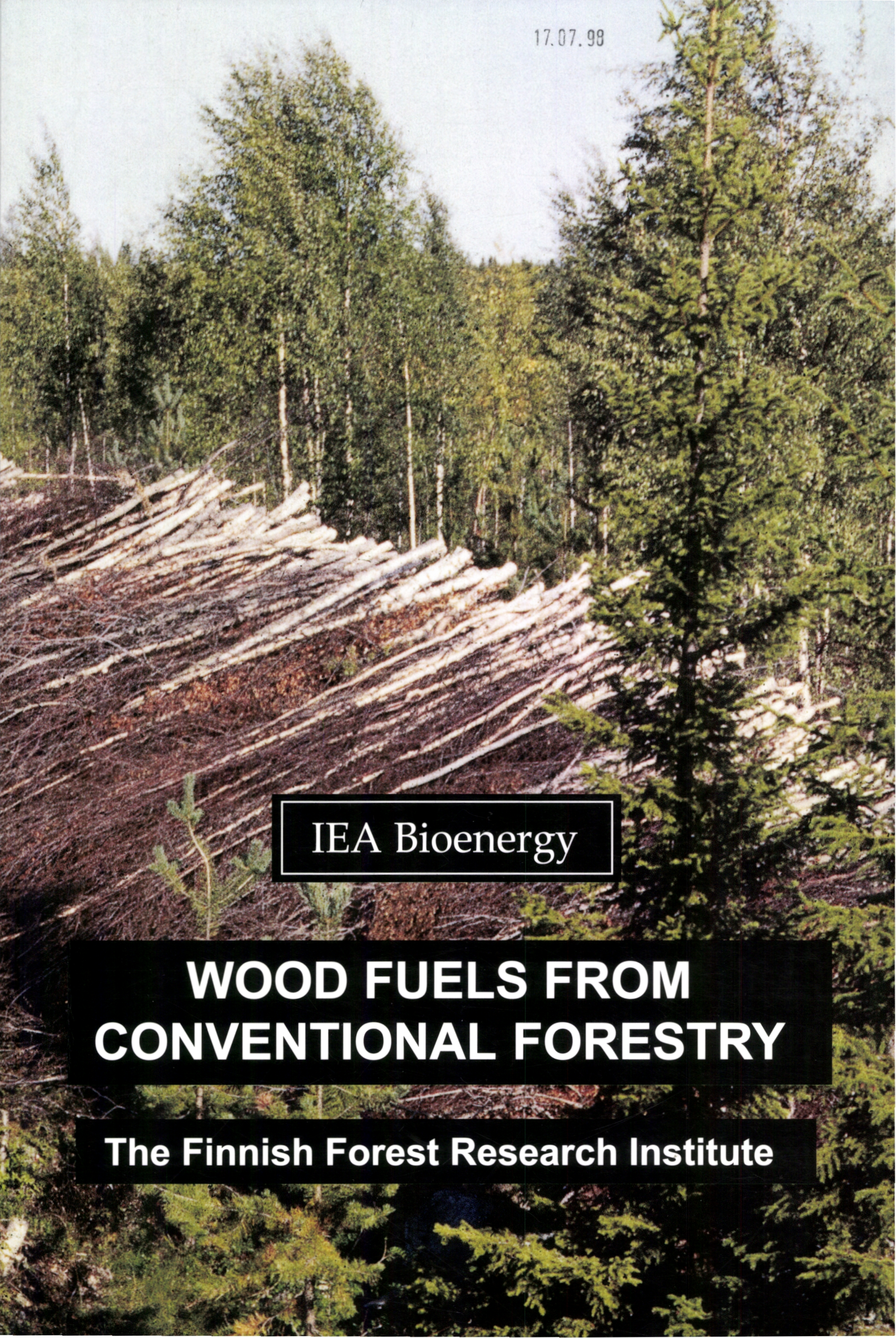

IEA Bioenergy

WOOD FUELS FROM CONVENTIONAL FORESTRY

The Finnish Forest Research Institute

IEA Bioenergy

WOOD FUELS FROM CONVENTIONAL FORESTRY

Proceedings of the third annual workshop
of Activity 1.2 (Harvesting) / Task XII / IEA Bioenergy
in Jasper, Alberta
October 18, 1997

Edited by
Pentti Hakkila, Maija Heino and Essi Puranen

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The publication is the Proceedings of the third annual workshop of Activity 1.2 (Harvesting)/Task XII/IEA Bioenergy in Jasper Alberta in October 18, 1997. It is composed of eleven papers dealing with various aspects of the production of wood fuels from conventional forestry. An overview is given of the Alberta forest sector, potential applications of bioenergy in Canada's remote communities, and timber procurement systems of the southeastern United States. Several articles discuss new techniques and the state of the art of wood fuel harvesting, and characteristics and standards of wood chips. An evaluation report of the Activity is also presented. The evaluation report describes the history of harvesting related cooperation within IEA Bioenergy and the main developments during past ten years, and discusses wood fuel harvesting issues and the advantages and disadvantages of IEA Bioenergy cooperation.

