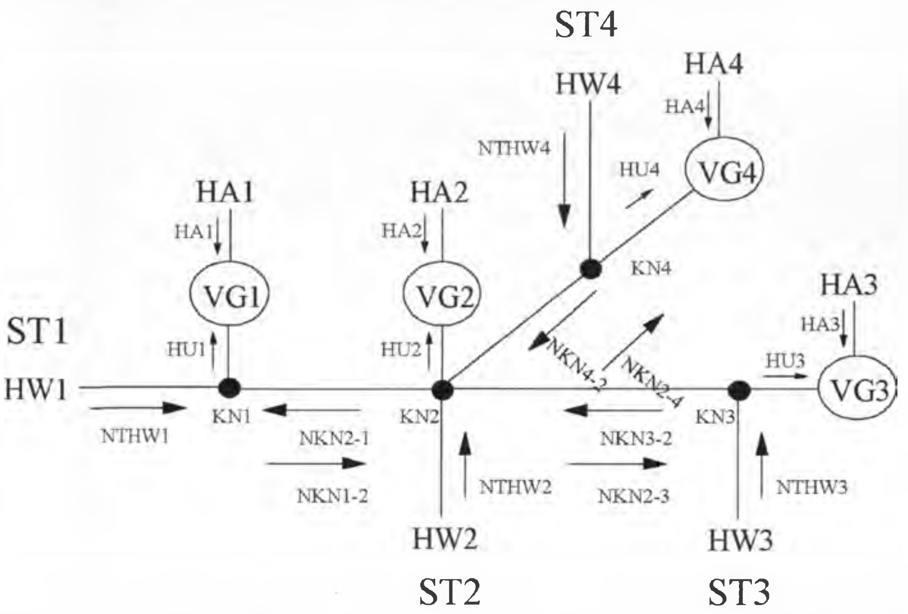

Fig. 4: Energy supply model.

The technologies are described by their capacity, efficiency and costs (investment, fix and variable costs). Considering the cost decrease with increasing capacity, data are given for the smallest and the largest plant that is available on the market. The costs within the bounds can be interpolated (*Gernhardt*, 1996). Fuels being available for the model are biomass (wood, straw, biogas, rapeseed oil), hard and soft coal as well as natural gas, propane gas and heating oil. Inside the model they are described by their thermal value and their prices/rates. Together with the data of the emissions of CO_2, NO_x, CO and SO_2 caused by the transformation, the fuel data are specified to the technologies. The optimal energy supply structure can be found by comparing the fossil and biogenic fuels and the transformation technologies, of which the data are given inside the model.

3 The decision model

The single components in a supply system have to be linked together to a decision model (Fig. 6). One part is the structure of the supply system with the data of the consumers, their annual heat consumption as well as its seasonal distribution, that results in the thermal capacity and the spatial structure. These data have to be connected with the costs of energy conversion plants, that consists of the costs of centralized and individual conversion plants and, if it is necessary to build a district heating system, then the installation costs for the distribution system. Furthermore, the costs of the fuels, that are transported from the

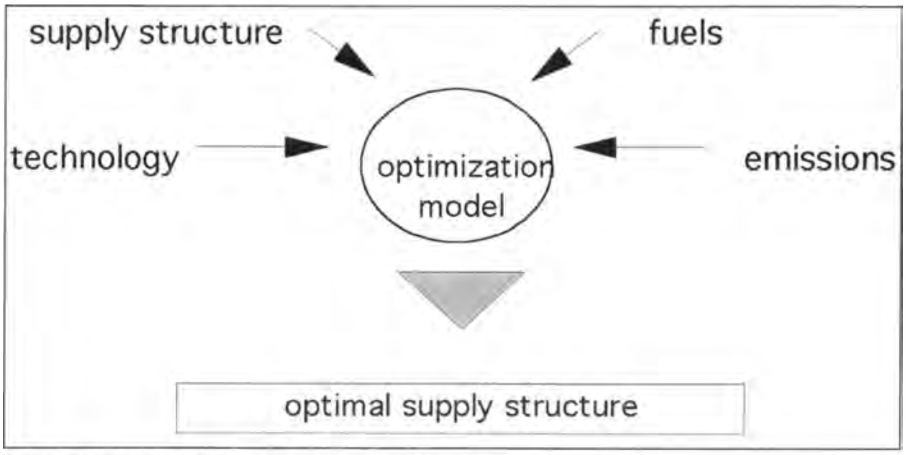

Fig. 5: Data base of the optimization model.

system surroundings into the supply system for a certain price (this could also be an income, if waste is used) must be considered. Ash and other waste-products that are obtained at the conversion process, have to be transported with costs to the system surroundings, if they can not be used as fertilizers in farming. To complete the data of the structure and costs of fuels, the knowledge of the existing potential of fuels is important.

Furthermore, different future developments have an effect on the decision model that can be defined by scenarios in the mathematical optimization model. A scenario describes a certain situation with varied restrictions, and possibly includes basic conditions which could have an influence on the system. For example, a scenario could be, that CO_2-taxes have to be taken into account within the system, or, that only biomass can be used for combustion, or, that only central heat supply is allowed, or, that the prices for fossil fuels are higher than today. In this way, it is possible to simulate as well political, economical as ecological circumstances or future aims. By fixing or changing different factors that act on the supply system, the scenarios shown in Fig. 7 important for the problem being examined here can be defined.

Starting from a "base scenario" that is based on the original prices, a scenario "prices of fuels" can be defined. Here, measures like CO_2-taxes, energy taxes, subsidies for biogenic fuels, or such other examples take effect. For example within the scenario "investment costs", aid programs or investment-costs-reduction-mechanism caused by the increase of plant construction exist. A requirement of CO_2-reduction by the state is given within the scenario "CO_2-emissions". On the one hand, income can be made by selling heat. Within the scenario "income heat sale" the amount of income is given as a starting point from the program user in order to analyze influences of different factors on the system. On the other hand, electricity can be sold, which produces an income as well. This can be taken into consideration within the scenario "income electricity sale". Of special interest is the refunding of biogenic produced electricity, that can be increased by political measures. An energy supply based on central energy conversion plants can be

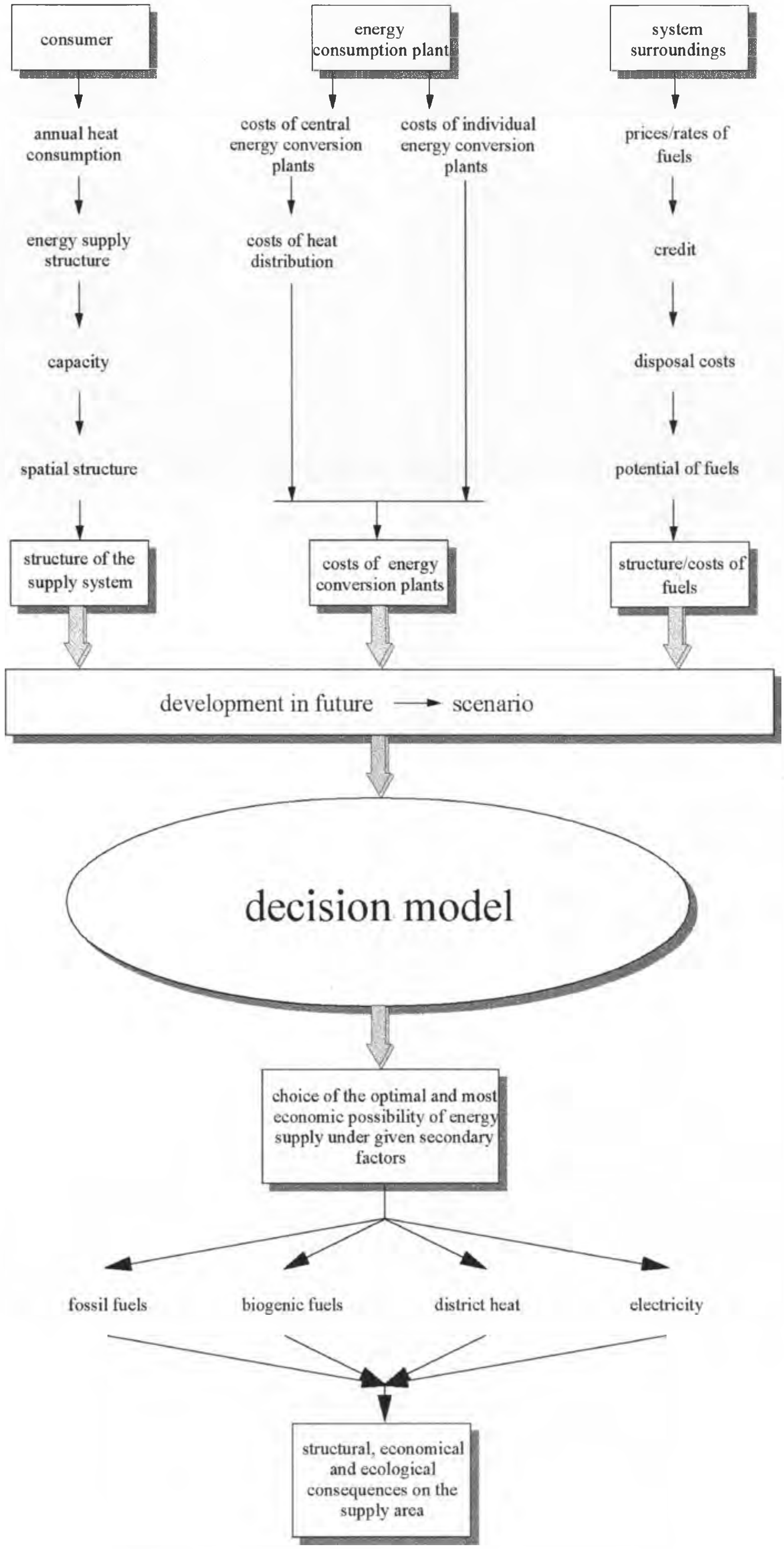

Fig. 6: Structure of the decision model.

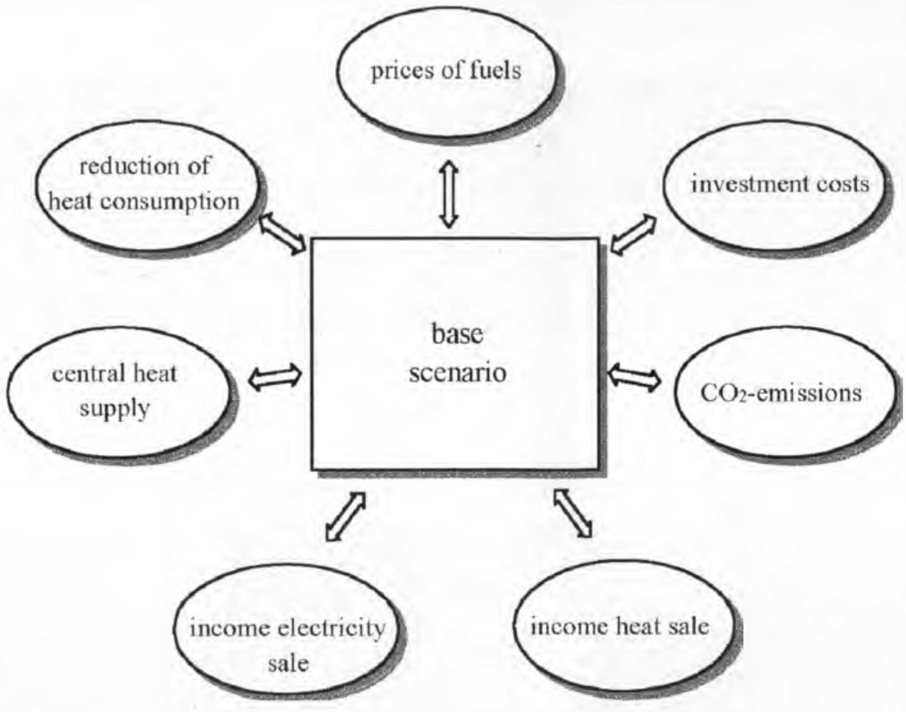

Fig. 7: Model of scenarios.

another requirement, that can be defined within the scenario "central heat supply". Within the scenario "reduction of heat consumption" possible consequences on the supply structure caused by the reduction of the existing heat supply can be examined. This scenario uses a reduction rate of heat consumption less than today's levels as a starting point.

By a following sensitivity analysis, that means changing one or more parameters within the system, like the fossil fuel prices for example, the effects on the target function as well as on the supply system and, therefore, the conditions for an economic use of biogenic fuels can be examined.

The economic supply structure gets chosen by linking all components and defining secondary factors. Structural, economical and ecological effects on the total system are shown as well. Economical, ecological, political and structural conditions for the economic use of biomass can be given through defined scenarios.

4 The mathematical optimization formulation

It is important for the mathematical optimization formulation, that the correct variable is used to describe the technologies. Within heat supply this is the heat capacity $\dot{Q}$. Additionally, it is important to define a yes-no variable (1-0-condition). The target function is the most important part of the mathematical formulation. Within the target function the components that derive from the problem and the variables are linked to solve the problem and the condition of minimization or maximization of the target parameter is given.

The construction or the mathematical model is explained by the example of the operating company "municipality TH". Considering only heat supply, the target function for this operating company has to include the following costs:

- investment costs for:
  - central and individual energy conversion plants (*IHW, IHA*),
  - fuel tank (*THW, THA*),
  - district heating system (*NI*)
  - individual heat exchange systems (*IHU*),
- fix costs for the energy conversion plants and the individual heat exchange systems (*LHW, LHA, LHU*),
- variable costs for the energy conversion plants (*AHW, AHA*),
- fuel costs (*BHW, BHA*),
- disposal costs for waste-products of the conversion process (*AEK*),
- costs for external district heat (*FKW*).

In order to consider different temporal amounts of income and costs, the dynamical evaluation of economic efficiency is used. If there is an income in the system, the annuity of the capital value has to be used in place of the annuity of the cash value. The annuity method describes an average capital or cash value referred on one year (*Winje* and *Witt*, 1991). Within this method the capital cash value is multiplied with the reciprocal of the cash value factor, which is called annuity factor R. If there are always the same amounts of income and costs in the time periods, the annuity of the capital value

$$An(C) = E - A - I_0 \cdot q^t \cdot \frac{q-1}{q^t - 1} = C \cdot R \quad (1)$$

or the annuity of the cash value

$$An(B) = A + I_0 \cdot q^t \cdot \frac{q-1}{q^t - 1} = B \cdot R \quad (2)$$

can be used. An average yearly expenditure in [DM/a] results of this statements.

For the said operating company, regarding only heat supply the annuity of the cash value has to be used with the condition of minimization of the target parameter because there is no income inside the system. The target function with the individual costs can be written as following:

$$\begin{aligned} Min = Z = {} & IHW + LHW + AHW + BHW + THW \\ & + THW + IHA + LHA + AHA + BHA \\ & + THA + NI + IHU + LHU + AEK + FWK \end{aligned} \quad (3)$$

If the combined heat and power is additionally included the costs of the co-generation plant (*KWK*-plant) (*IKWK, BKWK*) have to be taken into consideration in the target function as well the sale of electricity (*ELS*) or heat (*EFW*). A credit (*EG*) is defined if electricity is produced and used by oneself. The target function is based on the annuity of the capital value because of this income within the system. To keep to the condition of minimization, equation 1 is multiplied with minus one. The target function can be written as following:

$$\begin{aligned} Min = Z = {} & IHW + LHW + AHW + BHW + THW \\ & + IHA + LHA + AHA + BHA + THA + NI \\ & + IHU + LHU + AEK + FWK + IKWK \\ & + BKWK - ELS - EG - EFW \end{aligned} \quad (4)$$

The costs are calculated by the specific costs, that are given in dependency of the capacity or the work. The costs are calculated separately for the central and individual plants. Furthermore, a separation of fossil- or biomass-fired plants is done, so that different technology specific cost factors for defining a scenario as well as a sensitivity analysis can be varied.

The mathematical model has three dimensions, which means that most of the variables depend on the three components (index): technology, location and time. Within the mathematical equations the technical, ecological and economical parameters and variables are assigned to these three components. The components are united in groups, that can again be divided. Making up a sum over these components means that the values of variables and parameters of the individual components in a group are added up.

Therefore, the target function consists of costs depending on the capacity or the work. Mathematically, the target function can be written as following:

$$Min = Z = R \cdot \sum_{HW}\sum_{ST} k1_{HW} \cdot \dot{Q}_{HW,ST} + \sum_{HW}\sum_{ST} k2_{HW} \cdot \dot{Q}_{HW,ST} + \sum_{HW}\sum_{ST}\sum_{T} k3_{HW} \cdot Q_{HW,ST,T} + \ldots \quad (5)$$

$k1$ to $k3$ are parameters of the specific costs, that are give in dependency of the work or the capacity. The parameters whether have constant values or, using interpolation, have to be calculated out of different values. The capacity $\dot{Q}$ as well as the work Q are positive variables, that have to be ascertained by the program, where secondary factors are necessary. For the operating company "municipality TH" the following secondary factors are valid:

- balance for each location of energy conversion plants,
- balance for each distribution node,
- balance for each group of consumer types,
- limitation of capacity,
- linkage of thermal work and capacity,
- linkage of thermal and electrical capacity,
- calculation of electrical work,
- combination the groups of consumer types within a grid square to supply units,
- condition for supplying each consumer type either centrally or individually and
- guarantee of secure supply.

Corresponding to Figure 4 an equation for each energy conversion plant is formulated, where the sum of work of each energy conversion plant at each location (ST) and at each time sequence T has to be equal with the work taken away from the pipes at each time sequence T.

$$\sum_{HW} Q_{HW,ST,T} - \sum_{NTHW} Q_{NTHW,T} = 0 \quad (6)$$

This equation has to be set up at each location (ST). The balance causes that the demand for heat is covered at each time sequence (T).

Also, for each distribution node, the heat coming from the pipes going to the individual heat exchange systems (HU) has to be sufficient at each time sequence:

$$\sum_{HU}\sum_{VG} Q_{HU,VG,T} \cdot AZ_{VG} - \sum_{NKN+0-ab} Q_{NKN+0-ab,T} \cdot NV + \sum_{NKN+1-ab} Q_{NKN+1-ab,T} \cdot NV + \sum_{NTHW-ab} \left(Q_{NTHW-ab,T} \cdot NV\right) = 0 \quad (7)$$

The positive variable $Q_{NKNr0sab,T}$ represents the work of the pipe leading away from node (0). QNKN+1-ab,T is the work of the following node (1) leading to the node (0). $Q_{NTHW-ab,T}$ describes the work of a HW at a location leading away to the node (0). $Q_{HU,VG,T}$ is the positive variable of the individual heat exchange systems. Because these plants are required by each consumer within each group of consumer types VG, this variable is multiplied with the number of consumer within each group (AZ_{VG}). Furthermore, the loss of heat of the pipes has to be taken into account by the factor NV.

A balance around each group of consumer types can show that the work of the individual heating systems and the individual heat exchange systems covers the requirements of the consumers $RVA_{VG,T}$. To calculate the work of HA of each consumer the positive variable $Q_{HA,VG,T}$ is multiplied with the number of consumers AZ_{VG}. In addition, the heat loss of the *HU* has to be considered by the factor *VHU*. If there is a possibility of an external district heat connection this also goes into the equation.

$$RVA_{VG,T} - \sum_{HU} Q_{HU,VG,T} \cdot AZ_{VG} \cdot VHU - \sum_{HA} Q_{HA,VG,T} \cdot AZ_{VG} = 0 \quad (8)$$

Caused by the secondary factors

$$\dot{Q}_{HW,ST} \geq N1_{HW,ST} \cdot LL_{HW,ST} \quad (9)$$

$$\dot{Q}_{HW,ST} \leq N1_{HW,ST} \cdot LU_{HW,ST} \quad (10)$$

for central heating plants and KWK-plants at each location the possible variable $Q_{HW,ST}$ is bounded within the upper and lower bounds of capacity ($LL_{HW,ST}$, $LU_{HW,ST}$). The product with the binary yes-no variable $N1_{HW,ST}$ indicates the building or not-building of a technology. For individual heating systems, pipe and individual heat exchange systems the same secondary factors have to be made with the corresponding binary yes-no variables $N2_{HU,VG}$, $N3_{HA,VG}$ and $N4_{NT}$.