Key words: IEA, bioenergy, fuelwood, harvesting, conventional forestry

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Preface

The International Energy Agency, IEA, has established a collaborative Implementing Agreement on Bioenergy in order to advance the development and deployment of sustainable energy technologies. During 1995—1997 the IEA research cooperation was organized into three Tasks, one of which was Biomass Production, Harvesting and Supply, divided further into 11 Activities.

One of the Activities was A1.2 Harvesting. The objective was to develop efficient, cost-effective and environmentally sound means to harvest, store and deliver low-quality wood for fuel as a by-product of conventional forestry. The emphasis was in the production of fuel for chip fired heating and power plants.

Reduction of harvesting costs through the development of machinery, methods and procurement logistics played a central role in the program. Examples of promising machine development at national levels in conjunction with the Activity program are multi-tree harvesters for early thinnings, round-bale technology for logging residue, and a combination of chain flail and dry drum for the segregation of the fiber from fuel in undelimbed tree sections. Research was carried out primarily at the system level. Special attention was paid to the logistic issues of harvesting, integration of the recovery of fiber and fuel, and the ensurance of the sustainability of ecosystems despite intensive biomass recovery.

The competitiveness of fuel chips can be enhanced also by improving the quality of chips: lower moisture content, more even particle size, lower content of ash, etc. Product quality and storage were therefore important topics in the program.

An essential part of the Activity program were the annual meetings comprising of a technical session, business meeting and study tour. The papers presented in the technical sessions by scientists from participating countries were published by the Activity in the following proceedings:

— Harvesting, Storage and Road Transportation of Logging Residues. Proceedings of IEA-BA-Task XII Activity 1.2 held October 1995 in Glasgow, Scotland. Available from Peter Kofman, Danish Forest and Landscape Research Institute, Hørsholm Kongevej 11, DK-2970, Hørsholm.

— Forest Management for Bioenergy. Proceedings of a joint meeting of Activities 1.1, 1.2 and 4.2 of Task XII in Jyväskylä, Finland, September 9 and 10 1996. Finnish Forest Research Institute Research Paper 640. Available from Pentti Hakkila, FFRI, Box 18, 01301 Vantaa, Finland

This publication is the Proceedings of the third Annual meeting held in Jasper, Alberta, October 18, 1997. The meeting and the subsequent study tour were organized by Dr. David Puttock, Silv-Econ Ltd., with the assistance of Mr. Joe De Franceschi. I thank the organizers, speakers and participants for their contribution.

February 1998

Pentti Hakkila
Leader of Activity 1.2/Task XII/IEA Bioenergy

An overview of the Alberta forest sector

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1 Introduction

Alberta is often viewed as one of the three Canadian prairie provinces. This perspective however does not recognize that over one half of the province's land area of 64.4 million ha is forested. In general terms, the forested portion is along the western third and northern half of the province with the majority classified as Boreal Forest (Figure 1).

Flat open grasslands in the southeast give way to gently rolling hills and the foothills toward the west, culminating with the eastern slopes of the Rocky Mountain Range. Moving toward the north the cover changes from flat open grasslands to hardwood forests and then to mixedwoods on gently undulating topography. The forested parts of the province are characterized by pure coniferous stands of lodgepole pine (*Pinus contorta*) or white spruce (*Picea glauca*) along the foothills, and both pure or mixed stands of conifers and deciduous species, mainly white spruce and trembling aspen (*Populus tremuloides*) in the northerly parts.

Alberta's forest resources contribute significantly to both the social and economic well-being of its citizens. Many companies operating in Alberta depend on the forest resource for their raw materials, and they create considerable economic activity. In addition, Aboriginal people look to the forest for both their livelihood and for continuance of their traditional cultural activities. In concern with industrial development, the forests provide Albertans with a wide range of amenities.

This paper will provide an overview of the forest resource base in Alberta along with descriptions of the forest economy, some comments on other uses of the land, a brief discussion of current issues facing the forest sector in this province, and some descriptive statistics on the Aboriginal population. The paper will conclude with a brief discussion on the potential for biomass utilization for energy production in the context of the forest resource base.

Figure 1. Forest regions of Canada (Source: Minister of Supply and Services Canada 1992).

2 The forest resource base

Alberta's total area of 66.1 million ha (land and water) is divided into two broad classifications based on land use. These areas are known as the Green Area and the White Area (Figure 2). The Green Area totals about 38 million ha (53% of the province) and is primarily the unsettled portion of the province. It is defined as forest lands not available for agricultural development, other than grazing. The Green Area designation provides a secure land base for long-term forest management planning. The remaining White Area is dedicated to agricultural production, settlements, and other human activities

The majority of forest land in Alberta is owned by the provincial government and is known as provincial crown land. Eighty-seven percent of forested land in Alberta is provincial crown land. Nine percent is owned by the federal government (federal crown land), and includes Aboriginal lands, while the remaining 4 % is privately owned. The significant provincial crown ownership means the provincial government plays an important role in the management and allocation of the province's wood supply to industry.