To connect the work of the energy conversion plants within the balances with the capacity of the energy conversion plants within the target function the work and the capacity have to be linked:

$$\frac{Q_{HW,ST,T}}{ZAB_T} \cdot VSF \leq \dot{Q}_{HW,ST} \cdot VF_{HW} \quad (11)$$

In this way, it is determined, that the produced work of each HW at each location and at each time sequence ($Q_{HW,ST,T}$) divided by the hours of the time sequences ZAB_T has to be, at best, as high as the capacity $\dot{Q}$ multiplied by the availability VF_{HW}, that gives the real reachable permanence of operating, considering the prevailing technical and operational conditions (*VDWE e. V.*, 1981). To ensure the secure supply a 25 % higher capacity is required by the factor *VSF*. On the one hand, it is taken into account, that the real heat peak could be higher than the predicted mean. On the other hand a general safety factor is included that for dimensioning technical equipment and plants usually has a value of approx. 10 % to 15 %. This secondary factor has also to be made for heating systems, pipes and individual heat exchange systems by changing the indexes.

If also co-generation plants exist within the system, electricity produced is linked to the heat production. The linkage of the heat and power work is carried out by the electricity code number reference SIG_{KWK} that is assigned to each energy conversion plant.

$$SaE_{KWKF,ST,T} = Ea_{KWKF,ST,T} \cdot SIG_{KWKF} \quad (12)$$

Additionally, the electrical (P) and the thermal $\dot{Q}$ capacity have to be linked by the electricity code number reference:

$$P_{KWK,ST,T} = \dot{Q}_{KWK,ST,T} \cdot SIG_{KWK} \quad (13)$$

It has to be ensured that all consumers within a grid square VG are supplied either centrally or individually. This is attained by equating the yes-no variables $N2_{HU,"VG"}$ and $N3_{HA,"VG"}$, which are summed up over the corresponding technologies and each examined consumer group "VG", with the product of the number of groups of consumer types (AZV_{VG}) and the binary variables ($B1$, $B2$). These binary variables have to be defined for each grid square, for example with ongoing numbers.

$$\sum_{HU}\sum_{"VG"} N2_{HU,"VG"} = AZV_{VG} \cdot B1 \qquad (14)$$
$$\sum_{HA}\sum_{"VG"} N3_{HA,"VG"} = AZV_{VG} \cdot B2$$

Moreover, the sum of the binary variables $B1$ and $B2$ must have the value one for each grid square:

$$B1 + B2 = 1 \qquad (15)$$

To ensure that the demand for heat of each group of consumer types is covered by only one technology,

$$\sum_{HU} N2_{HU,VG} + \sum_{HA} N3_{HA,VG} = \qquad (16)$$

the sum of the binary variables of HU and HA has to have the value one.

By defining further inequations in the form of secondary factors different conditions for the supply and therefore for the result can be made. For example it could be required, that a CO_2-emission boundary is raised or a certain potential of biomass has to be used.

Because heat supply in rural areas is of priority interest it is only important to ensure the energy supply if serious problems occur like a long-term breakdown of an energy conversion plant. Otherwise it is started out, that repairs are taken in an appropriate time. For special consumer groups, for whom the energy supply has to be ensured, like for example hospitals, it is started, that power as well as heat supply is maintained by an emergency power unit. In the field of planning the use of energy conversion plants, where mainly power supply is analyzed, the question to ensure the secure supply is very important, because in producing industries power failures can cause restrictions of production and therefore financial losses. In rural areas there is normally no need to ensure the energy supply by special plants. But still there are possibilities within the model to require at least two central energy conversion plants at each location "ST" by defining secondary factors

$$\sum_{HW} N1_{HW,"ST"} \geq 2 \qquad (17)$$

so that one plant is mainly used to ensure the secure supply.

The transformation of the mathematical model into a computer based process (analytical process model) makes it possible to use the mixed-integer linear optimization formulation and therefore the determination of conditions for the economic use of biomass in energy supply.

5 Results and Discussion

The optimization model (analytical process model) was used on the operating company "municipality TH" in a typical rural municipality of Brandenburg with 660 inhabitants and with the structure of a linear village. Under the given conditions consumers in this municipality with a demand for heat higher than 100 kW and a high total heat consumption can be economically supplied with a biomass-fired, automatically loaded solid-fired boiler (H_FABio) (Fig. 8). The supply component amounts to appr. 22 % of the total capacity. Other consumers are supplied with an oil-fired boiler (H_OLGO).

A sensitivity analysis of the fossil (pF) and biogenic fuel (pBio) prices shows that the variable Z, representing the annuity of cash value, increases or decreases corresponding to the variation of fuel costs (Fig. 9). A change of the supply structure is linked to this. The gradient of this curve has a steeper course, principally because fossil-fired heating systems have been mainly used.

The change of the structure of energy supply becomes visible through the change of used biomass potential. The use in decentralized heating systems increases with decreasing prices for bio-

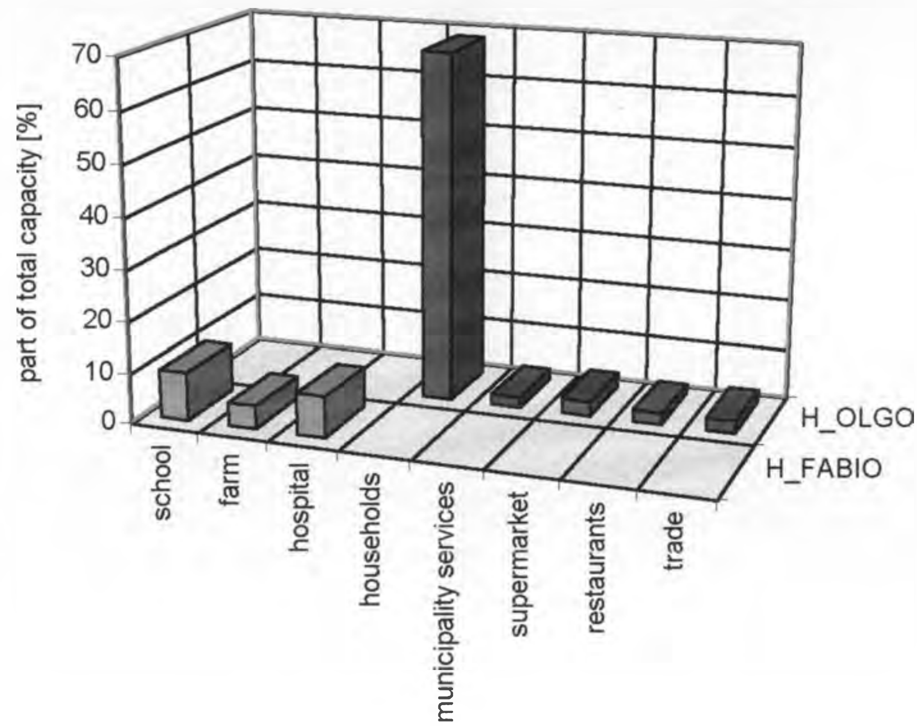

Fig. 8: Supply structure of a rural municipality.

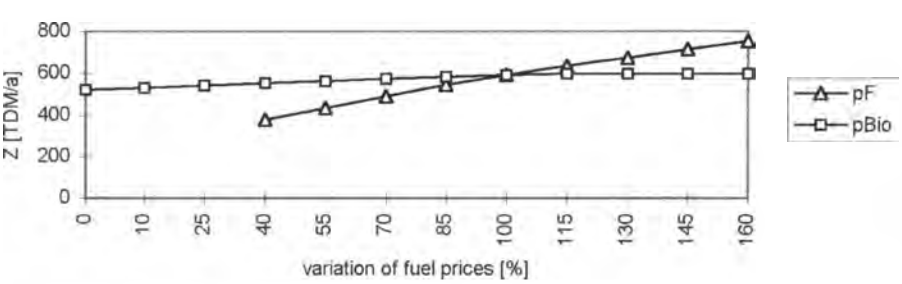

Fig. 9: Value of the variable Z by variation of the fuel prices.

mass. Corresponding biomass is not used anymore with decreasing prices for fossil fuels (Fig. 10).

The CO_2-emissions could decrease up to 25 % by the increasing use of biomass (Fig. 11).

Biomass can be fired in a heating plant with a capacity of 2.4 MW if a district heating system already exists and the prices for biomass are reduced by 30 % or the price for fossil fuels increases by 15 %.

If heat and electricity are produced in co-generation plants profits can be made by selling the electricity to power supply companies and a credit can be given for the non use of electricity from the power supply system. This is possible for a farm which uses the produced electricity itself and gets credit for this. A total energy supply based on biomass can be achieved, if the prices for biomass are decreased to 10 % of the today's biomass prices. A wood-fired heating plant (2.2 MW) and a rapeseed oil-fired district heating power station (144 kW) are suggested. The thermal load shared between the heating plant (HW_UBio) and the district heating power station (BHKW) is illustrated in Figure 12 for the different time sequences (summer morning SM; summer day ST; summer evening SA; summer night SN and also for winter and transitional period).

Figure 13 shows the power consumption of a farm (VG5) which is not supplied completely by the fired district heating power station. This is caused by the optimization of profits and expenses, that is reached at that point.

Different factors can improve the economic viability of biomass. In this connection, especially fuel prices/rates of fossil (pF) and biogenic (pBio) fuels, electricity sales of biogenic produced electricity (EINB) and the investment costs for biomass-fired heating plants (IBHW) as well as co-generation plants (IBKWK) have to be named. The value of the target function reacts with different sensitivities on these parameters (Fig. 14). The digit one standing in brackets within the legend symbolizes the operating company "municipality TH" with an individual heat supply. The same is valid for digit 2, with the difference of central heat supply. Digit 3 symbolizes the operating company "municipality TH" with central heat and power supply. Digit 4 stands for the "investor PA" with central heat and power supply. Only values are shown that result in a supply based on biomass by lifting up over or subsiding under 100 % of today's levels. The figure shows, that subsiding biogenic fuel prices as well as the investment costs of heating plants and co-generation plants results in a reduction of the target parameter Z. Z is also reduced by lifting up the electricity sale based on biomass. For all operating companies the increase of fossil fuel prices results in an increase of Z. Negative values of Z can only be reached for the operating company "investor PA" (besides the cost-free purchase of KWK-plants for the operating company "municipality TH" – Fig. 14). In this connection a profit

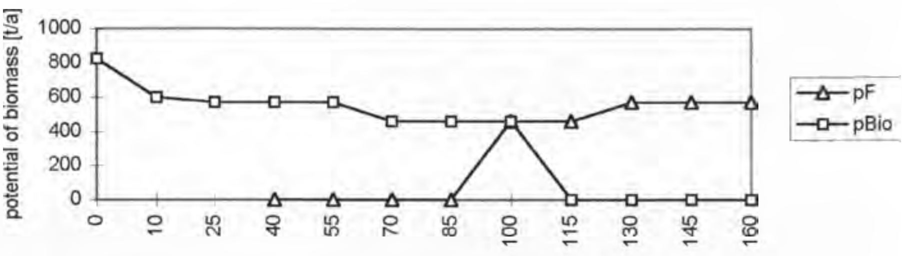

Fig. 10: Potential of biomass by variation of the fuel prices.

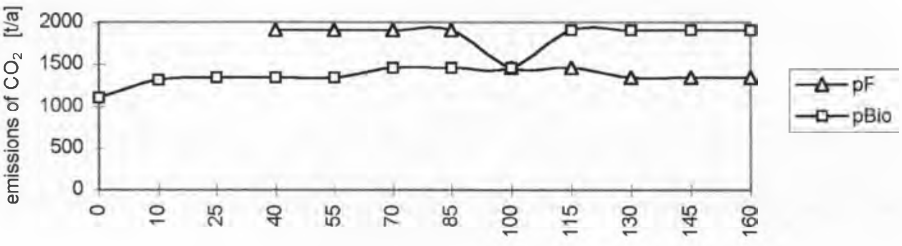

Fig. 11: CO_2-emissions by variation of the fuel prices.

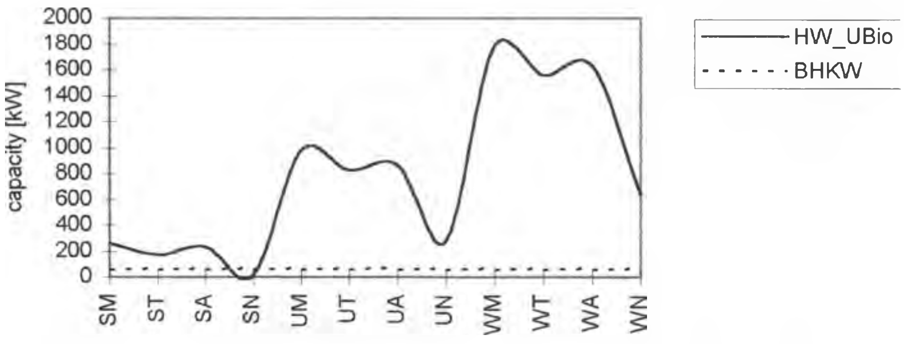

Fig. 12: Thermal energy structure of a heating plant (HW_UBio) and a district heating power station (BHKW).

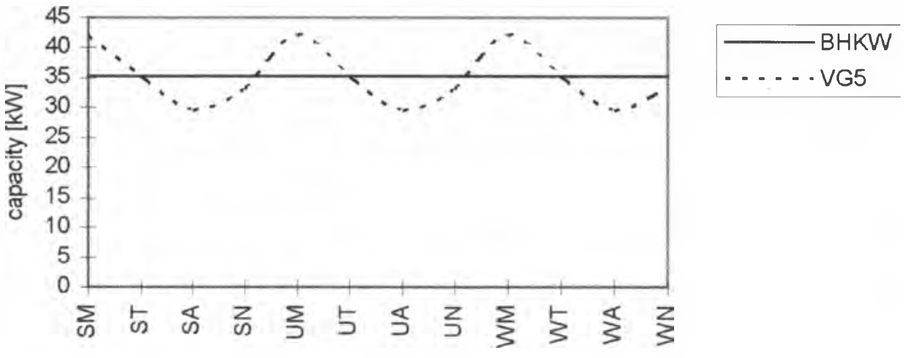

Fig. 13: Power structure of a district heating station and a farming industry (VG5).

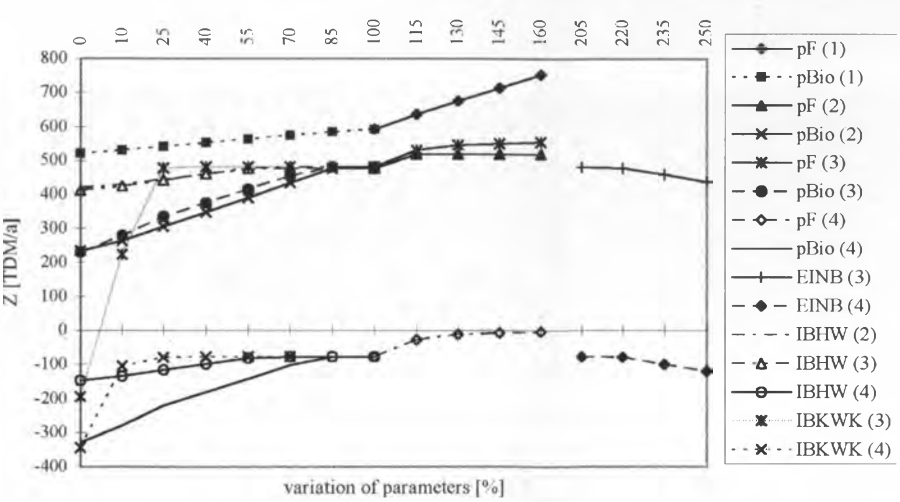

***Fig. 14:** Value of Z by variation of different parameters for the operating companies "municipality TH" and "investor PA".*

can be made by selling electricity and heat. The variation of fuel prices sooner leads to a change of Z than the variation of other parameters. Therefore, fossil fuels are substituted earlier by biomass. Moreover, the course of the graph of the biogenic fuel prices have the steepest gradient. Altogether it can be shown, that energy prices especially for biomass have the highest influence on the economic viability.

The given results show, that a supply based on biomass is possible. Using biomass in individual plants is already economic for some consumers without changing the origin prices. With a central supply the fossil and biogenic fuel prices have the highest influence on the economic of energy supply based on biomass for the operating companies "municipality TH" and "investor PA". Attempt should be made to reduce the biogenic fuel prices, because this would result in lower total consumption costs in comparison to an increase of fossil fuels.

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References

Gernhardt, D., 1996. Ein Verfahren zur Entwicklung optimaler Investitionsstrategien für preisgünstige und umweltverträgliche Energieversorgung. Bochum, Ruhr-Universität, Diss.

Hartmann, H., 1994. Energie aus Biomasse. Landtechnik-Bericht, Vol. 18, München.

Haschke, P. et al., 1994. Analyse und Potentialabschätzung zur energetischen Nutzung der land- und forstwirtschaftlich verfügbaren Biomasse im Land Brandenburg. Bericht im Auftrag des Referats Forschungsverwaltung des Ministeriums für Ernährung, Landwirtschaft und Forsten des Landes Brandenburg, Potsdam, pp. 3–15.

Landesamt für Datenverarbeitung und Statistik Brandenburg (ed.), 1996. Energiebilanz Land Brandenburg 1994. Statistische Berichte, Potsdam, pp. 4–16.

Landesumweltamt Brandenburg (ed.), 1994. Brandenburg regional '93, Potsdam.

Ministerium für Wirtschaft, Mittelstand und Technologie des Landes Brandenburg (ed.) 1994. Energiebericht 1993. Potsdam.

VDWE e.V. (ed.), 1981. Begriffsbestimmungen in der Energiewirtschaft Teil 2: Begriffe der Fernwärmewirtschaft. VWEW, Frankfurt/Main.

Viele veraltete Wärmeerzeuger in deutschen Heizungskellern, 1997. Gebäudetechnik: Schwarze Männer prüfen bundesweit 13 Mio. Heizkessel. In: VDI-Nachrichten, 38, p. 7.

Winje, D., Witt, D., 1991. Energiewirtschaft. Springer-Verlag, Berlin, Verlag TÜV Rheinland, Köln.

Author's address

Dipl.-Ing. Janet Nagel
Lehrstuhl Energiewirtschaft
Brandenburgische Technische
Universität Cottbus
Universitätsplatz 3–4
03044 Cottbus, Germany
e-mail: nagel@zucs1.rz.tu-cottbus.de

Biomass in Energy Supply, Especially in the State of Brandenburg, Germany

Janet Nagel

Abstract

As a result of growing visible damage to the environment connected with the use of fossil fuels, biomass is increasingly becoming a topic in energy economical and political discussions. Also, the limitation of fossil fuels and the belonging dependency on international energy markets make a change of view in direction of an energy supply based on biomass more and more necessary. Solid biomass from agriculture and forestry that is not used in industrial production, such as food production, as well as non contaminated or even contaminated solid biogenic waste-products and residue that have to be reused after the new commercial and industrial waste management act, is suitable for energy production to cover the existing heat and power consumption of single projects, like swimming pools, schools, or even for municipalities.

Against this background it will be

tried to analyze the technical possibilities of application, the ecological aspects, the existing potential of biomass, and the economic viability of energy supply based on biomass, especially on wood.

Keywords

heating plants, co-generation plants, state of the art, CO_2-emissions, comparison of biomass and hard coal, economic use of biomass, supply structure, potential of biomass, annuity of the capital value

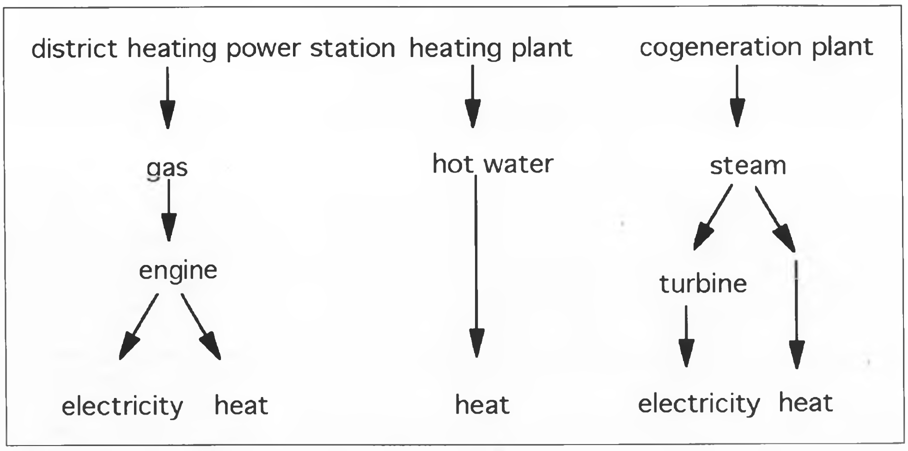

Fig. 1: Process principle of producing heat and electricity.

1 Technical possibilities of application

In heating plants biomass is fed to a chemical process in order to be converted into heat. During the combustion process heat is released by an exothermic reaction. The biomass is cut up and fed to the combustion chamber either by hand or by a conveyor belt. The heat produced with the process is transformed into low-temperature heat by heat exchanger. Technically speaking, the combustion of solid biomass is well developed.

In principle, it is possible to burn solid biomass in plants of different sizes and with different consumer energies (*Hein* et al., 1994):

- small combustion plants in households with a capacity up to 15 kW that are run with typically full load times of 1500 h/a, and mainly used to produce hot water and room temperature.
- small combustion plants in industries and trade that have a thermal capacity between 15 kW and 1 MW and which sometimes produce also process steam. These plants usually run with a full load time of 1500 to 2000 h/a.
- bigger plants with a capacity of 1 to 10 MW that are mainly run at woodworking industries and that produce electricity in addition to heat and steam. Here, 3000 to 4000 full load times per year can be reached.
- another possibility is to burn biomass together with coal in coal-fired power plants. In this utilization the production of electricity is in the foreground with an operation time of approx. 7000 h/a. Between 10 and 100 MW of thermal capacity could be used here.

The efficiency of the plants can clearly be increased by combining the production of heat and power (KWK). There are existing two process principles. Using a turbine in a cogeneration plant, power as well as low temperature heat can be produced. This process is not economic yet because of the high investment costs and therefore not used in practice. Another process are district heating power stations where gas which is produced in a wood or straw gasifier is fed to an engine to produce electricity. The waste heat can be used to produce low-heat temperature. This process is still in the development phase. There are problems, especially with the production of a clean wood or straw gas with a high thermal value, and with the combustion of gas engines which are not easily adapted to the quality of gas.

Also rapeseed oil or rapeseed oil methyl ester (RME) are suitable to be used in district heating power stations (BHKW). Rapeseed oil can be used instead of heating oil and thereby indirectly as diesel oil. Special engines are necessary to use these fuels. RME however, can be used in conventional diesel engines without any adaptation. RME can be used as a substitute for diesel oil. The different processes are shown in Figure 1.

Beside the higher fuel utilization in comparison to heating plants the processes of KWK are more economic because of the increase of income caused by the additional sale of electricity. On the other hand, local and long distant heating networks have to be constructed, which, in the FRG, are only economically viable beyond a heat load density of 25 to 60 MW/Km² (*Mebold* and *Maschallek*, 1988; *Tietz*, 1983; *Voß*, 1987).

A study by the *Institute für angewandte Ökologie e. V.* showed that in Brandenburg there would be an economic power heat linkage potential of 379 MW_{el} if public utilities implemented power heat linkage plants, the only peripheral condition is that they are credited for all work and performance costs that they avoid (*Matthes* et al., 1994).

The economic viability of heating plants increases with an increasing capacity caused by decreasing investment

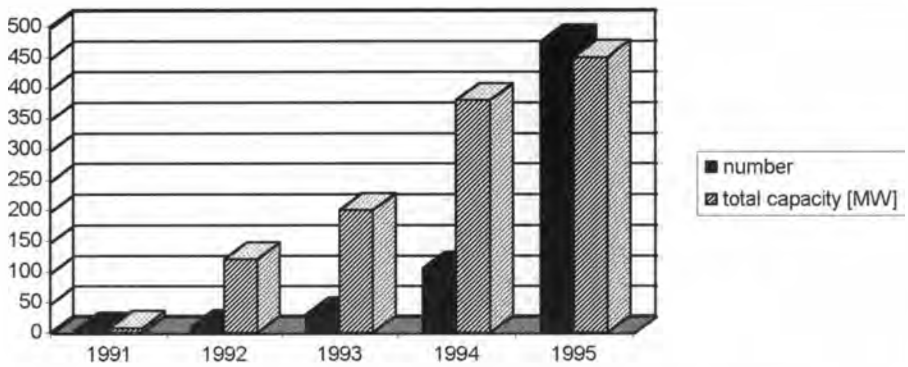

Fig 2: Increase in the number of wood-fired plants in Brandenburg since 1991 (Scholz et al., 1997).

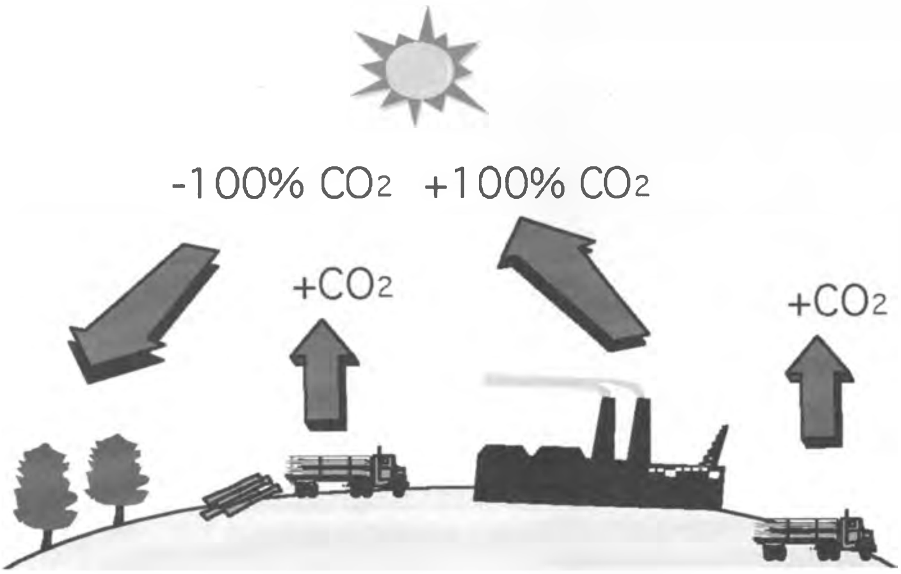

Fig. 3: CO2-emissions produced at the energy supply based on biomass.

and operation costs. A further increase of the economic viability can be reached by an increase of production because, with increasing number of units, the production costs can be reduced.

In Brandenburg the number of wood-fired plants is increasing continuously. Since 1991 at least 462 modern wood-fired plants have been installed and put into operation (*Scholz* et al., 1997) (Fig. 2). Numerically, small chopped wood boilers with a capacity of 10 to 50 kW predominate. However, looking at the total capacity, large-scale plants up to 500 kW are producing with more than 80 % a far higher share.

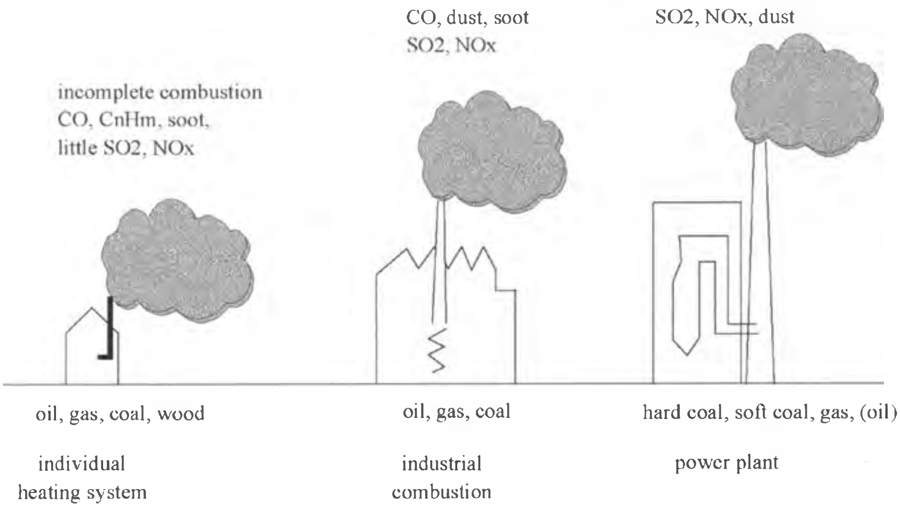

Fig. 4: Waste gas emissions at combustion plants of different sizes (Baumann, 1994).

Table 1: Net CO2-reduction potential in Germany using biomass fuels (Hartmann, 1994).

Process/raw material	Net CO_2-reduction potential [1]	
	Million tons per year	% of total emissions [2]
Energy plants	29.5	3.24
Straw	7.6	0.84
Wood (forest waste)	10.3	1.13
Wood (industrial waste)	5.3	0.58
Wood (land conservation waste)	0.3	0.03
Total	53.0	5.62

[1] Taking emissions caused during refinement into consideration.
[2] 910 million tons per year (1992, including the New Federal States).

2 Ecologically relevant aspects of the energetic use of biomass

The initial idea of returning to biomass for energy production was the target to substitute limited fossil fuels. In recent years however, the trend has additionally been to reduce the emissions of CO_2. In 1991 Germany decided to reduce the CO_2-emissions to a level 25 % to 30 % less than CO_2-emission levels from 1987 by the year 2005; this goal is still being followed after the conference in Kyoto (*Presse- und Informationsamt der Bundesregierung*, 1998).

The use of biomass is regarded as CO_2-neutral because CO_2-emissions arising at the combustion process have been absorbed before during the growth of the plants. The CO_2-emissions that effect the environment, arise at the biomass supply, which means at the harvesting, the transportation, the reprocessing and the waste disposal like ash or slag. The CO_2-circle is shown in Figure 3.

Therefore, it can be said that in substituting fossil fuels with biogenic fuels there is a CO_2 reduction potential of 53.0 million tons per year in Germany (Table 1), whereby the use of wood would make up the largest part (*Hartmann*, 1994).

Beside the CO_2-emissions, other products of waste gas produced at the combustion process have an influence on the environment. There are NO_x, SO_2, CO as well as dust and soot. Among other things, these are dependant on the size of plants as shown in Figure 4.

An evaluation of biomass in comparison to hard coal shows that wood can be evaluated as the best fuel and thereby its use in energy supply should be pushed (Table 2). For rapeseed oil and RME, which are evaluated in comparison to diesel oil it turns out that rapeseed oil equals +6 points and RME +13 points, which means, that these are far better than their reference fuel.

Table 2: Comparative evaluation of environmentally relevant aspects of the storage, reprocessing and use of biomass in comparison to hard coal (Hartmann and Strehler, 1995).

Judge main		Wood ships	Straw	Cereal plant	Miscant hus	Hay of land-scaping
Processes	Criterion					
Storage	Fungal infection and storage loss	-	o	-	-	o
	Fire hazard	o	-	-	-	-
	Spontaneous combustion	o	o	o	o	-
Reprocessing	Dust input	+	o	o	o	o
Use	CO	o	-	-	-	-
(Emissions)	C_nH_m	o	-	-	-	-
	NO_x	+	+	-	o	o
	SO_2	++	+	+	+	+
	Dust	+	-	o	o	-
	CO_2	++	++	++	++	++
Use	Occur of ash (amount)	++	-	o	+	-
(Residue)	Ash disposal (in circle)	++[1] (o)	++	++	++	o (++)[2]
	Occur of slag	+	-	o	-	--
Sum		+15	+1	+1	+2	-4

[1] Short rotation plantation.

[2] Better comparative without conservation restriction

explanation: clear advantage (++); advantage (+), equal (o); disadvantage (-); clear disadvantage (--)

Today, the damages caused by CO_2-emissions can neither be evaluated nor attributed to the polluters. If this in future becomes possible and the damage costs are covered by the CO_2 polluters, a re-calculation of figures showing economic viability will improve the competitiveness of biogenic fuels.

3 Supply structure in Brandenburg

The supply of electricity in the former GDR was produced by the use of coal-fired electrical-power or thermal-power stations. In contrast to the Federal Republic of Germany, heating requirements were met in the main by centrally located long-distance heating systems or by coal-fired single- or multiple-room stoves. These supply structures are also typical for Brandenburg, where single- and multiple-room stoves supply heat to approx. 30 % of all dwellings (*Landesamt für Datenverarbeitung und Statistik*, 1996b). The various types of energy used to heat dwellings include coal (34 %) – which is being extracted in the region, heating oil (14 %) and wood or other energy resources (22 %) (*Landesamt für Datenverarbeitung und Statistik*, 1996b). However, these supply structures, cause numerous environmental problems because coal with its high carbon content produces large amounts of pollution, dust and soot during combustion.

Since most heating systems are outdated and will either have to be renewed or altered, the municipalities have the historically unique opportunity of renewing or re-organizing the heating supply (*Ilum*, 1995). This opportunity can be used to build up a heat supply based on renewable energy, with biomass offering the most possibilities for potential use.

4 Potential of biomass

With a solar radiation of ca. 1000 W/m² and an average duration of sunshine about 1200 hours, there is a solar radiation of about 1200 kWh/m². Out of this, biogenic fuels can supply on the average the following solar energy contribution (*Plank*, 1994):

normal forest	15.7 MWh/ha/a
energy wood plantation extensive	45 MWh/ha/a
energy wood plantation intensive	90 MWh/ha/a
whole plant grain extensive	45 MWh/ha/a
whole plant grain intensive	90 MWh/ha/a
straw	13 MWh/ha/a
hay of landscaping	27 MWh/ha/a

If the energy potential of wood per inhabitant is taken into consideration, Brandenburg would be on the top of the list. Wood potential per person is 5.11 GJ/a and is therefore almost twice as high as in Bavaria (2.85 GJ/inhabitant a) (*Cames* et al., 1994). The amount available from the forestry industry for energy purposes is approx. 3 GWh (*Scholz* et al., 1997). Brandenburg has a large amount of softwood trees, 80 % of which are pines. There is approx. 10973 GWh/a of residual materials left over from agriculture, such as straw, grass and wood. The energy potential of these residual materials can be seen in Figure 5. In 1993 it would have been possible to grow up to approx. 150000 ha of energy plants on rotational and long-term fallow land which were unused in accordance with an EU-land retirement program (*Haschke* et al.,1994).

The biomass potential shown in Figure 5 could cover approx. 16 % of the total energy consumption of Brandenburg households, which in 1994 amounted to 247.64 PJ (*Landesamt für Datenverarbeitung und Statistik*, 1996a).

5 Economic field of applications

In order to examine the economic viability of different possibilities of energy supply, it is necessary to calculate the

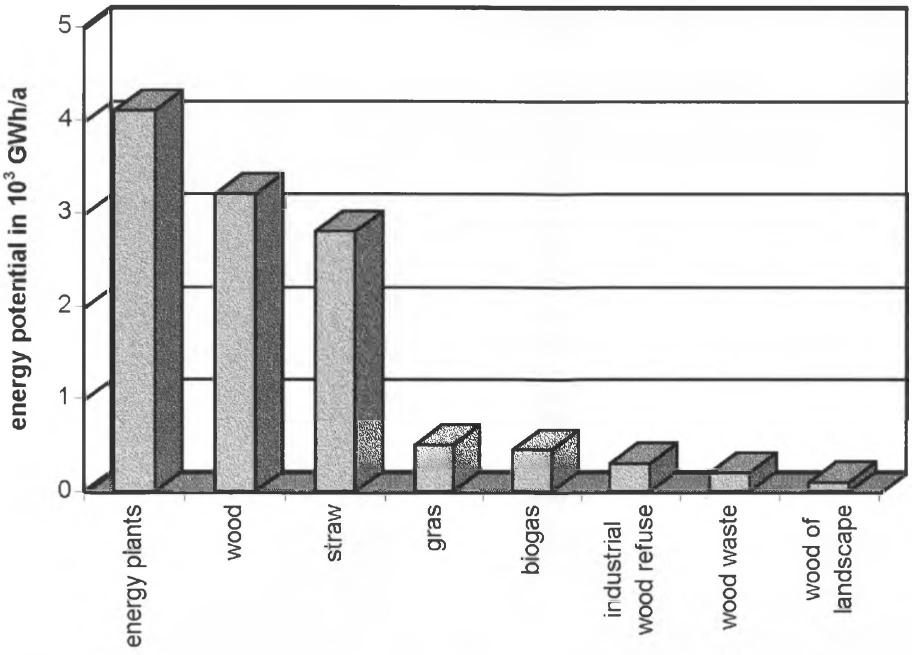

Fig. 5: Total potential of biogenic fuels in Brandenburg (Scholz et al., 1997).

costs of industrial combustion plants, fuels, and with a supply based on centrally located heating stations or district heating power stations, the heat distribution costs. If only the costs are taken into consideration, it can be stated that the supply costs of biomass-fired plants are approx. 20 % higher than those of individual heating stoves serving the whole community. An oil-based supply would however be the cheapest for a community of less than 200 inhabitants. For higher populated communities, a gas-based low temperature boiler would be cheaper. The same tendency can be seen when considering centrally located heating supplies. The network system costs are too high at this heat density. The combined generation of heat and power is more expensive using biomass-fired combustion plants than conventional plants, which moreover are more cost intensive than simple heating stations.

Different factors have an influence on the economic use of biomass. For example, investment costs of biomass-fired plants, fuel prices and payment of electricity produced out of biomass and fed into the public power supply system have to be named. The economic conditions for the use of biomass were analyzed for a typical rural municipality with 660 inhabitants and a structure of a linear village with a mixed-integer linear optimization model (Table 3). The examinations were based on the assumption that a district heating system already existed and they were carried out under the condition that the municipality joined together with an operating company. The dynamical evaluation of economic efficiency using the annuity of the capital value [An(C)] was employed. Electricity produced in a co-generation plant can be used in farming industry and in this way the electricity that has not to be taken out of the public power supply system can be credited. If production exceeds the need, it can be fed into the public power supply system by payment.

The prices for biomass should be 75 % of the actual price (0.03 DM/kWh$_{Hu}$) so that a biomass-fired heating plant together with a gas-fired district heating power station is economically viable. In this way the actual gas-fired heating plant is substituted. Or the fossil fuel prices have to be increased to 120 % from 0.033 DM/kWh$_{Hu}$ plus 13 DM/kW up to 0.4 DM/kWh$_{Hu}$ plus 15.6 DM/kW in order to attain an energy supply based on a biomass-fired heating plant. Under these conditions the district heating power station has a lower thermal capacity in comparison to today's levels. The payment of electricity produced out of biomass fed into the public power supply system has to be increased to 220 % (actual price: 15.25 Pf/kWh). Also state subsidies for biomass-fired heating plants or co-generation plants help to improve the economic use of biomass and thereby to substitute fossil-fired plants. For heating plants the state subsidies have to take 45 % of the costs and for co-generation plants they have to

Table 3: Conditions for an economic use of biomass for a municipality in Brandenburg.

Conditions	Prices/Rates [DM/kWh$_{Hu}$]	Technology	Distribution of capacity (thermal) [%]	An(C) [TDM/a]
Actual costs		HW_G; KWK_G	75.7 24.4	480.1
PBio = 75%	Wood = 0.023	HW_UBio; KWK_G	92.4 7.6	467.8
PF =120%	Natural gas =0.04 plus 15.6 DM/kW	HW_UBio; KWK_G	92.4 7.6	541.1
EINB = 220%	0.0335	HW_G; KWK_G; BHKW_Raps	75.4 7.4 17.2	478.19
	[TDM]			
IBKWK = 75%	181.1 281.2	HW_G; KWK_G; BHKW_Biogas	74.2 16.3 9.5	477.8
IBHW = 45%	405.1	HW_UBio; KWK_G	69.6 30.4	475.9

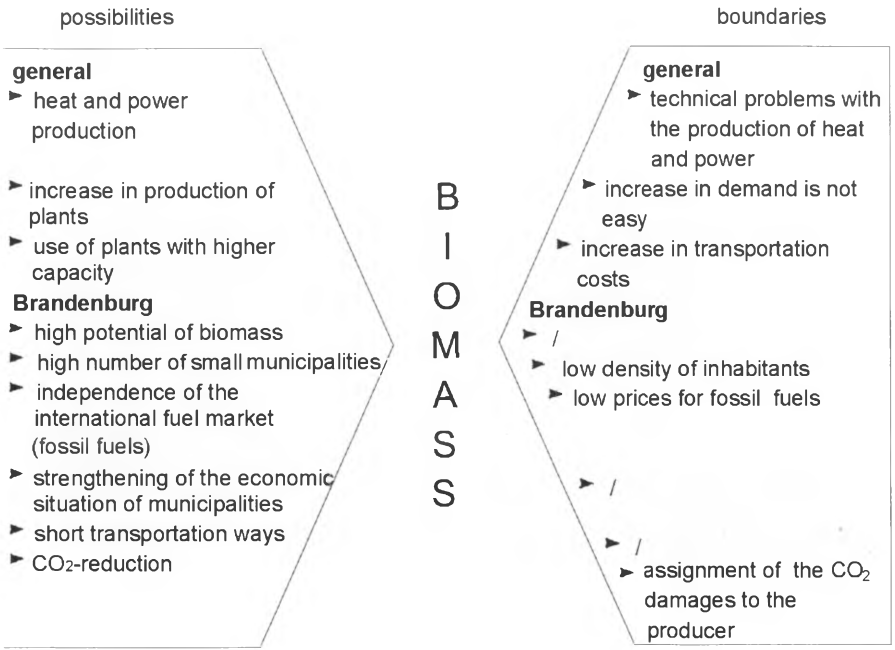

Fig 6: Possibilities and boundaries of the economic use of biomass, especially in Brandenburg.

take 75 %. The results show that in district heating systems biomass can be used by changing the conditions.