The land base of the Green Area contains 2.2 billion m^3 of standing timber of which two-thirds is coniferous and one-third is deciduous. Of the productive area, almost one-half is pure coniferous trees, one third is pure deciduous trees and the remaining 20 % is mixedwoods. White spruce and lodgepole pine are the dominant coniferous species (56 % and 40 %, respectively), while trembling aspen and balsam poplar (*Populus balsamifera*) comprise the majority of the deciduous volumes (97 %).

The provincial government has developed guidelines to determine the Annual Allowable Cut (AAC) to account for the many uses of the land and its suitability for commercial harvest. After areas such as wildlife reserves, parks, inoperable stands, recreation areas, and others are removed from the AAC calculation, only about two hectares in five are actually available for harvest, and of these, only about 1 % can be harvested annually. This leaves a net AAC of 12.8 million m^3 of coniferous volumes and 9.2 million m^3 of deciduous volumes available to the forest industry. As of January 1995, only about 6 % of the coniferous AAC and 27 % of the deciduous AAC remained unallocated; however, recent forest industry developments (some of which are in the final stages of negotiation) have resulted in the allocation of virtually all the remaining unallocated volumes.

2.1 Forest management

The Green Area land base is managed by the provincial government either directly or through various types of tenure arrangements with industry. These arrangements or tenures provide industry with a long-term perspective for their timber harvest practices. There are three types of dispositions in Alberta's land tenure system, the Forest Management Agreement (FMA), the timber quota, and the timber permit. Each of these systems have a number of requirements related to land management and public involvement to ensure compliance with public policy on natural resource development.

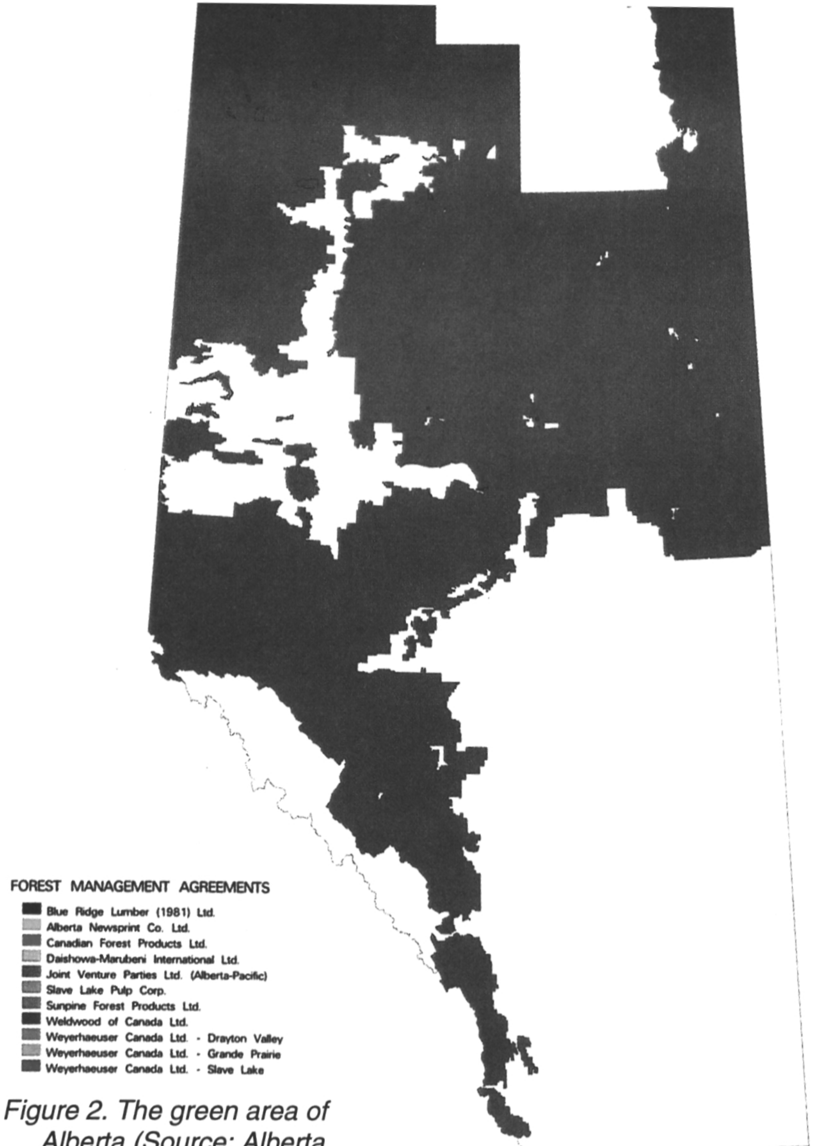

Figure 2. The green area of Alberta (Source: Alberta Environmental Protection, Land and Forest Service).