6 Conclusion

Lots of different technologies are available to use biomass for heat and power or for combined heat and power production. Some of the processes are not yet matured, but the use of biomass is already possible. Economical problems exist because of the higher investment and operating costs in comparison to fossil fired plants. Here, for example state subsidies are necessary to improve the economic viability. Looking at the ecological effects of burning biogenic fuels, wood comes off very well. But, the other types of biomass are less damaging to the environment than their reference fuels. Concerning the CO_2-emissions, biomass can help reduce the emissions because the CO_2 arising at the combustion was admitted before at the growth. Especially in Brandenburg, the potential of biomass that can be used for producing energy is very high. To improve the economy the conditions have to be changed. This is possible by establishing taxes like CO_2-taxes or state subsidies for biomass-fired energy conversion plants or by changing the payment for electricity produced by biomass. In conclusion, there are many possibilities as well as restrictions in the use of biomass in the energy supply as shown in Figure 6.

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References

Baumann G. et al., 1994. Abgasemissionen bei der Verbrennung von Holz und anderen Biomassen. In: Thermische Nutzung von Biomasse – Technik, Probleme und Lösungsansätze; Tagungsband, Bundesministerium für Ernährung, Landwirtschaft und Forsten (ed.) and Fachagentur Nachwachsende Rohstoffe e. V. (ed.), Schriftenreihe: Nachwachsende Rohstoffe, Vol. 2, Stuttgart, pp. 145–164.

Cames, M. et al., 1994. Kriterien und Instrumente zur Bewertung des Potentials der Kraft-Wärme-Kopplung in Brandenburg Phase II. Öko-Institut, Institut für Angewandte Ökologie, Studie im Auftrag des Landesumweltamtes Brandenburg, Freiburg/Berlin, p. 13.

Hartmann, H., Strehler, A., 1995. Die Stellung der Biomasse im Vergleich zu anderen erneuerbaren Energieträgern aus ökologischer, ökonomischer und technischer Sicht – Abschlußbericht. Schriftenreihe: Nachwachsende Rohstoffe, Vol. 3, Münster, p. 276.

Hartmann, H., 1994. Energie aus Biomasse. Landtechnik-Bericht, 18, München, pp. 62–67.

Haschke, P. et al., 1994. Analyse und Potentialabschätzung zur energetischen Nutzung der land- und forstwirtschaftlich verfügbaren Biomasse im Land Brandenburg. Bericht im Auftrag des Referats Forschungsverwaltung des Ministeriums für Ernährung, Landwirtschaft und Forsten des Landes Brandenburg, Potsdam, pp. 3–15.

Hein, K. R. G. et al., 1994. Biomasseverbrennung – Stand der Technik. In: Thermische Nutzung von Biomasse – Technik, Probleme und Lösungsansätze; Tagungsband, Bundesministerium für Ernährung, Landwirtschaft und Forsten (ed.) and Fachagentur Nachwachsende Rohstoffe e. V. (ed.), Schriftenreihe: Nachwachsende Rohstoffe, Vol. 2, Stuttgart, pp. 119–133.

Ilum, K., 1995. Towards Sustainable Energy Systems in Europe – SESAM. Aalborg Universitetsforlag, Aalborg.

Landesamt für Datenverarbeitung und Statistik Brandenburg (ed.), 1996a. Energiebilanz Land Brandenburg 1994. Statistische Berichte, Potsdam, pp. 4–16.

Landesamt für Datenverarbeitung und Statistik Brandenburg (ed.), 1996b. Gebäude- und Wohnungszählung 1995. Potsdam, pp. 4–43.

Matthes F. C. et al., 1994. Kriterien und Instrumente zur Bewertung des Potentials der Kraft-Wärme-Kopplung in Brandenburg Phase I. Öko-Institut, Institut für Angewandte Ökologie, Freiburg/Berlin, pp. 1–37.

Mebold, H., Marschallek, H., 1988. Leitungsgebundene Energieversorgung in Mannheim. In: Brennstoff, Wärme, Kraft, 40, No. 9, pp. 361–366.

Plank, J., 1994. Logistik der Brennstoffgewinnung. In: Thermische Nutzng von Biomasse – Technik, Probleme und Lösungsansätze, Tagungsband, Bundesministerium für Ernährung, Landwirtschaft und Forsten (ed.) and Fachagentur Nachwachsende Rohstoffe e.V. (ed.), Schriftenreihe: Nachwachsende Rohstoffe, Vol. 2, Stuttgart, pp. 89–110.

Presse- und Informationsamt der Bundesregierung (ed.), 1998. Erklärung der Bundesregierung : Kyoto – Erfolg und weitere Verpflichtung im weltweiten Klimaschutz. In: Bulletin (1998-01-20), No. 5, pp. 41–45.

Scholz, V. et al.; Arbeitsgruppe Bioenergie Brandenburg and Ministerium für Ernährung, Landwirtschaft und Forsten des Landes Brandenburg (ed.), 1997. Energie aus Biomasse – Stand und Möglichkeiten der energetischen Nutzung von Biomasse im Land Brandenburg. Potsdam.

Tietz, H.-P., 1983. Erschließungs- und Standortplanung für die Fernwärmeversorgung. Karlsruhe, Universität (TH), Diss.

Voß, A., 1987. Perspektiven der Energieversorgung - Möglichkeiten der Umstrukturierung der Energieversorgung Baden-Württembergs unter besonderer Berücksichtigung der Stromversorgung. Stuttgart.

Author's address

Dipl.-Ing. Janet Nagel
Lehrstuhl Energiewirtschaft
Brandenburgische Technische
Universität Cottbus
Universitätsplatz 3–4
03044 Cottbus, Germany
e-mail: nagel@zucs1.rz.tu-cottbus.de

Biosims – A Method for the Calculation of Woody Biomass for Fuel in Sweden

Matti Parikka

Summary

The study was designed:

1. to calculate regional woody biomass resources for fuel, taking ecological restrictions on harvesting into consideration,
2. to test a method of calculating the quantity of woody biomass and woodfuel,
3. to test a method of analysing the consequences for ecological restrictions and
4. to show a woodfuel balance for the region.

The test region was the county of Dalarna (Kopparberg) in Sweden. For purposes of calculation, the region was divided into three parts (Northern, Middle and Southern). The study refers to year 1993.

The results show that 24– 56% of the total forest land area would be affected by the modification of harvesting restrictions in the county of Dalarna. Translation of these results to woody biomass quantities shows that the total potential of woody biomass for fuel, 7990 GWh per year, is reduced to 5700 GWh per year. The total use of woody biomass for fuel is 930 GWh per year. The remaining potential of woody biomass for fuel in the county of Dalarna is 4770 GWh per year.

The Biosims model (*Parikka*, 1996 & 1997 a & 1997 b) was used to calculate the raw material base for woody biomass and woodfuel. Routines for the evaluation of ecological restrictions are included in the model. The Biosims model uses forest data gathered from sample plots in the National Forest Survey (NFS). Other data, e.g. ecological and production data, can also be adjusted to local conditions. The sources of woodfuels are grouped into two principal categories: 1) logging residues and 2) direct woodfuel harvesting. Stumps are excluded from the calculations. The results can be transformed, e.g. into energy equivalents and biomass nitrogen content.

The model makes it possible to analyse the effects of various types and intensities of legal restrictions in Sweden on the woodfuel supply. Modified ecological restrictions have also been developed and tested. Recommendations for ecological restrictions are based on variables, e.g. vegetation class, included in the NFS data. The calculations assume that recycling of wood ash accrues after biomass. The set of variables and their values have been selected by the Regional Forestry Board. The primary aim of this selection is to transform the current general principals into a form that the Biosims model can handle.

Routines have been developed for using data from the NFS system in the inventory of woody biomass, e.g. the coordinates (longitude, latitude) of the NFS sample plots can be used. As the forest data include precise local co-ordinates, it is possible to use the model for local woodfuel supply systems, e.g. for district heating plants.

Introduction

The use of woody biomass for fuel has increased by 100% in 15 years in Sweden. The current level is about 41 TWh (*Anon.*, 1997) per year and the total annual supply, excluding black liquor, is about 130 TWh (*Hektor* et al., 1995) per year. The appraisal of wood supply and the corresponding demand, "the wood balance", has long focused on industrial pulp wood and saw-logs. Fuel wood was encountered as a minor factor from around 1950, and has remained minor since then, even during the years of the "energy crisis" in the beginning of the 1970's (*Hektor* et al., 1996). The use of woodfuels is controlled by regulations. The National Board of Forestry has issued recommendations (*Anon.*, 1986) on the use of logging residues etc., with the purpose of minimising the risks for long-term adverse effects on soil fertility and the environment.

Moreover, to ensure the supply of raw material to the forest industry the Wood Fibre Act of 1987 was introduced. This law restricted the use of trees above the diameter of 5 cm at breast height for purposes other than industrial products. The act also included those by-products from the saw milling industry that had possible industrial uses. Even after the regulations were revised in 1987 a large surplus of potential woodfuels, mainly in the form of unused logging residues, remained. The law was abolished in 1991.

A transition process (*Hektor* et al., 1996) is now taking place and many conditions are changing, including policy level decision making, forestry practices, agricultural policy and the forest industry. The planning objective will be to secure an efficient supply of woodfuels for local or regional markets. The raw material will consist not only of waste and residues from industry and from logging operations, but to an increasing extent also of trees harvested in thinnings and other stand improvement cuttings. New cutting calculations were made in 1992 using new data from the NFS (*Anon.*, 1992). The results show that both the annual growth and the growing stock have increased considerably compared with previous calculations. Regarding to the Swedish energy policy the Nuclear Power Shutdown Act of 1997 (Ds 1997: 14) was introduced.

Objectives of the study

The study was designed:

1. to calculate regional woody biomass resources for fuel, taking ecological restrictions on harvesting into consideration,
2. to test a method of calculating the quantity of woody biomass and woodfuel,
3. to test a method of analysing the consequences for ecological restrictions and
4. to show a woodfuel balance for the region.

The test region was the county of Dalarna (Kopparberg) in Sweden. For purposes of calculation, the region was divided into three parts (Northern, Middle and Southern, see Table 1). The study refers to year 1993.

Table 1: The rural districts in the county of Dalarna.

Part of the county	Rural district
Northern	Malung Älvdalen
Middle	Orsa Mora Leksand Rättvik Gagnef Vansbro
Southern	Falun Borlänge Hedemora Ludvika Smedjebacken Säter Avesta

Materials and Methods

The Biosims model

The Biosims model (*Parikka*, 1996 & 1997 a & 1997 b) was used to calculate the raw material base for woody biomass and woodfuel in the county of Dalarna in Sweden. The model can analyse the effects of various types and intensities of legal restrictions in Sweden on the woodfuel supply and the costs. It is designed to be flexible and it can be applied to other countries as well. Routines for the evaluation of ecological restrictions are included in the model. The Biosims model uses forest data gathered from the sample plots in the National Forest Survey (NFS). Other data, e. g. ecological, production and cost data, can also be adjusted to local conditions.

The woodfuels are consequently grouped into two principal categories: 1) logging residues (later thinning, final felling) and 2) direct woodfuel harvesting (first thinning trees and trees cut in operations with other principal purposes such as cleaning, farming, rejected saw logs or pulp wood, etc.). Stumps are not included. The quantity of woodfuel in the stumps is large, but since it is not economically feasible to extract it, this source is omitted from the model. Industrial by-products and other woodfuels are accounted directly from industry and energy statistics.

Program modules

The program has been built up in modules. This approach is flexible and makes it possible to enlarge the model easily by adding new modules. The modules can be modified without reprogramming of the whole model.

The current modules are: (1) Parameter module, (2) Translation module, (3) Area module, (4) Filtering module, (5) Classification module, (6) Eco module, (7) Statistics module, (8) Calculation module, (9) Report generator including a link to GIS (Geographical Information System).

Parameter module contains predefined information. Parameters are placed in matrixes and databases.

Translation module is used in those cases when new information has to be translated and added to existing databases for use in the program. It is a link or a key between new databases and databases in the Biosims. This module is also used for translation of data to the GIS.

Area module is used for definition of regions and supply zones. Using co-ordinates is also possible (longitude and latitude) for identification of the sample plot.

Filtering module is used to delete observations when needed. Traditional logical operators are used (if – then – else). New filtering routines can be implemented without changing the current structure.

Classification module is used for sorting and definition of sub classes by definitions. Traditional logical operators are used (if – then – else). New classification routines can be implemented without changing the current structure.

Eco module is used for definition of schemes for ecological restrictions. Even this module is based on logical operators. Schemes are defined for first thinning and other thinning and clear cutting. New schemes can be defined and implemented.

Statistics module can directly use the databases included in the Biosims. Standard statistics procedures included in the SAS software package can be used. Defining new formulas when needed is possible.

Calculation module includes all functions needed for biomass and volume calculations, calculation of biomass nitrogen content and translation and conversion functions and factors.

Report generator. The report generator uses standard database procedures for output (on screen or on printer) included in the SAS software package. User defined reports can be generated. Calculations and summaries of forestry and biomass related data can be done. Ready to use classifications (i. e. a classification module) of the data can be used in reports. A link to the GIS is included in the report generator. This makes it possible to use the GIS to plot results at the map.

Calculation methods

Two different methods for woody biomass calculations are used: 1) the regression estimate method (*Art* and *Marks*, 1971), i.e. a woody biomass inventory or utilisation level based on regression functions and 2) the ratio method (*Crow* and *Schlaegel*, 1988; *Cannel*, 1984), i.e. a woody biomass inventory or utilisation level based on traditional forest inventories and conversion functions between volume and woody biomass. Both methods can be used to calculate woody biomass at stand level and at regional level. The regional level calculation is mainly based on the ratio method.

The dry substance of woody biomass is calculated by using the biomass functions (*Marklund*, 1988) for the main domestic tree species (*Pinus silvestris, Picea abies, Betula pubescens, Betula verrucosa*). The volume of marketable timber is calculated by using the volume and the yield functions (*Näslund*, 1947; *Ollas*, 1980). The results can be transformed, e.g. into energy equivalents and biomass nitrogen content.

Table 2: A definition of variables included in the modified ecological restrictions.

Variable	Value	Explanation
Soil moisture	1-4	Dry soil (1) - Wet soil (4)
Mineral soil/Peatland	1-4	Mineral soil (1) - Peatland (4)
Sediment/Till	0-1	Sediment (0) - Till (1)
Soil texture	1-8	Till: Stony till (1) - Clayey till (8) Sediment: Stone (1) - Clay (8)
Ground layer	1-6	Lichen type (1) - Mesic moss type (6)
Vegetation class	1-18	Tall herbs with no dwarf shrubs (1) – Lichen (18)

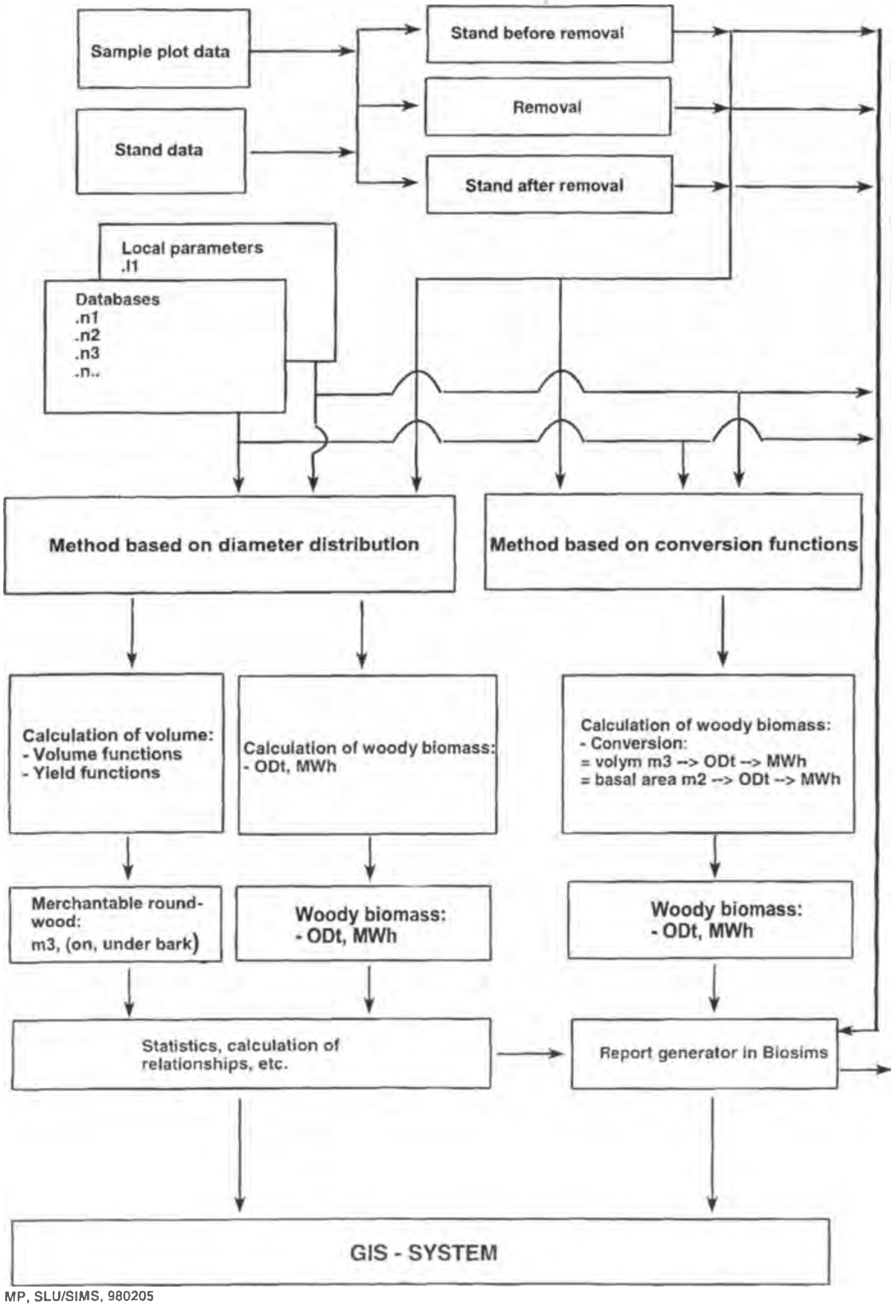

Fig. 1: Calculation methods.

Restrictions

The National Board of Forestry has issued recommendations (*Anon.*, 1986) for predictions regarding whole tree harvesting and the removal of forest residues to provide for a sustained nutrient level in the soil. These recommendations are now under revision as new research results are presented.

Modified ecological recommendations have been tested and presented (*Parikka*, 1997a & 1997b). These recommendations are based on the following variables: 1) soil moisture, 2) solid ground/peatland, 3) soil texture, 4) ground layer and 5) vegetation class, included in the NFS data. The set of variables and their values have been selected by the Regional Forestry Board (see Table 2). The primary aim of this selection is to transform the current general principals into a form that the Biosims model can handle. Increasing the removal of woodfuel would be possible if wood ash were used for compensatory fertilisation (*Lundqvist*, 1993; *Olsson*, 1995). Therefore calculations assume that recycling of wood ash accrues after biomass. Two examples of conversion tables for the ecological restrictions in the region of Dalarna are shown in Table 3.

Table 3: Two examples of conversion tables for the ecological restrictions.

A conversion table for clear cutting and other thinning.

Variable	Classification	Value	Additional information
Soil moisture	1	no	
	2-4	yes	
Solid ground/Peatland	0-1	yes	
	2-3	yes	if vegetation class<4
Soil texture	1-3	no	
	4-5	yes	if vegetation class<14
	5-8	yes	if vegetation class<17
Ground layer	1-3	no	
	4-6	yes	
Vegetation class	1-13	yes	
	14-16	yes	if soil texture>5
	17-18	no	

A conversion table for first thinning.

Variable	Classification	Value	Additional information
Soil moisture	1	no	
	2-4	yes	
Solid ground/Peatland	0-1	yes	
	2-3	yes	if vegetation class<4
Soil texture	1-3	no	
	4-8	yes	if vegetation class<17
Ground layer	1-3	no	
	4-6	yes	
Vegetation class	1-13	yes	
	14-16	yes	if soil texture>5
	17-18	no	

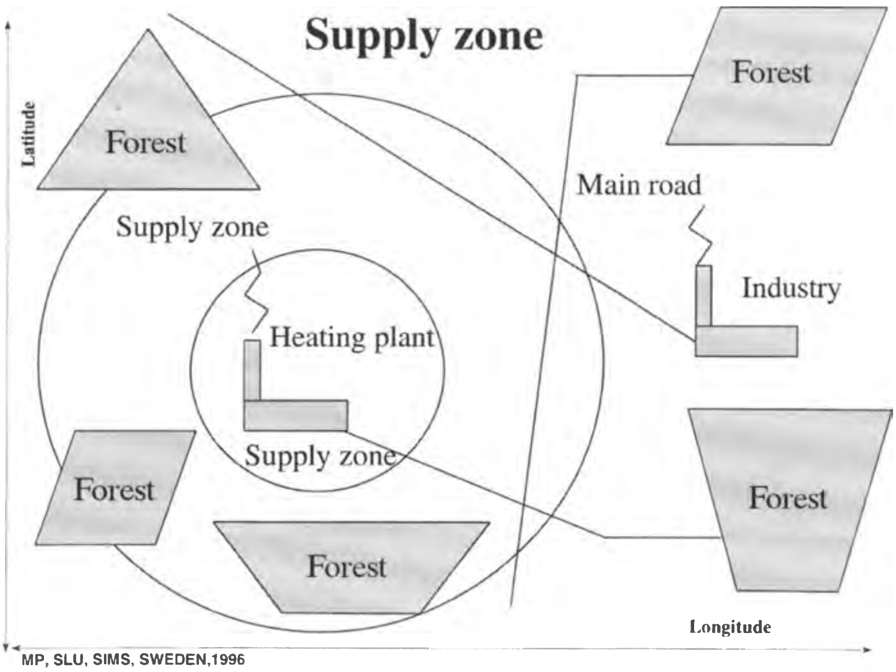

Fig. 2: An example of a "supply zone".

Description of a supply zone

Routines have been developed to use the benefits from the NFS system for the inventory of woody biomass, e.g. using co-ordinates (longitude, latitude) for the NFS-data sample plots. Using other categories of geographical descriptions is also possible, e.g. "World Geographical Code" (*Hektor* et al., 1996). As the forest data include precise local co-ordinates, it is possible to use the model for local woodfuel supply systems, e.g. for district heating plants. It is also possible to use a GIS-system, e.g. ArcView GIS (*Anon.*, 1996), to plot results at the map.

The program software

The Biosims Program has been developed using SAS (Statistical Analysis System is a registered trademark of the SAS-institute). The source code of the program is portable between different computer platforms, e.g. mainframe and PC. All databases are initially formatted in ASCII code (American Standard Code for Information Interchange). This fact guarantees both easy access to data and compatibility.

Results

Ecological restrictions

Table 4 shows an application of the conversion table (Table 3) for ecological restrictions in the county of Dalarna. The results show that 24–56% of the total forest land area would be affected by the modification of harvesting restrictions. Soil texture and vegetation class are the most significant variables.

Annual supply of woody biomass

Translation of these restrictions (Table 4) to woody biomass quantities shows that the total potential of woody biomass for fuel (Table 5), 7990 GWh per year is reduced to 5700 GWh per year.

Consumption of woody biomass for fuel

District heating

The use of woody biomass for fuel in district heating in the county of Dalarna was 218 GWh 1993.

Table 4: An application of the conversion table for ecological restrictions in the county of Dalarna. The results are shown in percent of the total forest land area. YES = Removal allowed, NO = Removal not allowed.

	The county of Dalarna					
	Northern		Middle		Southern	
Variable	(YES)	(NO)	(YES)	(NO)	(YES)	(NO)
Soil moisture	94.2	5.8	94	6	95.4	4.6
Solid ground/Peatland	91.7	8.3	91.8	8.2	93.1	6.9
Soil texture	59.3	40.7	74.5	25.5	88.1	11.9
Ground layer	70.6	29.4	86.1	13.9	93.1	6.9
Vegetation class	52.2	47.8	72.6	27.4	85.2	14.8
Sum	**43.1**	**56.1**	**60.7**	**39.3**	**75.8**	**24.2**

Table 5: The annual supply of wood biomass for fuel in the county of Dalarna.

	Total quantity	After ecological restrictions
A. Forest residues, GWh	GWh	GWh
* Northern	1 330	570
* Middle	2 610	1 580
* Southern	2 050	1 550
= Total (A. Forest residues), GWh	**5 990**	**3 700**
B. Direct woodfuel cuttings, GWh		
* Stemwood from first thinning	1 300	1 300
* Non industrial wood incl. others	700	700
= Total (B. Direct woodfuel cuttings), GWh	**2 000**	**2 000**
= Total (A+B), GWh	**7 990**	**5 700**

Table 6: The use of woodfuel in district heating in the county of Dalarna, GWh, 1993. Source: Anon. (1993).

Name of district	Consumption, GWh
Avesta	30
Borlänge	55
Falun	11[1]
Hedernora	6
Mora	54
Säter	27
Rättvik	35
SUM	**218**

[1] First year in operation

Table 7: The use of wood and wood chips in farm and other estates in the county of Dalarna, GWh. Source: Anon. (1991).

Type of estate	Consumption, GWh
Farm estate	200
Other estate	510
SUM	**710**

Households

The use of woody biomass for fuel in households in the county of Dalarna was 710 GWh 1991.

Wood fuel balance

Table 8 shows an outline of woodfuel balance in the county of Dalarna. The balance refers to year 1993. The total use of woody biomass for fuel is 930 GWh per year. The remaining potential of woody biomass for fuel in the region of Dalarna is 4 770 GWh per year.

Discussion

The results show that 24–56 % of the total forest land area would be affected by the modification of harvesting restrictions in the county of Dalarna. This means that the commonly used average reduction of 14 %–18 % (*Anon.*, 1992) for the whole country by the means of ecology is not enough for regional and county wide studies. The difference is much wider and should be taken into account. The potential additional supply of woodfuel is 4770 GWh per year in the county of Dalarna. In this study technical and economical restrictions are not included in the calculations. These aspects are very difficult to calculate in the future. The productivity in forest operations and in woodfuel utilisation has increased rapidly during the last 20 years. There is no reason to believe that this development is going to stop because of increasing demand of woodfuels.

On both national and local levels there are several practical fields of application for the model described above. The principal issue is the ability to quantify the long-term supply of woody biomass with a reasonable degree of relia-

Table 8: An outline of woodfuel balance in the county of Dalarna, GWh per year.

	Total supply
Potential of woodfuel after ecological restrictions, GWh/a (Table 6)	5700
User	**Use**
A. District heating, GWh/a (Table 3)	220
B. Estates etc., GWh/a (Table 4)	710[1]
Sum (A+B), GWh/a	930
	Potential supply
Potential additional supply of woodfuel, GWh/a	4770

[1] The figure refers to the use of woodfuel 1991.

bility. Possible effects caused by stricter environmental restrictions should also be assessed. As the forest data include precise co-ordinates, it is possible to use the model for local woodfuel supply systems. The model has been used in several studies in Sweden, e.g. *Parikka & Vikinge* (1994), *Delin* et al. (1995), *Hektor* et al. (1995 & 1996) and *Parikka* (1997 a). These studies show that the model can be used for energy planning at stand and at regional levels and it can as well be used by woodfuel producers as a tool for decision making. It has also been used for calculation of nitrogen relief from the forest land by removal of green biomass.

References

Anon. (1986). Skogstyrelsens författningssamling [The Forestry Act]. SKSFS 1986:1. Skogsstyrelsens allmänna råd om begränsning vid uttag av träddelar utöver stamvirke på skogsmark [The general guide lines for the removal of other tree sections than stem sections on forest land]. Skogsstyrelsen [The National Forestry Board]. Jönköping.

Anon. (1987). Instruktion för fältarbete vid riksskogstaxeringen [Field Instructions for the National Forest Survey]. Swedish University of Agricultural Sciences. Department of Forest Survey. Umeå.

Anon. (1991). Förbrukning av trädbränsle i småhus på jordbruksfastighet och annan fastighet [Consumption of woodfuel in farm and other estates]. Statistiska Centralbyrän [Statistics Sweden]. Örebro.

Anon. (1992). The New Forest Policy and the Cutting Calculation 1992. Swedish Government Publications 1992: 76. Stockholm.

Anon. (1993). Statistik 1993 [Statistics 1993].Värmeverksföreningen [Heating Plant Association]. Stockholm.

Anon. (1996). ArcView GIS. The Geographic Information System for Everyone. Environmental Systems Research Institute Inc. Redlands CA. USA.

Anon. (1997). Energy in Sweden 1997. NUTEK [Swedish National Board for Industrial and Technical Development]. Stockholm.

Art, H. W., P. L. Marks (1971). A Summary Table of Biomass and Net Annual Primary Production in Forest Ecosystem of the World. In: Forest Biomass Studies, pp. 1–32.

Cannel, M. (1984). Woody Biomass of Stands. Forest Ecology and Management, 8, pp. 299–312.

Crow, T. R., B. E. Schlaegel (1988). A Guide to Using Regression Equations for Estimating Tree Biomass. Northern Journal of Applied Forestry 5, 15–22.

Delin, L., B. Hektor, M. Parikka, L. Åstrand (1995). System Study – Techno/Economical Reviews of a Number of Process Combinations of Ethanol Processes and other Relevant Industrial Processes. NUTEK. Stockholm.

Hektor, B., Lönner, G., Parikka, M. (1995). Trädbränslepotential i Sverige på 2000-talet [Woodfuel Potential in Sweden at the year 2020]. Swedish University of Agricultural Sciences. Department of Forest-Industry-Market Studies (SIMS). Series: "Utredningar" no. 17. Uppsala.Sweden. (In Swedish).

Hektor, B., Lönner, G., Nilsson, P., 0., Parikka, M. (1996). Trädbränslepotential i Södra Sverige [Potential of woodfuel in the south of Sweden]. Vattenfall. R1995-10.Vällingby. Sweden. (In Swedish, English summary).

Lundqvist, H. (1993). Whole Tree Harvesting – Ecological Consequences and Compensatory Measures. Examples from Sweden. In: Environmental Issues in Supply of Biomass for Energy from Conventional Forestry (J.-E., Mattson, Ed.). Swedish University of Agricultural Sciences. Department of Forest Operational Efficiency. Garpenberg.

Marklund, L.-G. (1988). Biomass Functions for *Picea abies, Pinus silvestris* and *Betula pubescens*. Swedish University of Agricultural Sciences. Department of Forest Survey. Report no. xx. Umeå.

Näslund, M. (1947). Funktioner och tabeller för kubering av stående träd Tall, Gran, Björk i södra och hela Sverige [Functions and tables for calculation of volume of standing trees: Scots Pine, Norway Spruce, Birch]. Skogshögskolan. Stockholm.

Ollas, R. (1980). Värdering av stående skog – nya utbytesfunktioner [Calculation of volume of standing trees - new yield functions]. Sågverken. Stockholm.

Olsson, B. (1995). Soil and Vegetation Changes after Clear-felling Coniferous Forests – Effects of Varying Removal of logging residues. Swedish University of Agricultural Sciences. Department of Ecology. Report no. xx. Uppsala.

Parikka M., B. Vikinge (1994). Kvantitet och ekonomi vid bränsle och massavedsuttag i första gallring [Quantities and Economy at Removal of Woody Biomass for Fuel and Industrial Purposes from Early Thinning]. Swedish University of Agricultural Sciences. Department of Forest-Industry-Market Studies. Uppsala. (In Swedish; English summary).

Parikka, M. (1996). Methodology and techniques for the appraisal of woodfuel balances in Sweden. In: World renewable energy congress. 15–21 June 1996. Denver. Colorado. USA. Vol II (ed. Sayigh, A.A.M.). Pergamon. (2).

Parikka, M. (1997 a). Trädbiomassa och trädbränsletillgångar i Dalarna med beaktande av ekologiska hänsyn [Woody biomass- and woodfuel resources and the effect of ecological restrictions on harvesting in Dalarna, Sweden]. Swedish University of Agricultural Sciences. Department of Forest-Industry-Market Studies (SIMS). Series: "Utredningar" no. 19. Uppsala. Sweden. (In Swedish; English summary).

Parikka, M. (1997 b). Biosims – a method for the estimation of woody biomass for fuel in Sweden. Swedish University of Agricultural Sciences. Silvestria no. 27. Uppsala. Sweden. (In Swedish; English summary).

Author's address

Dr. Matti Parikka
Swedish University of Agricultural Sciences
Department of Forest – Industry – Market Studies (SIMS)
PO Box 7054, 75007 Uppsala, SWEDEN
e-mail: matti.parikka@sims.slu.se
Homepage:
www.sims.slu/mparikka/mattis.htm

Carbon Balance of Bioenergie and Forestry Strategies

Josef Spitzer and
Bernhard Schlamadinger

Bioenergy can reduce net CO_2 emissions, because unlike fossil fuels, plants take up the CO_2 before it is released back to the atmosphere.

Motivation for bioenergy production is:

- Bioenergy to replace fossil energy
- Biomass (wood) as carbon store
- Biomass as energy efficient raw material
- Net carbon balance strongly time dependent

However, there can be associated changes of carbon in vegetation, litter and soils. When biofuels are produced along with wood products, one has to consider the carbon stored in products and the substitution of energy-intensive materials.

The model GORCAM (Graz/Oak Ridge Carbon Accounting Model) is a tool developed to calculate the time dependent fluxes between various carbon pools and the atmosphere and to analyse carbon balances of bioenergy and forestry. Model parameters describe the management regime, previous land use, fate of the harvest, efficiency of fossil fuel substitution and energy inputs for operating the system. Besides clearcutting other forestry methods like thinning, selective logging and short rotation can be analysed.

Results show that initial on-site carbon, growth rate, efficiency of harvest use, and time-frame are most important.

For high growth rates and efficient harvest use, fossil fuel substitution dominates the carbon balance. Strategies like fuelwood plantations on previously bare land lead to emission reductions from the beginning. Harvest of existing forests results in a net carbon source or sink, depending on the efficiency of biomass use. Afforestation leads to significant carbon uptake until the forest matures, only harvest – for fossil fuel displacement – and replanting provide further carbon sequestration.

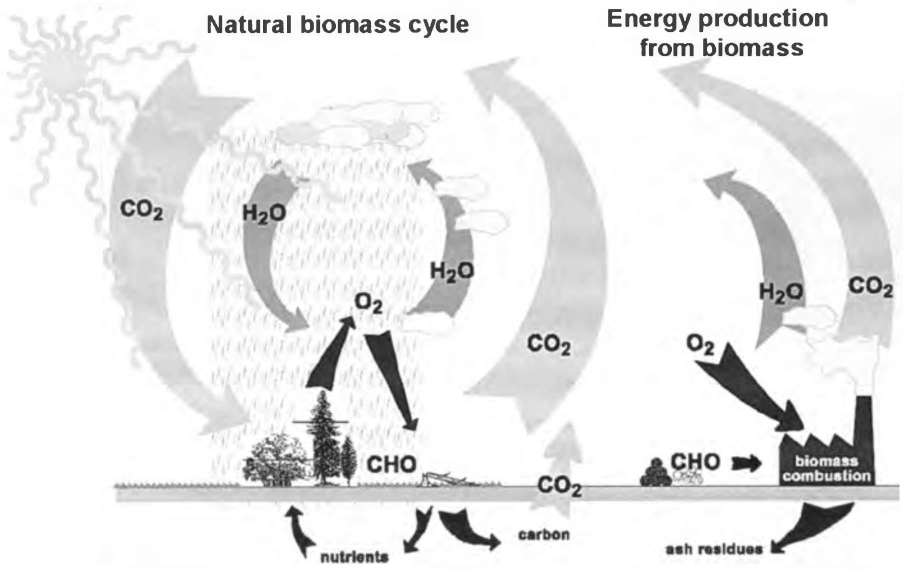

Fig. 1: Carbon Cycle.

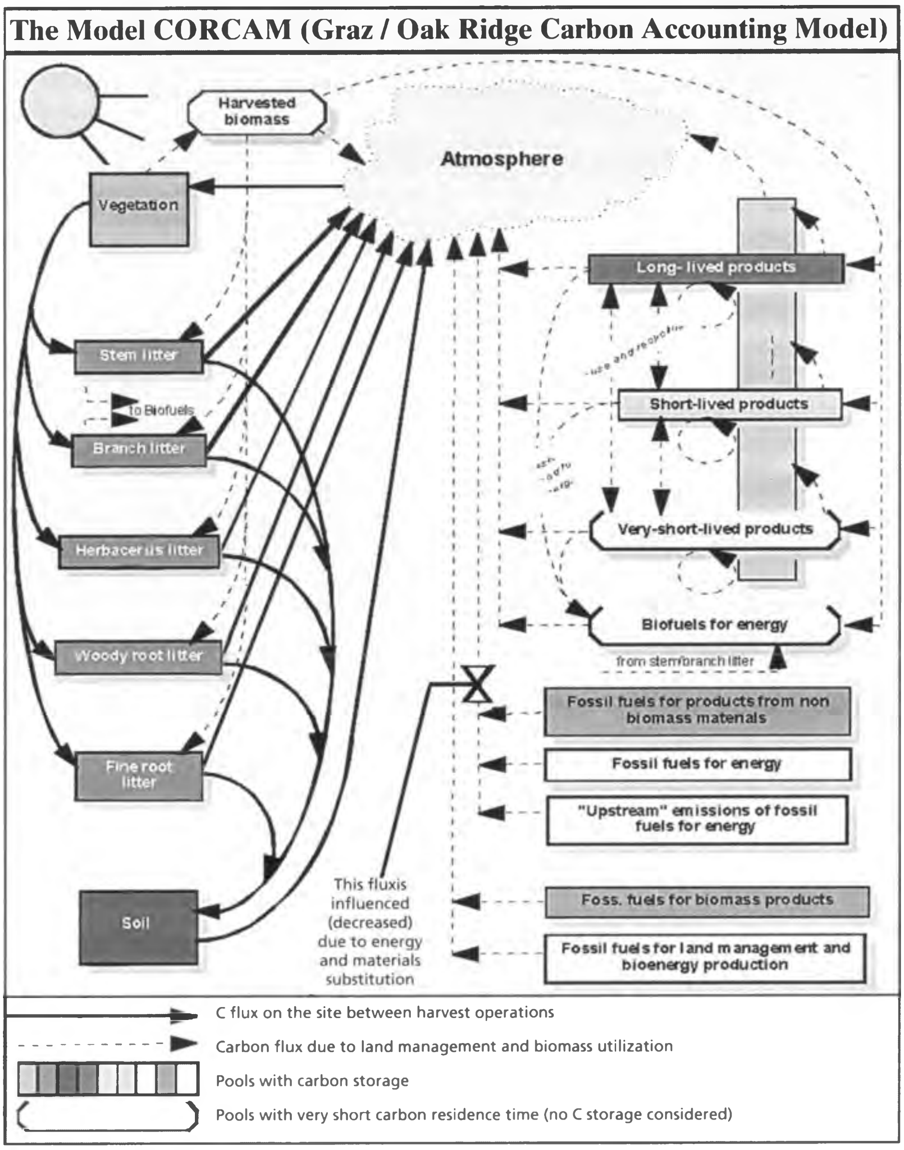

Fig. 2: Model Flow Chart.