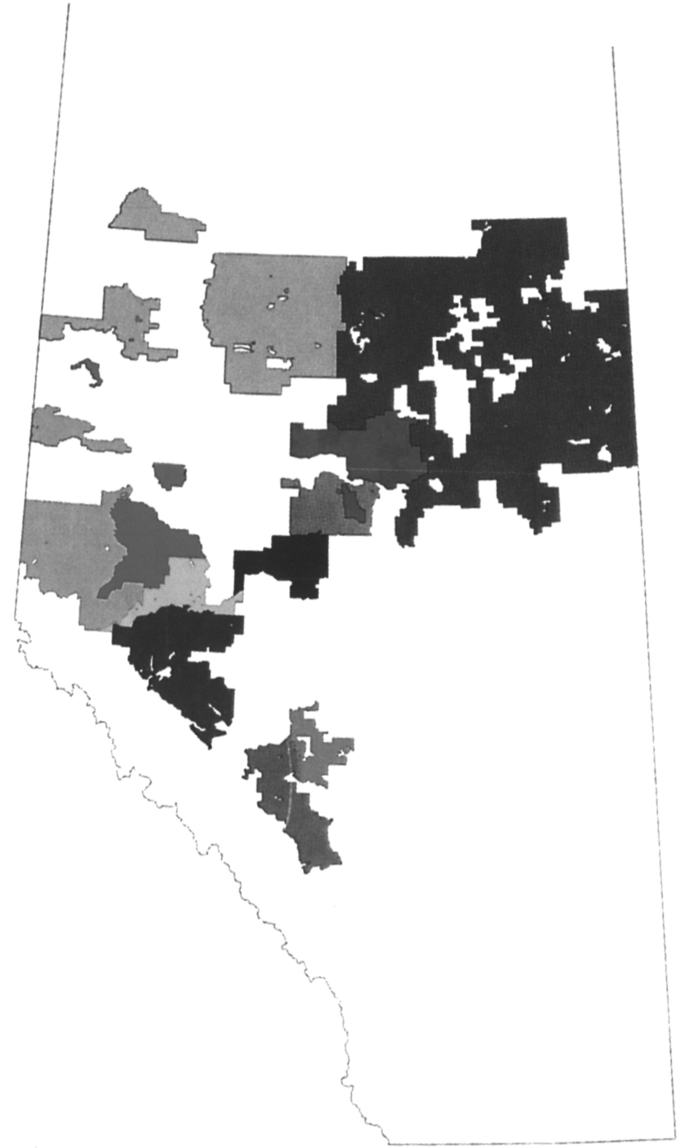

Figure 3. Forest management agreements (Source: See Fig. 2).

The FMA is designated for the larger industrial developments and is a long-term (usually 20 years) agreement between a company and the provincial government to allow the company to establish, grow, and harvest timber within a specified land area. The agreement is land based and AAC is allocated within the context of the land base. The company must have a major wood processing facility and is required to carry out its business in accordance with a forest management plan. The plan must be approved by the provincial government and must include consultation with and participation from the general public and the local communities. As of December 31, 1995, 11 FMAs were in place covering 136,120 km^2 or about 40 % of the Green Area (Figure 3).

The timber quota is intended to provide a secure wood supply to small- and medium-sized operators. This is a volume based agreement; therefore, forest management planning responsibility is assumed by the provincial government. There are about 50 registered quota holders in the province.

Local community needs and small operator requirements are satisfied by *timber permits*. This category allows access to small volumes of timber for individuals or groups such as Aboriginal communities. The permit holder usually pays a reforestation levy or can assume reforestation costs directly.

Reforestation activity is conducted by both industry and government depending on the tenure arrangement in place. In all cases, regenerated stands must meet legislated standards. Since 1991, Free-To-Grow standards have been implemented in Alberta to ensure new forests will meet or exceed the productive yield of the original stand. Currently, 20 % of harvested areas are left to regenerate naturally, 20 % are direct seeded, and 60 % are planted. In the near future, planting is expected to increase to 65 % with areas left to natural regeneration reduced to 15 %. In 1995, the forest industry and the Alberta government planted 75 million trees.

Regardless of the type of disposition in place, long-range forest management plans, annual operating plans, and harvest practices are considered in the context of the integrated resource management plans. This approach facilitates the coordination of activities of multiple users on the same land base and ensures all forest users' needs are addressed.