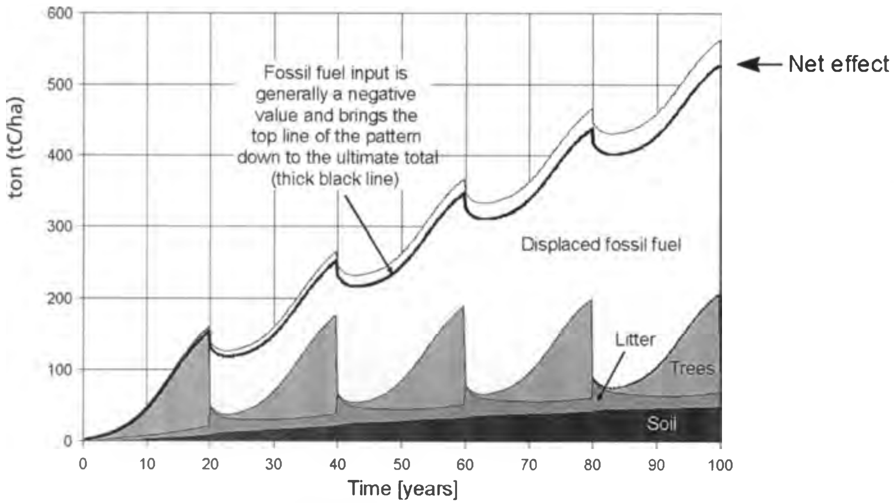

Fig. 3: Example: Short-Rotation Forestry (1 ha).

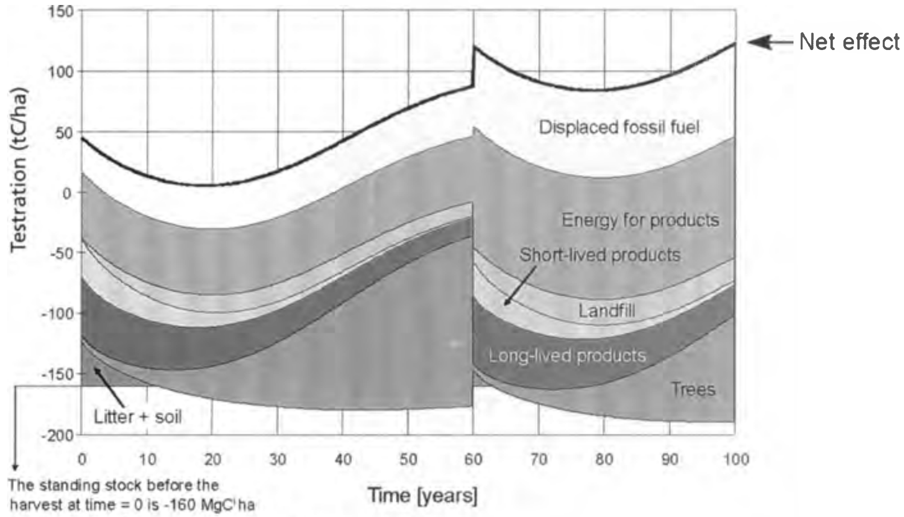

Fig. 5: Example: Conventional Forestry (1 ha).

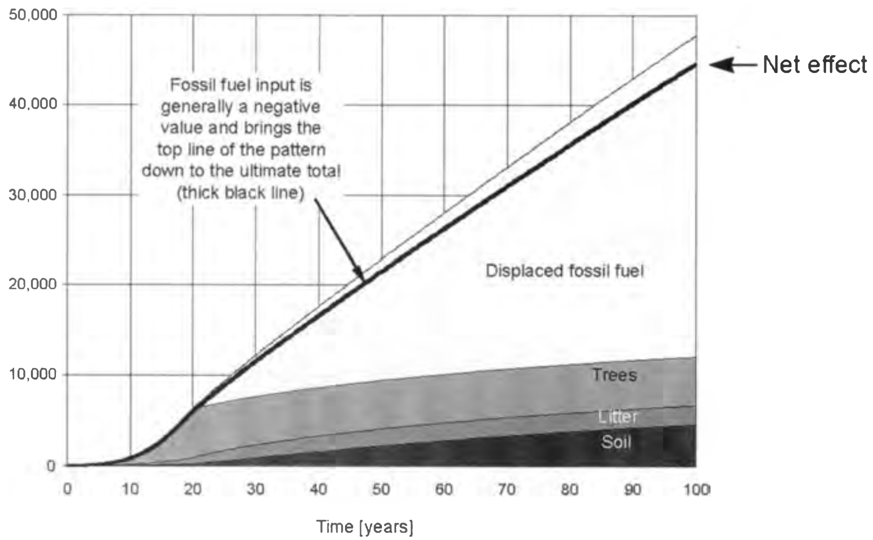

Fig. 4: Example: Short-Rotation Forestry (100 ha).

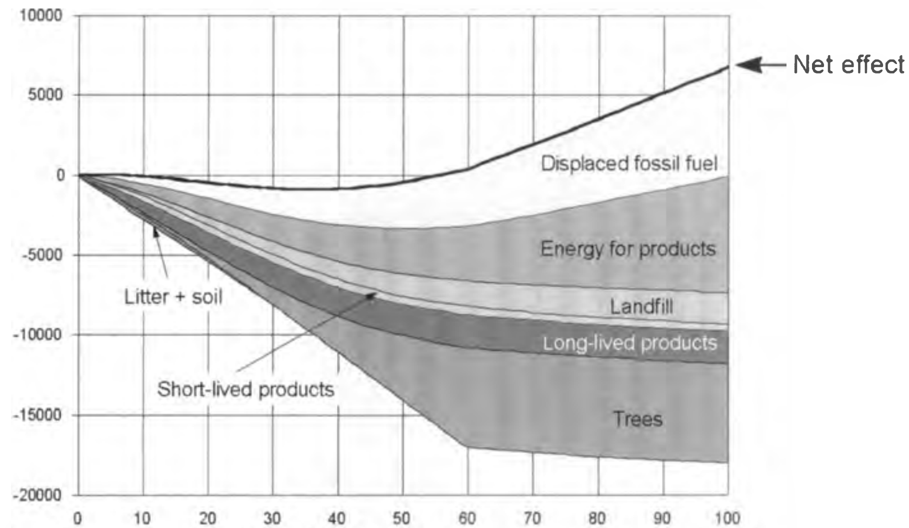

Fig. 6: Example: Conventional Forestry (100 ha).

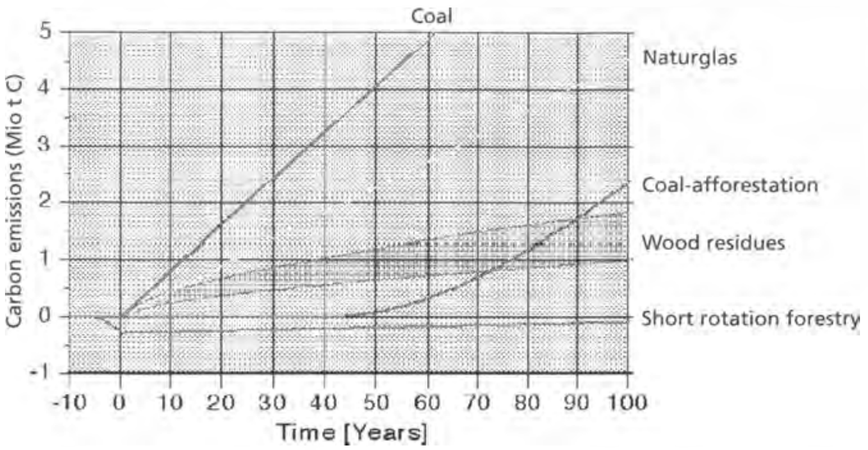

Fig. 7: Example: Fossil Power Plant (1 PJ/a).

Additional literature

Schlamadinger, B., L. Canella, G. Marland, J. Spitzer, 1997, "Bioenergy Strategies and the Global Carbon Cycle", Sciences Geologiques, in press.

Marland, G., B. Schlamadinger, 1995, "Biomass Fuels and Forest-Management Strategies: How Do We Calculate the Greenhouse-Gas Emissions Benefits?", Energy 20: 1131–1140.

Schlamadinger, B., G. Marland, 1996, "The Role of Forest and Bioenergy Strategies in the Global Carbon Cycle", Biomass and Bioenergy 10: 275–300.

Marland, G., B. Schlamadinger, L. Canella, 1997, "Forest Management for Mitigation of CO_2 Emissions: How Much Mitigation and Who Gets the Credits?", Mitigation and Adaption Strategies for Global Change 2: 303–318.

Internet

www.joanneum.ac.at/GORCAM.htm
www.joanneum.ac.at/IEA-Bioenergy-TaskXV
www.fao.org/waicent/faoinfo/forestry/wforcong/publi/V1/T4E/3.HTM#TOP
(it is recommended to use the downloadable PDF file, within which the document can be found on pages 139–148)

Authors' address

Dr. Josef Spitzer
Dr. Bernhard Schlamadinger
JOANNEUM RESEARCH
Institute of Energy Research
Elisabethstraße 11
A-8010 Graz, AUSTRIA
e-mail: josef.spitzer@joanneum.ac.at
e-mail:bernhard.schlamadinger@joanneum.ac.at

Global Availability of Wood and Energy Supply by Fuelwood and Charcoal[1]

H. Schulte-Bisping and F. Beese

Introduction

Roundwood production is an important resource and energy factor on a global scale. In many regions of the world however wood demand can only be supplied by overexploitation of forests and savannahs.

Methodology

Data sets used for the assessment:

- forest areas by countries (FAO 1997)
- a 0.5° × 0.5° grid of net primary productivity (*Cassel-Gintz* et al. 1997)
- energy data by countries (*World Bank* 1995)
- wood-based energy (*Saeger* 1995)

Results

Developed countries of the world consume more than 70 percent of industrial roundwood. Annual fuelwood and charcoal production increased by about 270 percent from 0.7 billion m^3 in 1950 to 1.9 billion m^3 in 1994.

Today two in five people rely on fuelwood as their main source of domestic energy for cooking and heating. Regions with a high share of energy supply by fuelwood are in Central Africa, South East Asia, Latin America and Sweden.

Estimates of FAO state that 3000 million people will rely on wood fuel by the end of the century. Based on calculations of NPP, present forest areas and population, the average annual wood increment amounts to 0.5 tonne oil equivalent per capita. In relation to the present wood-based energy consumption per capita, a number of countries overexploit their resources already today.

Countries with deficiency of fuelwood: Afghanistan, Algeria, Bangladesh, China, Cuba, Egypt, El Salvador, Haiti, India, Iran, Iraq, Kenya, Lebanon, Libya, Thailand, Tunisia, Turkey

Countries where consumption of fuelwood and wood increment is equivalent: Gambia, Mexico, Morocco, Niger, Nigeria, Rwanda

In view of increasing population and future demand the deficiency of fuelwood will become more critical in large areas of the world.

1 Extract of a poster presentation, figures are not reproduced. Figure titles are:
Fig. 1: Global production of total roundwood.
Fig. 2: Share of energy supply by fuelwood (global map).
Fig. 3: Net annual increment of wood per capita (global map).
Fig. 4: Wood-based energy consumption per capita (global map).

References

Allen, J. E. (1993) Energy resources for a changing world. CUP, Cambridge

FAO (1997) State of the World's Forest. Advance copy, Rome.

Nilsson, S. (1996) Do we have enough forests? IUFRO. Occas. Paper No. 5.

Cassel-Gintz, M. A. et al. (1997) Fuzzy logic based global assessment of the marginality of agricultural land use. Clim Res. Vol. 8:135–150.

Saeger, J. (1995) Der Öko-Atlas. Verlag J. H. W. Dietz Nachfolger, Bonn.

World Bank (1995) The World Bank Atlas. Washington, D.C.

Authors' address

Dr. Hubert Schulte-Bisping
Prof. Dr. F. Beese
Institute for Soil Science and
Forest Nutrition
Georg-August-University of Göttingen
Büsgenweg 2
D-37077 Göttingen, Germany
e-mail: hschult1@gwdg.de

Energy from Renewables

Galina Telysheva, Tatjana Dizhbite, Jurijs Hrols, Galina Dobele, Uldis Viesturs

Abstract

At present, the share of bioenergy in the world common energy balance is not high despite the intensive efforts in this field. This share for EC countries is forecasted to reach 12 % in 2005.

In many cases, including Latvia, the existing potentials of renewable resources could improve significantly the energy supply and decrease the dependence on fossil energy resources. However, the yield of wood wastes (from mechanical processing, cutting, etc.) has its own limitations. Therefore, a considerable increase in energy production from renewables is possible by developing of forest plantations and special agricultural crops.

The aim of the report is to present the state-of-the-art in the field of energy production from wood and prospects for positive changes in the future. Special attention is paid to the necessity of developing technological processes and products on the basis of wood and wood wastes enabling to obtain:

- easily transportable solid fuel with a higher heating value (charcoal, energetic briquettes from dispersed biomass, etc.);
- liquid fuel (ethanol, thermal conversion resins);
- special auxiliary substances applicable for cutting energy consumption in various power-intensive processes (grinding, dispersion for pumping-over of high-viscous and concentrated suspensions, plasticization, etc.);
- valuable chemical products (levoglucosan, levoglucosenon, sorbents, active charcoals), using the possibility of combining the processes of their production with energy production (combustion, pyrolysis) and gaining profit for the local energy consumption structure;
- energy/heat, using different biomass types (sewage sludge, garbage, refuse, etc.) as well as fossil fuels and plastics wastes, ensuring not only energy saving but also improving economic indexes of the process (decreasing NO_2 and S contents in gaseous emissions), under conditions of a joint thermal conversion with wood;
- environmentally friendly products (plant growth stimulants, etc. necessary for forest restoration, plantation cultivation, forest management, ultimately, the augmentation of wood stocks and the improvement of its quality;
- energy of wood stands/wood containing toxic substances, radionuclides inclusive, thereby decreasing the possibility of environmental contamination occurring in cases of natural calamities.

In Latvia, bioenergy production problems are being developed in the framework of the following programmes: "Theoretical models of ecological forestry", "New materials of wood and plant origin", "Biofuel production technology and possibilities of its application in Latvia".

Latvian Energy Resources

The three Baltic States, Estonia, Lithuania and Latvia are located on the eastern shore of the Baltic sea and have a combined population of approximately 8 millions. Among Baltic States Latvia has the highest area covered with forest.

Forest occupies 44.6 % of Latvian area [1].Total current annual increment in Latvia is equal 16.5 million m^3 and

Table 1: Latvian forest harvesting volume, 1000 m^3.

Cutting system	Allowable cut	Cut in fact		
		State forests	Other	Total
Final cutting	5675.0	2728.9	1396.6	4127.5
Clear cutting		2712.1	1241.4	3953.5
Shelterwood		1.5	8.5	10.0
Selective cutting		15.3	148.7	164.0
Intermediate cutting	2674.3	1683.5	639.1	2322.6
Precommercial thin		9.2	3.9	13.1
Thinning		746.1	178.4	924.5
Sanitation cutting		918.5	450.7	1369.2
Regeneration cutting		9.7	6.1	15.8
Other		70.1	243.4	313.5
Total	**8349.3**	**4482.5**	**2281.1**	**6763.6**

allowable forest harvesting volume is more than 8 million m^3 and 85 % from this is cut in fact at present (Table 1) [2].

However, forest utilisation in Latvia is extensive now and structure of its usage is unprofitable, including export, so about 45 % of stocked wood are exported in the form of round timber, chips and firewood. Today's Latvia has a project for kraft pulp mill with capacity of 600 thousand tons cellulose per year. This project can be realised only when foreign investments will be attracted.

Forest is the main natural resource in Latvia, however, wood is not widely used in the Latvian power centralised system.

Before the restoration of independence in 1990 all Latvian power system was based on resources of other Republics of the USSR. Fossil fuel supplies were available from Russia at very low cost. In many cases earlier existed peat and wood burning installations were replaced by that working on gas and oil. All fossil fuel costs in Latvia are predicted to rise at the international rate over the next years. Imported electricity is mainly supplied by Estonia and Lithuania, but there are no long term supply agreements for this. Three big and several small hydropower stations and a couple of wind generators are in running in nowadays Latvia.

The power system of individual countries of Baltic States were not operated as independent systems and were originally designed and constructed on the basis of interconnected operation. Therefore, in Baltic States, as in the most of countries in transition from centrally-planned economy to a market based one, a decrease of dependence from import of fossil fuel by mobilising and sustainable usage of internal resources is the key factor in their economy.

Wood utilisation, particularly conversion of boilers from fossil fuels to wood, appears to be occurring as much as a result of financial attractiveness of the activity of local authorities (wood is plentiful, relatively inexpensive heating fuel) as from any legislative or policy encouragement in Latvia.

At present two different concepts using biomass for energy production are followed. In the Nordic countries like Denmark, Sweden or Finland with large amounts of biomass available, heat and power plants in the capacity range above 50 MW are of major interest. In countries like Austria, Germany or Switzerland small, decentralised heating plants in the range of 1 MW are at present favoured [3].

The small and medium enterprises are more attractive for Latvia. Such enterprises are characterised with the more environmental compatibility especially due to the local nature of renewables stock, and serve as a basic source of new opportunity for employment and development of state infrastructure at regional level. At present more than 240 boilers have been reconstructed with the total capacity over 28-MW, and in the nearest few years the number of boiler-houses will increase by 300, particularly in small towns and rural districts. Introduction of modern technologies for the generation of heat from wood in Latvia has been sponsored by international programs of the Nordic countries, particularly Denmark and Sweden [4].

The scheme of wood resources usage in Latvia with taken into account today's consumption structure is presented in Figure 1 [5]. In the frame of the existing forestry a volume of wood resources for energy production is limited 3.6 million m^3, under condition keeping the present forest productivity. However,

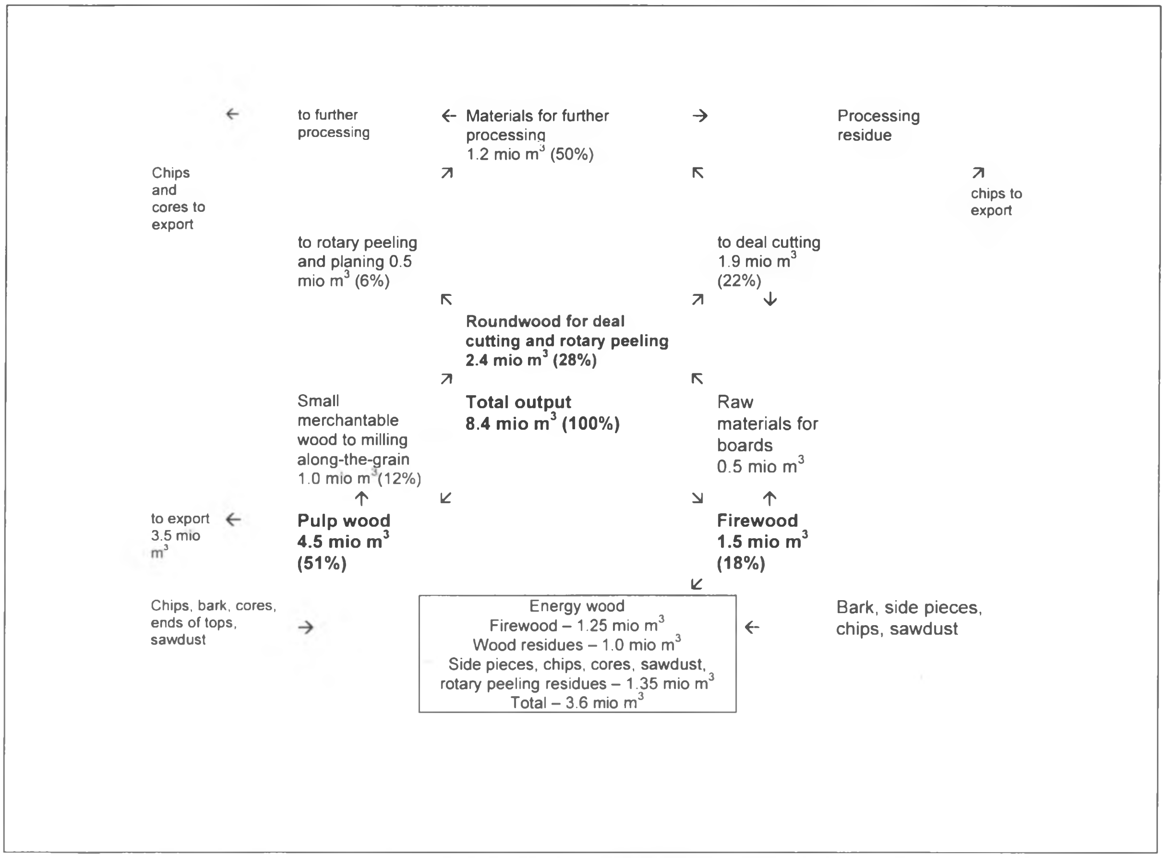

Fig. 1: Scheme of wood resources usage in Latvia.

taking into account the potential alternatives for wood waste utilisation, the actual potentialities are much lower.

Hence, a considerable further increase in bioenergy production is possible by establishing of new plantations on agricultural and pasture lands and promoting the natural regeneration in secondary forests. In many cases energy production seems to be the only possible method for utilisation of forest biomass grown on the soils polluted with toxic pollutants from metallurgical and chemical industries, radionuclides, etc. Cultivation of quick-growing poplar species on soils polluted with radionuclides allows to extract from soil and to concentrate radionuclides, in particular, ^{137}Cs and ^{90}Sr [6]. However special environmentally sound technologies have to be developed for usage this contaminated wood as a fuel wood [7].

Obtaining of fuel chips from plantation wood and forestry residues developed in Sweden [8], could be a good model for Latvian forestry. The afforestation of long-fallow lands, whose current approximate area is equal to 500 thousand hectares, owing to the inefficiency of agriculture, is estimated to increase up to 1 million hectares in the future [9].

Currently the area of forest plantations in Latvia is estimated as 7.1 thousands ha for spruce and 1.2 thousands ha for aspen. In connection with defeat of coniferous wood standing by fungi Heterobasidion and Fusaria gray alder plantations have been founded recently. At present there are 7.0 thousands ha of the grey alder plantation on defeated forest lands. The growing of species such as alder-tree (*Alnus glutinosa*) and aspen (*Populus tremula*) is very promising for Latvia [9].

An annual increment of wood under optimal plantation conditions would be equal to 6.2 m³/hectare for alder and 7.7 m³/hectare for aspen. However, the real current increment, taking into account sanitation cuttings, is considerably lower (Fig. 2).

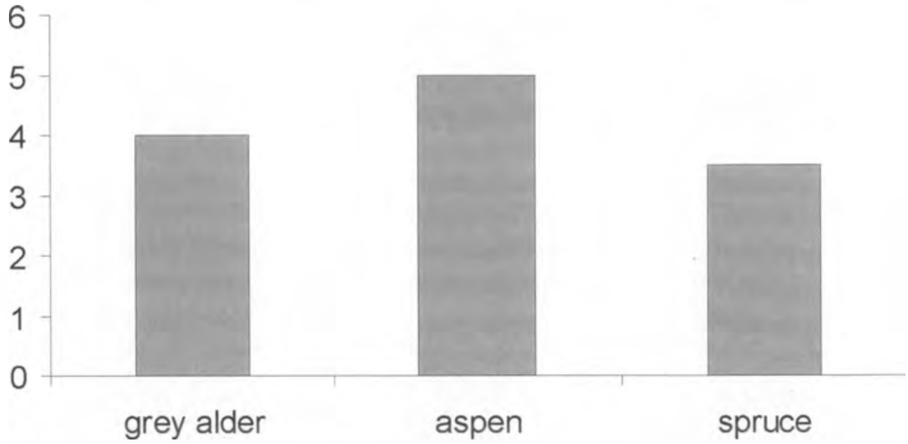

Fig. 2: Real current annual increment of plantations.

Therefore, in 20 years of plantation growing as of the moment of cutting, the stand will be equal to: 120 m³/hectare and 169 m³/ hectare for alder and aspen, respectively. Productivity of 40 years old plantations are near the same as of natural forest (Table 2) [9].

The quality of planting materials are reflected on subsequent tree growth and wood plantation productivity.

For this purpose novel lignosilicon containing products on the basis of lignin – waste of chemical wood processing have been synthesised in IWCH and have been tested in nursery to promote root system development, to protect plant against diseases and to stimulate plant growth. The tests of this novel products of natural origin are rather promising. These products in dosage of 1 g per running meter promote in one year of growth an increase in root mass twofold in comparison with control; the amount of secondary roots increase significantly; stem diameter increase in 70 %. The amount of plants defeated with Fusaria sp. decrease [10].

A profitable alternative for direct utilisation of low-quality and plantation wood as a fuelwood is the production of solid, liquid and gaseous fuels as a result of technological processes, whose final products are promising for the use in the chemical and pharmaceutical industries, polymer materials production, agriculture, etc. (Fig. 3).

The products of these industries are also applicable for the development of auxiliary means and materials promoting the reduction in expenses of the energy produced already.

The exclusion of a part of low-quality and plantation wood from the group of direct raw materials resources used for bioenergy production can be compensated by the use of other renewables, including agricultural crops, recycling lignocellulosic materials, municipal and industrial sludge, water treatment sludge, etc. under condition of maintaining the corresponding productivity of forests.

Table 2: Influence of forest age on standing stock.

Species	Forest Formation	Age	Standing Stock m³/ha
grey alder	plantation	40	200
aspen	plantation	40	300
aspen	natural	60	320
spruce	plantation	40	320
spruce	natural	80	360

Biomass thermal conversion for energy

The existing technologies of biomass thermal conversion for energy can be divided into four main groups: combustion, gasification, liquefaction, and pyrolysis. The list of thermal methods for biomass conversion shown in Figure 4 is not complete and is constantly being extended.

Biomass combustion is the oldest and the most popular method for energy production. It does not require considerable investment, combustion is uni-

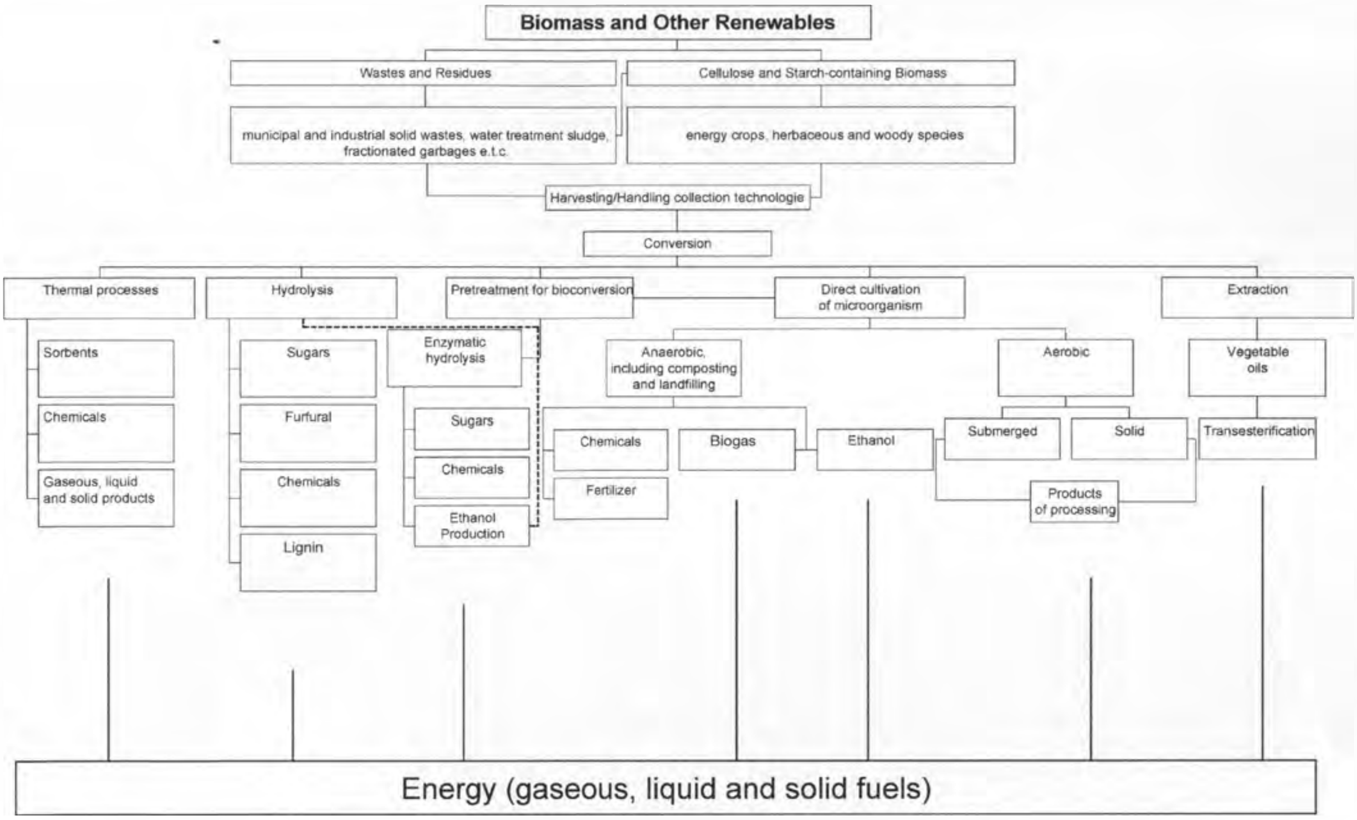

Fig. 3: Alternative technological processes of wood utilisation instead of direct combustion.

form if the raw material is homogeneous, there is low ash and slag formation, heat capacity is high, and equipment has little corrosion. The advantages of the combustion method when treating wastes are an approximately 10-fold decrease in waste volume, reduction of risk of soil and water pollution, and recovery of the formed heat.

The problem of increasing the efficiency of chips digesters from 70 to 80 % is under discussion. The solution of this problem will enable to save 0.143 m^3 of wood per 1 m^3 of fuel [11].

The utilisation of the forest and wood processing industries wastes such as sawdust and bark for energy production is rather promising. Up to 0.50 million m^3 of sawdust and 0.30 million m^3 of bark per year are currently concentrated in saw-mills of Latvia.

The briquetting of sawdust, practically not used earlier in the national economy, will enable the production of fuel briquettes. The output of fuel briquettes can reach 0.18 million t/year in case of utilising the whole sawdust concentrated in saw-mills. In favour of application of energetic briquettes from biomass, besides the renewedness of the raw material sources every year the positive ecological effects of their utilisation are expressed: sulphur content is 6 times less than in the coal, the amount of ash is 2 to 7 times smaller, heat value is approximately the same as that from brown coal – 15 to 17 MJ/kg [12].

In the nearest future, the digestion of waste paper not subject to recycling, packaging materials as well as sewage sludge and municipal wastes will become urgent. The solution to these

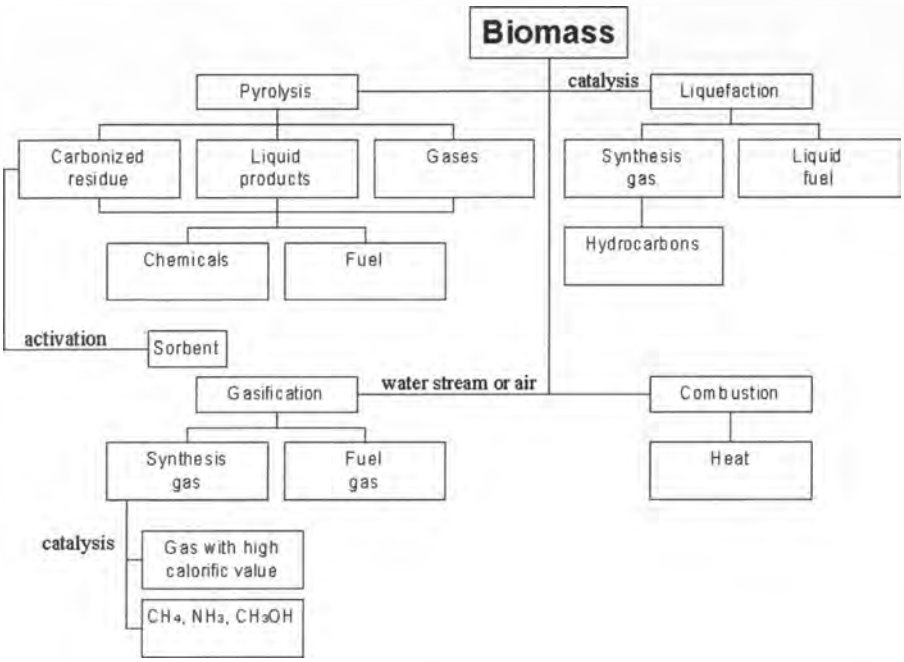

Fig. 4: Thermal methods for biomass conversion.

problems will not only ensure an additional energy production, but will improve environmental conditions [13]. However, Latvia has no own experience in this direction.

In comparison with the combustion method, the treatment by gasification has the significant advantages: the gases obtained may be used as energetical or technological fuel, while, during combustion, only the energetical use of heat from the raw material is practically possible [14].

Recent and on-going fundamental research reveals expanding options for biomass gasification for production of electric power or higher value fuels. Various pilot and demonstration plants are operational now world wide to aid the design and development of cost-effective and environmentally sound technologies for bioenergy production by gasification.

It is difficult to propose the implementation of gasification in Latvia in the nearest future, while power production systems, where biomass gasification is coupled to advanced gas turbine cycles, are in stage of pilot and small demonstration plants. However the best possibility for commercialisation of gasification process for us could be location of possibledemonstration facilities in one of countries in transition state, for example in Latvia, that takes a convenient geographical position relatively the other Baltic states and Belorussia.

Liquefaction could be an attractive option for feedstocks with a high water content, such as agricultural and domestic waste or biosludge. The high energy-consuming of liquefaction process complicates its utilisation in countries with deficit of energy production.

The dry distillation method ensures effective use of organic wastes as fuel (gas with a high heat of combustion and solid carbon residue) and liquid products (ethylacetate, methanol). Older pyrolysis techniques have low efficiency, but the pyroligneous liquors, derived from such processes sometimes have commercial value. For example, the ATOCHEM plant located in Premery (France) is a wood carbonisation plant that produces 20000 tons/year of charcoal. The derived pyroligneous liquors are subjected to several distillation steps to produce various fine chemicals such as methylcyclopentenolone and hydroxymethylpyrone [15].

The major product of wood dry distillation, charcoal, is a tradable product as a clean fuel of high calorific value. The charcoal production technology is not complicated and is applicable to small- and medium-sized rural enterprises with an output of 500 to 1500 t of charcoal per year, which will process 3200 to 9500 m^3 of wood per year [16].

A technology has been developed and recommended by the Latvian State Institute of Wood Chemistry (IWCh), in which 4 to 6 apparatuses for charcoal production are combined in units with a joint furnace and a technological wood drier [16]. Volatile products of thermal degradation of wood – gas mixture combustion fumes are used as a fuel for maintaining the dry distillation process as well as heating and drying of wood. A rational gas supply and a high temperature of combustion in the furnace ensures the conformity of the products of combustion to the standards defined by environmental protection and sanitary supervision organisations.

Charcoal production for domestic needs is especially advisable in most remote regions, far from ports, motor highways or railroads, since, in terms of mass charcoal comprises only 1⁄3 (one third) of the wood mass and, in terms of volume, it comprises 60 to 70 % of the initial wood volume. From 1 cubic meter of wood with a packing density (compactness of wood) of 0.65, 110 kg of commercial charcoal and 5 to 10 kg of fineness (siftings) (with sizes of below 20 mm) can be obtained. From 1 cubic meter of alder wood, 80 to 85 kg and 5 to 10 kg of charcoal, respectively, can be obtained.

Low-temperature pyrolysis is considered to be a rather feasible method for the production of fuel and chemicals when realised in fast heating regime [14].

Pyrolysis processes for liquid fuel production from biomass, and several projects are now at the commercial and demonstration stage. This technology produces bio-oil (a potentially substitute fossil fuel), and charcoal and gases are obtained as subproducts. The implementation of pyrolysis processes for energy production could serve as a basis for the simultaneous development of the operating capacity for production of valuable commodity output such as sorbents and chemical substances for pharmacy and organic synthesis.

Oxidative pyrolysis, often one of stages of the gasification process, is thermal degradation of organic raw materials during partial combustion of volatile products. During oxidative pyrolysis, coke (a solid carbonised residue) is formed, while the mineral products (ash and slag) are the solid residues of gasification and combustion. The carbon product, formed during oxidative pyrolysis, may be further used as solid fuel or, after activation, applied as a sorbent.

The studies carried out at the IWCh have shown that thermal treatment for such renewables as sludge in the pyrolytic regime is more attractive than combustion [17]. To implement the pyrolysis process, no fine dispersion of the material is required, the pyrolysis temperature is lower than that required for sludge combustion and usually does not exceed 900 °C. The economical benefits of pyrolysis, when performed with a sediment moisture content less than 55 %, also present the possibility of creating a closed thermal balance without involvement of external heat sources at the expense of combusted pyrolytic gases. The quality of the sorbents obtained at IWCH by using this technology guarantees the effectiveness of their applications in various fields (Table 3). For comparison, characteristics of commercial birch activated carbon are presented.

The application of catalysts during pyrolysis of biomass and the chemical activation of solid residue increases the carbonised product yield and allows to regulate its properties [18]. There have been many studies in this field worldwide including IWCh. We offer an original technology for production of carbon microporous sorbent (specific porous surface 2000 m^2/g, volume of microporous 1 cm^3/g) on the basis of hydrolysis lignin.

The pyrolysis regimes which make it possible to turn the process towards formation of individual chemicals were carried out.

An original technology for levoglucosan obtaining by lignocellulose pyrolysis has been designed at the IWCh and tested in a pilot scale [19]. A good levoglucosan yield has been achieved: 20–26% from the mass of oven dry lignocellulose or 47.5–63 % from the that of cellulose. The purification of levoglucosan by selective dissolution and crystallisation using 90–96 % ethanol ensuring its content in the purified product 95–96 %, has been also developed at the IWCH. On the basis of levoglucosan a lot of valuable chemical products were synthesised and new materials on their basis were created (Fig. 5).

Acidically catalysed pyrolysis makes it possible to obtain another promising chemical product, dehydrated 1,6-anhydro sugar – levoglucosenone (LGS) [20]. Levoglucosenone has proven to be a very convenient "chiral synthon" in practically all the fields of synthetic organic chemistry [21], for the preparation of the variety of biologically important natural products, i.e. optically active sulphur and nitrogen heterocycles, and rare carbohydrates. The potential of levoglucosenone is illustrated by its application in the synthesis of (+)-Prelog-Djerassi Lactonic Acid (used in the synthesis of macrolide antibiotics); (−)-allo-Yohimbane; Tetrodotoxin (one of the marine toxins); D-altrosan and D-allosan (Anhydrosugars); Nonhydrolysable C-di- and C-trisaccharides (potential enzyme inhibitors) as well as a variety of other compounds including butenolide and flavour chemicals like whisky lactones.

Studies aimed at the development of LGS production technologies are carried out by the Latvian State Institute of Wood Chemistry jointly with the Hamburg Institute for Wood Chemistry. The LGS content in volatile products may exceed 70 % [22].

It seems that pyrolysis technology for energy production could be easier realised in Latvia owing to their lower energy-consumption (in comparison with gasification) and possibility of valuable and promising chemicals production on the same equipment depending on local and common market needs.

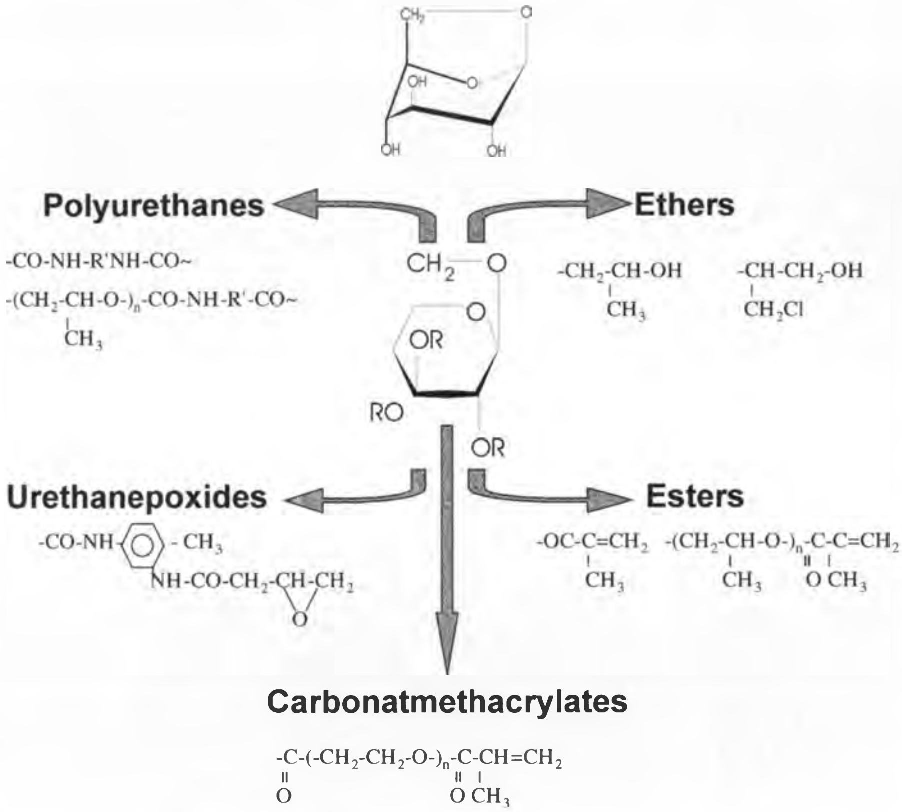

Fig. 5: Products on the basis of levoglucosan.