3 The forest economy

The forest industry is an important component of Alberta's economy and ranks third in the province after the energy and agriculture sectors. In 1995, shipments from the industry totaled $4.3 billion, an increase from $2.5 billion in 1992 and $900 million in 1985. The growth is attributed to higher commodity prices, a doubling of panel production, and growth in the secondary sector. In 1995, 26 000 people were directly employed in the sector while another 39 000 jobs were created supplying and servicing the industry and its workers. The industry has experienced substantial growth in the 1990s and has outperformed the industry elsewhere in the country. For example, annual sales have more than doubled from $1.6 billion in 1990 to $3.6 billion in 1996. Employment for the same period increased by 50 %.

Industry expansion began in 1983 when the provincial government implemented a strategy to diversify the provincial economy to include the forest sector. As a result, $5 billion of investment occurred during the 10-year period 1986—1996. This expansion led to the establishment of pulp mills and panel plants. Much of the expansion was encouraged by the abundant timber supplies and new hardwood processing technology and markets, which utilized the untapped aspen resource. An additional $1.3 billion investment is planned over the next four years in northwestern Alberta.

In 1995, the forest industry in Alberta harvested 19.8 million m^3 of both hardwoods and softwoods, an increase from the 15 million m^3 harvested in 1992. This harvest level ranks Alberta fourth in the country after British Columbia, Quebec and Ontario. Lower prices during 1996—97, however, are expected to reduce the harvest to 1992 levels.

Alberta's primary forest sector consists of a variety of mill types. The sector includes numerous sawmills ranging in size from small portable one-man operations producing a few thousand board feet of rough lumber to large state-of-the-art sawmills producing many millions of board feet of planed and kiln-dried lumber. It also includes eight panel plants, six pulp mills, one newsprint mill, and two paperboard and felt producers.

In 1995, Alberta's sawmills produced 2.1 billion board feet of lumber (8 % of total Canadian production). The panel mills produced about one quarter million square meters (10 mm basis) of panel products with OSB (oriented strand board) comprising the major share of production at 78 % of output. The pulp mills produced 1.5 million tonnes of bleached kraft pulp (4 mills) and 365 00 tonnes of chemi-thermo-mechanical pulp (2 mills). The one newsprint plant produced 230 000 tonnes and output from the two paperboard and felt mills totaled 70 000 tonnes.

Secondary manufacturing of forest products has also seen substantial growth. Since 1992, this sector has grown about 1.5 times in terms of employment and payroll. The sector now comprises almost 700 companies from the previous 600 and produces a variety of products centering on the re-manufacture of lumber, production of engineered building components, and cabinet and furniture materials.

Total employment in the forest industry is estimated at 65 000 people with 13 500 in logging and primary manufacturing, and 12 500 in the secondary sector with a further 39 000 indirect and induced jobs. These jobs created personal earnings of $2.5 billion in 1995. Employment in the logging and primary sectors averaged 1.31 person-years per thousand m^3 harvested, similar to the Canadian average.

Government revenues from the forest industry result from personal and corporate taxes generated from income derived in the sector, and on stumpage charges paid by the industry. Personal earnings in 1995 generated $600 million in taxes to the federal and provincial governments while stumpage payments totaled $45.5 million. In addition, industry has absorbed the cost of many forest management activities previously assumed by the government.

4 Current issues

Some of the issues currently facing the forest sector in Alberta are:

(1) wood supplies,
(2) certification,
(3) other uses of the land, and
(4) Aboriginal participation in the forest sector.

These issues are not in listed in any priority and are not all encompassing, but are intended to highlight a few areas of concern or opportunity for the forest sector in Alberta.

(1) *Wood supplies* - Although Alberta is endowed with a vast forest resource, forest lands suitable for forest industry development have virtually all been allocated; therefore, the future growth potential may appear limited. Add to this the continuing pressures to reallocate lands from timber production to other uses such as recreation or conservation purposes, or losses to fire, and the issue of wood supply gains importance. The industry can prepare for the possibility of future shortfalls and enhance its existing wood supply. Mean annual increment across the province averages 1.98 m^3 per ha. More intensive management such as juvenile spacing and commercial thinning could increase merchantable yields and thus mitigate the negative effects of a reduced wood supply. Many mature aspen stands currently scheduled for harvest contain a substantial softwood understory. Careful harvesting to protect those understories can provide substantial volumes when the stand is re-entered for the second harvest.

Another source of wood supply is from private land. Current harvests from private land totals about 2.7 million m^3 . This harvest is not included in the provincial AAC determination and may not be sustainable. Industry has an opportunity to work with land owners to encourage sustainable management of private forest lands to ensure future wood supplies.

(2) *Certification* - The global environmental movement has resulted in development activities world wide to come under closer scrutiny. The forest industry is no exception and the sustainability of the forest resource has come into question. Forest products have been the target of consumer resistance. In response to the criticism, the issue of certification has emerged as a means of assuring consumers that certified products originate from firms that are sensitive to the environment and practice sustainable forest management. Development of a certification system is underway in Canada (for example, the Canadian government through the Canadian Council of Forest Ministers, has developed a series of criteria and indicators for sustainable forest management). In Alberta, the Alberta Forest Products Association, whose members represent the major forest industries in the province, responded with the development and implementation of the "Forest Care" code of practice.