Table 3: Characteristics of sorbents obtained on the basis of waste water sediments and lignocellulosic raw materials.

	Sorbents on the basis of			
Properties of sorbents	**Sludge+ coagulant**	**Sludge + coagulant + biomass waste**	**Various lignin containing wastes, (chemical activation)**	**Birch wood, vapour-gas activation (commercial)**
Sorption capacity, mg/g				
Iodine	600-800	900-950	> 2000	700
Phenol	220-280	300-350	750	250
Heptane	250-320	380-400	800	300
Methylene blue	350-400	370-420	800	225
Total volume of pores, cm^3/g	0.50-0.90	0.60-1.0	1.7	1.0
including Micro	0.10-0.30	0.30-0.40	1.2	0.3
Meso	0.20-0.25	0.15-0.35	0.3	0.1
Macro	0.25-0.35	0.20-0.30	0.2	0.6
Specific surface, total, m^2/g	850-900	1100-1300	2500	600
Characteristic radius of micropores, Å	5	7	5-12	5-6
Ash, %	60-75	25-28	< 1	7-8

Production of power ethanol

Special experiments were performed [23–25] comprising the suitability and yields of ethanol using different local brands. Ethanol production from wood biomass is much more complicated and is still a problem on a laboratory and a demonstration project scales.

Low cost ethanol can be produced using a novel technology where the first stage is conversion of pentosans into furfural. It is possible to obtain furfural and bioethanol from straw.

Grain, potato and sugar beet can be used to bioethanol. Today, three ethanol factories with a total annual capacity of 1.1 mln litres ethanol operate in Latvia.

The consumption of gasoline in 2005 is expected to be about 700000 tons. The concept envisages ethanol additives of 5 % at first. This means that 35000 tons of ethanol will be used as a fuel additive. About 100 000 tons of grain should be used to obtain this amount of ethanol. The cost of ethanol obtained from grain is about 0.60–0.70 USD per 1 litre.

Processing of straw to obtain ethanol, furfural and acetic acid may reduce the cost to 0.32 USD per 1 litre of ethanol.

The implementation of the bioethanol program in Latvia depends on advances in agrotechnology, the modernisation of ethanol production and the taxation policy.

Production of biogas for energy

Several methane fermentation installations are currently in operation in Latvia including the waste water treatment plant in Riga, a manure treatment plant at the pig-breading farm in Ogre and installations at dairy factories. It is estimated that 6 mln GJ could be potentially obtained annually by fermentation of animal manure. In the near future, the refuse landfills around Riga can be equipped for biogas gathering and utilisation.

To optimise the process, thermophyllic methane fermentation of agricultural wastes was realised in laboratory, pilot and industrial scale bioreactors [26, 27]. It has been established that the inactivation of pathogenic bacteria, gelmints, weed seeds and pesticides degradation occurs during the thermophyllic process. In this case, pesticides are also biodegraded.

Pilot scale methane fermentation of brown juice, a by-product of leaf protein production, was carried out in Latvia. In our experiments, the plant juices after fermentative coagulation of protein contained organic acids. It means that the first stage, i.e. hydrolysis and acetogeneses, is realised during protein coagulation. The second stage, namely methanogenesis, was carried out with the inoculum (50 %) from pig manure methane fermentation at a temperature of 36 °C. In further experiment, it was demonstrated that good results can be obtained during the methane fermentation of brown juice together with animal manure and/or additives of straw (max. 8 %). The intensification of methanogenesis was reached using fibre surfaces in a bioreactor during the fermentation of brown juice

Semiclosed system for biofuel production

Biofuel production in Latvian conditions could be exemplified by the use of a semiclosed biotechnological system. The main 3 components of the system are as follows:

1. Agriculture.
   Necessary arable land – 300 ha (1st year 100 ha for barley + clover; 2nd year – 50–70 ha for clover + 30–50 ha for rape; 3rd year – 100 ha for wheat/rye or 50 ha for sugar beet + 50 ha for wheat.
2. Animal husbandry.
   A pig-breeding farm (800–1000 pigs, utilising barley and rape seed meal with additives);
   A cattle farm, utilising stillage and clover with additives.
3. Biotechnological units.
   An ethanol factory with a capacity of 4000 tons per year;
   Methane fermentation in bioreactors at a pig-breeding farm and an ethanol factory.

The use of biodiesel and latol (gasoline with a 5 % ethanol additive) in motors will reduce air pollution, while methane fermentation of liquid wastes will protect water and soil. At the same time, the realisation of the biofuel program will stimulate the re-cultivation of approximately 400000 ha of the agricultural land in Latvia and promote the regional sustainable development [28, 29].

Energy saving technologies

The products of different chemical wood processing give definite benefits related to the energy issue indirectly. For example application of novel products with high surface and dispersion activity (surfactants, dispersants, plastisizers), synthesised in IWCh on the basis of lignin provide decrease in energy consumption in the process of grinding, pumping of high viscosity and concentrated suspension and mixing in heterogeneous systems [30, 31].

The by-products of pulp and paper industry tall oil and lignosulphonate have been also used by the scientists of IWCh as a raw material for polyol component in freon-free polyurethane foams [32–35]. The original PU foams are in operation for outside thermoinsulation of building in Latvia during 7 years, decreasing energy consumption in that houses.

In Latvia, bioenergy production problems are being developed in the framework of the following programs: "Theoretical models of ecological forestry", "New materials of wood and plant origin", "Biofuel production technology and possibilities of its application in Latvia". These programs are based on the international experience and the results of investigation of Latvian specialists [36]. To promote the realisation of these programs, an international co-operation seems to be required.

Conclusions

In spite of the intensive work, the share of bioenergy in the common energy balance world-wide is not high. For example, in Austria, Denmark and Finland it exceeds 5–10 %, but more than a half of it is produced from the waste of the pulp industry (Finland), the combustion of low-grade wood, peat, etc. However, environmental protection requires the maximal utilisation of all anthropogenic wastes, and energy production from biomass wastes is rather attractive from this point of view.

In order to turn this declaration into the reality in Latvia within the framework of the mentioned state programs, involving also the international partnership the following actions are necessary:

- evaluation of economic value and prospects for energy production from by-products
- valorisation of local potentialities of renewable energy resources;
- comparative evaluation of economic value of direct energy production from wood biomass and obtaining of market valuable products by chemical processing of biomass with simultaneous energy production. Determination of plant biomass volume, required for this purpose;
- maximum utilisation of different renewable domestic wastes, including municipal wastes, water treatment sludge, fractionated garbage etc., for energy production;
- selection among a great number of alternative modern ecologically clean unwastable technologies for energy production.

References

1. Slodzes vide. Latvijas vides stavokla parskats, 1997. 15. nodala "Meza resursi". Riga. 1997, pp.123–128.
2. Forest Statistics. Latvian State forest service, Riga. 1997.
3. *Lamp, A. Reichel, F. Zeigel.* In: Book of Abstracts of the European Congress on Renewable Energy Implementation, 5–7 May, 1997, Athens, p. 112.
4. *Skele, H. Putans, I. Kikans.* In: Proc. AgEng Oslo 98. Int. Conf. on agricultural engineering. Oslo, 24–27 August, 1998. Part 2, pp. 1059–1060.
5. *Skrupskis.* In: "Koksnes atkritumu izmantošana latvias kokapstrade", Proc. Int. Seminar, Riga, 27 September, 1995, "Thermie" EC comission DG XVII, pp. 7–10.
6. *Hrols, L. Belkova, D. Cirule, N. Arkhipov.* In: Abstracts ISEB'97 Meeting, Bioremediation. Leipzig, 24–27 September, 1997, p. 88.
7. *Grebenkov, A. P. Iakoushev, A. A. Mikhalevich, V. N. Solovjov.* In: Book of Abstracts of the European Congress on Renewable Energy Implementation, 5–7 May, 1997, Athens, p. 49.
8. Samson, Sustainable Farming, 1, No 4, pp. 21–27.
9. *Hrols, M. Daugavietis, L. Lipins, P. Zalitis, H. Tuherm, U. Viesturs.* In: "Les-Drevo-Zivotne Prostredi", International scientific Conference FOREST-WOOD-Environment'97, Zvolen, 8–11 September, 1997, p. 27–31.
10. *Telysheva, G. Lebedeva, U. Viesturs.* In: Zornik referatov "Vibrani procesy pri chemiskom spracovani dreva" (odborny seminar), Zvolen, 1996, pp. 223–230.
11. *Blumberga, I. Veidenbergs.* In: "Koksnes atkritumu izmantosana latvijas kokapstrade", Proc. Int. Seminar, Riga, 27 September, 1995, "Thermie" EC comission DG XVII, pp. 11–34.
12. *Brkic, T. Janic.* In: Proc. AgEng Oslo 98. Int. Conf. on agricultural engineering. Oslo, 24–27 August, 1998. Part 2, pp. 1008–1009.
13. Kara, Paperi ja Puu, 1994, 76, No 1, pp. 44–49.
14. *Viesturs, G. Telysheva, G. Dobele, T. Dizhbite*, Proc. Latvian Acad. Sci., Section B, 1995, No 9/10, pp. 97–112
15. Pakolel, G. Couture, C. Roy, TAPPI, 1994, 77, No 7, pp. 205–211.
16. *Zanderson, A. Yurrioo, G. Dobele, G. Telysheva.* In: "Productive functions of forests", proc. XI World Forestry Congress, 13–22 October, 1997, Antalya, Vol. 3, p. 312.
17. *Dobele, N. Bogdanovich, G. Telysheva, U. Viesturs.* Applied Biochemistry and Biotechnology, 1996, 57/58, pp. 857–876.
18. *Dobele, T. Dizbite, G. Rossinskaya, G. Telysheva.* In: "Cellulose and Cellulose Derivatives: Physico-chemical aspects and industrial application", 1995, Woodhead Pub. Ltd, Cambridge, UK, pp. 125–130.
19. *Pernikis, J. Zanderson, B. Lazdina.* In: "Developments in Thermochemical Biomass Conversion", 1997, Woodhead Pub. Ltd, Cambridge, UK, pp. 536–548.
20. *Dobele, G. Rossinskaja, B. Rone.* In: "The Chemistry and Processing of Wood and Plant Fibrous Materials", Ed. J. Kennedy, G. Phillips, P. Williams, Woodhead Publ., Cambridge, UK, 1996, pp. 345–350.
21. Levoglucosenone and Levoglucosans, Chemistry and Applications, Ed. Z.J. Witczak, ALTPRESS, 1994.
22. *Dobele, G. Rossinska, G. Telysheva, O. Faix, D. Meier. J.* Anal. Appl. Pyrolysis, 1998, in press.
23. *Linde, M. Bekers, I. Vina, H. Kaminska, Đ. Upite, R. Scherbaka.* In: Proc. Intern. Conf. "Biomass for Energy and Industry", 1998, Würzburg, Germany, pp. 464–467.
24. *Laukevics, M. Bekers, A. Danilevocs, E. Kaminska, A. Lisovska, D. Upite, A. Vigants.* Proc. Latvian Acad. Sci., 50, No 3, pp. 137–139.
25. *Bremer, R. Galaburda, M. Bekers, J. Laukevics.* 13th Int. Congr. Chemical and Process Engineering, 23–28 August, 1998, Praha.
26. *Bekers, P. Jansons, U. Viesturs, G. Telysheva.* In: In: Book of Abstracts of the European Congress on Renewable Energy Implementation, 5–7 May, 1997, Athens, p. 127.
27. *Bekers, U. Viesturs, G. Telysheva, E. Gudriniece, V. Gulbis, A. Shkele.* In: Proc. Reg. Forum "Energy Strategies in the Baltic States: From Support to Business", 17–19 September, 1997, Riga, Vol. 1, pp. 181–196.
28. *Bekers.* Proc. Latvian Acad. Sci., Section B, 1995, No 9/10, pp.113–120.
29. *Bekers.* In: Proc. Int. Symp. "Environmental Biotechnology", Part II, 21–23 April, 1997, Oostende, pp. 319–321.
30. *Telysheva, T. Dizhbite, E. Paegle, A. Kizima.* In: "The Chemistry and Processing of Wood and Plant Fibrous Materials", Ed. J. Kennedy, G. Phillips, P. Williams, Woodhead Publ., Cambridge, UK, 1996, pp. 399–404.
31. *Telysheva, T. Dizhbite, M. Akim.* In: Proc. EWLP'96. 4th European Workshop on Lignocellulosic and Pulp. "Advances in characterization and processing of wood, non-woody and secondary fibers", Milan, Italy, 1996, pp.518–523.
32. *Zaikov, A. Alksnis.* Polyurethane esters. Moscow, "Nauka", 1997. 181 p. (in Russian)
33. *Stirna, V. V. Yakushin, I. V. Sevastyanova.* Wood Chemistry/Koksnes Kimija, 1994, No 1, 53–61.
34. *Gromova, A. S. Arshanitsa, G. M. Telysheva, A. D. Sevastjanova.* In: "Cellulosics: Chemical, Biochemical and Material Aspects", Ed. J. Kennedy, G. Phillips, P. Williams, Ellis Harwood Ltd, London, 1993, pp. 549–553.
35. *Cabulis, V. Zeltins.* In: Proc. Reg. Forum "Energy Strategies in the Baltic States: from support to business", 17–19 September, 1997, Riga, Vol. II, pp. 118–119.
36. *Bekers, E. Gudriniece, G. Telysheva, U. Viesturs, J. Zandersons, G. Bre-*

mers. In: Proc. 10th European Conf. Techn. Exhibition "Biomass for Energy and Industry", June'98, Würzburg, pp. 1271–1274.

Note

Due to space limitation, mainly the results of investigations of Latvian scientists are mentioned in the References list. A careful analysis of the literature sources available all over the world has been done in the aforementioned references.

Authors' address

Dr. Galina Telysheva
Tatjana Dizhbite
Jurijs Hrols
Galina Dobele
Prof. Dr. Uldis Viesturs
Latvian State Institute of Wood Chemistry
27 Dzerbenes Str.
LV-1006 Riga, Latvia
Phone: (371) 7 553063,
Fax: (371) 7 310135
e-mail: koks@edi.lv

Expositions

Scott Convertech Ltd.

Convertech Ltd. is developing a new technology to produce materials, chemicals and fuels from biomass. The Convertech process will sequentially fractionate biomass into its components. The primary products will be Cellulig™ (dry, low-ash biomass solids) and commodity chemicals.

Biomass is a sustainable resource – it is stored solar energy. Its utilisation is CO_2 neutral, hence, biofuels help to solve the problem of global climate change. However, to utilise its full potential, the biomass components need to be separated, similar to the refining of crude oil. The Convertech process will be a biomass refinery. It will be the gateway to the new carbohydrate economy.

Input Biomass

Biomass is stored solar energy. It includes:

- energy crops
- agricultural residue (e.g. straw)
- wood (forestry and wood processing residue)
- park and garden waste.
- food processing waste

Biomass consists of:

- water
- biopolymers (cellulose, hemicellulose and lignin)
- inorganic substances (e.g. silica and alkali metals)
- essential oils

Biomass offers an "environmentally friendly" alternative to conventional sources of **materials**, **chemicals** and **energy**.

The Convertech process will be capable of treating most types of biomass. Also, it can be tailored to produce a variety of outputs. The prime requirement is that the feed can be reduced in size to small solids (e.g. wood chips).

Eventually, the prime feed for the Convertech process are expected to be dedicated energy crops. However, food crop residues such as straw or corn stover are also well suited.

The Convertech Process

The Convertech process is based on a set of entrained flow **steam reactors**, linked through a novel rotary valve called the **interlock**. The reactor system will permit fast, linear and cost-effective processing of biomass.

The process concept combines the following steps:

Process	Effect
Size reduction of biomass	Small biomass solids, e.g. wood chips
Washing of biomass solids	Reduction of ash content in fuel
Preheating in steam	Release of essential oils (extractives)
Steam hydrolysis	Separation of hemicellulose (biopolymer)
Superheated steam drying	Dry biofuel or panel board feed (Cellulig™)

Products

The Convertech process will be adaptable to suit different requirements. The core technology is designed to separate ash, hemicellulose and water from the biomass solids. However, if suitable equipment is added, lignin and cellulose (the other two constituents of biomass) can also be separated. Both, lignin and cellulose have many applications, ranging from liquid fuels (e.g. ethanol) to prepolymers for engineered materials.

Power Generation from Cellulig

The Convertech fuel called Cellulig™ is an excellent feed for combustion, gasification, char manufacture and liquefaction. Even though the amount of ash in biomass is small (<5wt%), it prevents **efficient electricity generation** as it builds up in high temperature boilers and downstream equipment. The Convertech process solves this problem by reducing the amount of ash in the fuel prior to thermal conversion. The fuel is dried in superheated steam. The spent "dirty steam" is recycled upstream to facilitate the hydrolysis and preheating processes.

Commodity Chemicals

Most of the hemicellulose that will be extracted with the Convertech process can be converted to commodity chemicals such as furfural (2-furaldehyde). Furfural and its derivatives have applications as metallurgic chemicals, coatings, adhesives and others.

Wood Composites

The dry, low-ash solid product **Cellulig™** of the Convertech process is also suitable for the manufacture of **panel boards**. Rather than using formaldehyde based resins, an output of the Convertech process (furfural) is used as a binder. The Convertech process facilitates the fractionation and reconstitution of biomass, using only natural products.

Animal Feed

Cellulig™ is expected to be suitable for supplementing animal feed because steam treatment is known to improve digestibility of lignocellulosic materials.

Key Technology Features

The key part of the Convertech process are the entrained flow steam reactors and the interlock.

Reactor System

The steam reactors are heated externally by thermal fluid up to temperatures of about 250 °C. The momentum and heat transfer inside the reactors is carried out by steam at various conditions. The pressure inside the reactors varies accordingly. The steam also serves as the reaction agent.

Interlock

As biomass solids cannot be "pumped" like fluids or gases, the feeding of biomass solids into pressure vessels has been a problem for pressurised biomass processing equipment. Convertech solves this problem with its innovative rotary valve – the **interlock**. This device enables fast continuous feeding of biomass solids from one pressure level to another.

Process Efficiency

The Concertech process is efficient because it **"recycles"** the energy stored in the steam generated during the drying operation to facilitate the fractionation processes upstream. To generate the required process heat, part of the produced biofuel Cellulig™ can be utilised. If electricity generation is the goal, some of the reject heat available from e. g. cogeneration can be used to supply the thermal energy for the process.

The Future

Completion of the final design for the core processing units is expected in 1998.

World-wide adaptation of the Convertech technology by **license** and sublicence agreements with Convertech is the favoured commercialisation route. Only the key components such as the interlock will be manufactured and supplied from New Zealand. The plants are compact, modular, pressurised steel pipe structures, well able to be constructed by engineering companies in the host country.

Company History

The first Convertech processing concept was developed by K. E. Scott & Associates in 1989. Convertech was formed 1993. The development of the biomass refinery concept led to the design and building of a **pilot plant** in Hawarden, North Canterbury, New Zealand. The pilot plant successfully proved the technical feasibility of the Convertech technology. To demonstrate the technology's capabilities, one module of a **full-scale plant** was built at Burnham, Canterbury, New Zealand and commissioned in 1997. To date, an international team of scientists and engineers is completing the technology development.

Contact Convertech

Scott Convertech Ltd.
PO Box 13 776
Christchurch
NEW ZEALAND
Fax: +64 3 379 33 03
e-mail: convrtch@convertech.co.nz
Internet:
http://www.southpower.co.nz/conver.htm

The following companies demonstrated wood combustion rechnologies:

Kraft- und Wärme aus Biomasse GmbH
KWB-Fraidl
Ottinger Ring 15
D-86704 Tagmersheim
Tel./Fax: +49-90094-1467

Spillingwerk GmbH
Werftstraße 5
D-20457 Hamburg
Tel.:+49-40-789 175-0
Fax: +49-40-789 2836

Paul Künzel GmbH & Co.
Postfach 19 53
D-25409 Pinneberg
Tel.: +49-4101-70 00-0
Fax: +49-4101-70 00-40

Lausitzer Braunkohle AG LAUBAG
Knappenstraße 1
D-01968 Senftenberg
Tel.: +49-3573-783 400
Fax: +49-3573-783 636

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Fax: +49-228-37 80 53

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