This code is intended to certify Alberta forest companies that abide by a number of principles and practices that set standards for performance in the care of the forest, the environment, and the community. The Alberta forest products industry is export oriented and therefore must be sensitive to global attitudes.

(3) *Other uses of the land* - The value of forest land exceeds the value of the timber on it. Wildlife habitat and recreation are only two of the non-timber values associated with forest land. In recognition of the multiple benefits and the multiple uses of forest land, the government of Alberta developed the Alberta Forest Conservation Strategy. This strategy, developed over a number of years, provided numerous forums to collect public input and gather opinions from a wide range of interest groups, organizations and individuals in all parts of the province. The strategy, which is now in place, will "....guide the policies and actions of all those who live, work and play in the forests of Alberta..."

5 Aboriginal people in Alberta

Almost 5 % of Canada's 27 million people are of Aboriginal origin. This proportion is even higher in Alberta where almost 210 00 or 8.2 % of the total provincial population of 2.5 million residents are of Aboriginal descent. The greatest proportion of Aboriginal people live in rural areas either in First Nation communities on Indian reserves if they are "status Indians", or on Metis settlements, or other rural non-aboriginal towns. In total, 43 First Nation communities are located in Alberta.

Many of the concerns of Aboriginal people pertain to their lack of opportunities to participate in the forest sector even though forest developments are occurring on their traditional lands. In response, provincial governments are increasing Aboriginal people's participation in decisions regarding forest resource development, and partnerships are evolving among Aboriginal communities, industry, and government to give Aboriginal people a bigger role in the decision-making process. In addition, forest companies are including Aboriginal people's traditional use of the land in the company's forest management and operational planning process. This facilitates dialogue between the industry and local Aboriginal communities and ensures traditional Aboriginal values are given full consideration in forest resource development, planning, and operations.

A major barrier to participation in the forest sector by Aboriginal people is their lack of training. A variety of training programs are underway to improve the ability of Aboriginal people to participate in the forest industry. For example, the "First Nation Forestry Program" of the Canadian Forest Service is designed specifically to improve the capacity of First Nation people to participate in the forest sector both as employees and as business men and women. Some forest companies, and other government agencies also have specific programs to increase Aboriginal participation in all facets of their operations.

The forest industry is by its very nature a rural based industry. Aboriginal people's tradition and culture is also rural based. Both the logging and manufacturing components of the forest industry are often located in and among aboriginal communities. Interaction between the forest industry and Aboriginal communities therefore is inevitable and these communities can and do contribute to the development of the forest industry in Alberta.

6 Potential biomass supplies for energy production

The potential supply of biomass for energy production is substantial in Alberta even if only logging wastes are considered. Some broad estimates of the amount of waste biomass produced from logging operations can be based on the harvest level. A previous study in Saskatchewan, Canada reported that at pre-harvest volumes of 150 to 250 m^3 per ha, 19 % to 32 % of the pre-harvest volume is left on the forest floor after commercial logging (De Franceschi 1991). If this rate is applied to the Alberta 1996—97 harvest level of 15 million m^3, between 3.5 and 7.1 million m^3 of wood is left unutilized after logging. If the entire provincial AAC of 22.1 million m^3 is harvested, the total biomass left unutilized could be as high as 10.5 million m^3 annually exclusive of milling wastes.

In Alberta, only two commercial scale plants that utilize waste biomass to produce electricity are currently in operation. There could be a number of reasons why biomass use is so limited. Some of these reasons are:

1) Cost of collecting and transporting wood waste;
2) Institutional constraints (i.e., resistance by power companies to biomass technology); and
3) Low cost and convenience of other forms of energy make biomass applications unnecessary.

Natural gas is the most common source of heating in Alberta. Ninety percent of the electricity produced in this province is generated from coal with the remaining 10 % produced from natural gas and hydro-electric projects. Energy costs for an average home (103 m^2, family of 4 persons) in central Alberta total less than $1.200 annually with $500 for electricity and $700 for natural gas. These costs are based on annual consumption of 6 600 kWh of electricity and 150 GJ of natural gas (4 250 m^3). Recently, wind generated electricity was introduced into the provincial grid system. Even though costs were higher, consumers purchased this electricity and demonstrated their acceptance for the more environmentally sensitive energy. Therefore even with the relatively low costs of conventional fuels, alternative forms of energy are beginning to be considered. The large amount of waste biomass produced by the forest industry is a potential source of fuel for energy production. The low cost of conventional fuels, however, hinder the development of this biomass resource.

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Potential applications of bioenergy in Canada's remote communities

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1 Introduction

In 1995, the Canadian Forest Service began an initiative to facilitate the introduction of bioenergy fuel supply and combustion systems in remote First Nations communities in Northern Canada. The Canadian Forest Service was delegated responsibility for forest management on First Nations reserves by the Minister of Indian and Northern Affairs. That Department was interested in initiatives that would create employment and foster self-reliance in aboriginal communities.

In this initiative the Canadian Forest Service has also worked closely with the CANMET Energy Diversification Research Laboratory in Varennes, Quebec which is administering a new program - Renewable Energy for Rural Remote Communities. The Canadian Forest Service and CANMET are, in fact, separate divisions of the same Federal Department-Natural Resources Canada.

There are some 310 remote communities in Canada. These are communities that are largely north of the natural gas and electricity infrastructure. Approximately 150 of these communities have access to significant biomass and timber resources. In addition, there are perhaps 200 semi-remote communities that are connected to the electric power grids and may have year around roads, but which do not have access to natural gas which is the low cost source of heat in Canada.

Ensight Consulting was hired under contract by the Canadian Forest Service to help develop the northern Ontario bioenergy initiative. Five remote communities in northern Ontario were visited and workshops were conducted to introduce the concept of biomass heating in public buildings. Prefeasibility studies of converting the larger public buildings to woodchips were carried out in three of those communities. Extensive discussions were held with the community of Wunnumin Lake about implementing a demonstration project. Two community representatives traveled to Prince Edward Island to see small commercial biomass-fired mini-district heating systems in that province. There are some 80 small commercial biomass-fired systems in that province. To date, Wunnumin Lake has yet to decide to develop a proposal for a biomass demonstration project. They have been studying a variety of community energy options.

Other products of the northern Ontario bioenergy initiative were a technical note on small scale bioenergy district heating systems and a quick analysis questionnaire which were published in 1997.

2 Discussion

What has been learned in these studies? Many of the villages are remote aboriginal communities. They are typically located in heavily forested areas of Canada's Boreal forest. In most cases, the forests are not presently being harvested, apart from small volumes of domestic firewood. However, in some cases, such as Fort Hope, forest companies are negotiating Crown licenses not far to the south of their communities. (Some Bands have become parties to Crown license management agreements.) Often the surrounding forests are overmature and forest fires are very common. Unless the fires directly threaten a community, they usually do not fight them, as there are no resources to do so.

Most of these communities do not have year around roads. However, most do have winter road access. Winter roads are made over land and frozen lakes and they allow vehicle access in the January-April period. Efforts are made to transport as much diesel and heating oil as well as other bulky goods over these winter roads as possible. The distances can range up to 500—600 km north of the main paved road network in Canada. Any goods that are not brought in over the winter roads must be shipped by air-freight which is much more expensive.

The size of these remote communities typically ranges from 400—600 people. The population growth rates are generally quite high by western standards. They are usually located on a reserve that encompasses their traditional hunting and trapping area. The layout of the communities varies. Some are relatively compact, with buildings close together. In others, buildings are quite dispersed.

The public buildings are typically heated with light oil. These buildings generally include a school, a hospital or health clinic, a band office, a small hotel, an equipment maintenance garage, sometimes a hockey rink and possibly a recreation centre. In the prefeasibility studies, the consultants were looking for large oil heated public buildings or clusters of oil heated buildings that could be heated by a single woodchip-fired heating plant. The cost of heating oil is very high relative to southern Canadian standards. In PEI today, the price for light heating oil is about 34¢ (Cdn.) per litre. In these remote communities it ranges from 80¢—$1.20 per litre, depending on whether it came in by truck over the winter road or was flown in.

The private homes are small, usually bungalows built on treated posts. Some newer homes have basements. They are virtually all heated with round wood radiant "air-tight" stoves. While heating private homes with woodchip heating systems would not save homeowners money, several communities have expressed interest in the idea, particularly for their elderly people. Other community members presently are delegated to cut wood for these people.

3 Lack of fuel supply infrastructure

In studying the biomass energy potential in these remote communities, it became obvious that while one could identify suitable sites for biomass heating plants and establish their approximate installed costs, it was much more difficult to identify suitable biomass fuel supply options and estimate delivered woodchip costs. In most cases there is no existing forest industry infrastructure. Wood fuel is procured on an ongoing basis (week by week) using chainsaws and skidoos and sleighs for transportation. Conventional commercial woodchip production equipment and approaches are too large and too capital intensive for these communities.

There is an information gap in the bioenergy field which has to be addressed if bioenergy is to become widely used in remote communities in northern Canada. In order to address this gap, the Canadian Forest Service applied to ENFOR (Energy From The Forest Program) in January of 1997 for funding to study alternative ways to supply woodchip fuel to remote communities on a reliable and economic basis. Funding was received and a project was started in October of 1997 with Ensight Consulting as the contractor.

Specific objectives of the study include:

- Developing scenarios for the harvesting, transporting, storage and handling of biomass fuel in ways that are consistent with the volume requirements and the human and physical operating environment in remote communities
- Developing a costing model which will permit the calculation of delivered biomass fuel costs based on local demand and input costs;

The study will nominally involve visiting up to six remote communities (3 in Ontario and 3 in the northwest) to evaluate: the suitability of each community for biomass heating systems; the community infrastructure relative to biomass utilization; their potential wood supply requirements and general forest resources; human resource strengths and weaknesses; available equipment that could potentially be used in biomass fuel production, transportation and handling.

The main deliverables for the project include:

1) A Technical Information Note, tentatively called Biomass Fuel Supply Options for Remote Communities which details the recommended biomass production systems for typical remote communities, estimated fuel production rates and delivered woodchip costs.

   The Technical Information Note shall describe at least two recommended alternative systems for biomass fuel production that would be appropriate for typical remote communities. For communities that have at least a small commercial forest industry, one can develop a biomass fuel supply system built around conventional commercial forestry equipment such as skidders, log trucks and possibly a used large motorized chipper.

   For communities with no existing commercial forest operation, one possible approach could be a system built around a heavy-duty farm tractor and related logging, transport and chipping equipment. It would involve the use of a heavy duty farm tractor as a power source for the extraction and processing of timber, domestic fuelwood and chipping wood. (Harvesting would probably still involve the use of chainsaws.) The tractor would also be used to transport these materials from the harvest sites over frozen lakes and winter roads to a storage and processing yard located in the community. There, further processing would produce end-use products employing the same tractor as a power source. The end-use products could include sawn lumber, dry split firewood and woodchips which would be produced as required by the heating plants.

Because the volumes of fuel that will be needed will be relatively small (especially when perhaps only one small commercial biomass plant has been installed in a given community) alternative uses of the tractor and other machines will be studied. Those uses might include blowing snow during the winter, powering a back hoe or digging attachment in the summer or running a standby generator when there are problems with central diesel plants.

2) The second deliverable is an economic costing model for woodchip production. It shall be delivered in a format suitable for inclusion in the RETScreen Tool. RETScreen is a prefeasibility tool developed by the Federal CANMET Energy Diversification Research Laboratory that can be used to evaluate various renewable energy options in remote communities.

A parallel ENFOR project will involve the development of a planning framework and guidelines to enable communities to design and implement a sustainable forest harvesting plan for supplying community biomass plants. That will be done by a forester in the next few months.

Phase II of the ENFOR project is the application/testing of the harvesting approaches developed in Phase I in selected remote communities in 1998/99. For example, this could involve the transport of a tractor and selected forestry implements into a northern community over a winter road in January of 1999. This equipment would be used in a physical trial to demonstrate the integrated use of a heavy duty farm tractor and various tractor-powered forestry implements in the extraction, transport and processing of timber, domestic fuelwood and chipping wood. Phase II would conclude at the end of the winter road period (March of 1999). At that time, it is hoped that the Band in question or a private company in the community would purchase the tractor and the various implements used in the project as used equipment.

The tractor-powered forestry equipment that is presently under consideration for such an integrated forestry operation are: a winch; a medium-duty grapple loader; an 8—10 tonne trailer; a chipper and possibly a stroke delimber with a splitting attachment. The actual selection of implements would have to wait until a specific community is selected and its needs are assessed. Discussions have been held with Kesla OY of Finland about supplying Patu tractor-powered equipment for such a trial. New Holland of Canada may supply one of their articulated 9060 tractors for the project.

Phase III, which is beyond the scope of the current project, would involve the installation and testing of a biomass combustion plant in one or two communities as a pilot/demonstration project. Funding has yet to be identified for this phase.

4 Conclusions

So what can one conclude about the potential advantages of utilizing biomass energy in remote communities in Canada?

- Canada has many remote communities which are surrounded by significant and largely unutilized forest resources.
- The cost of heating oil is very high in remote communities and woodchips can be very competitive. Woodchips @ $40/tonne are equivalent to heating oil @ about 20¢ per litre.
- Woodchip production can and ideally should be integrated with the efficient production of saw timber and roundwood firewood for private home heating. Many Bands have expressed interest in producing lumber for home construction. Woodchip production can enhance the economics of producing of both fuelwood and timber.
- Woodchip production will create some employment in remote communities which desperately need jobs.
- Woodchip production for small central heating systems can serve as a stepping stone to larger scale biomass production for more extensive district heating systems and electric power generation plants if this is appropriate to the available forest resources. This gradual approach is necessary to develop biomass fuel production and plant operation skills in these communities. It will also serve to convince people in remote communities that biomass energy utilization will not denude the landscape and drive away all wildlife.
- Biomass utilization will displace heating oil, reducing CO_2 emissions. It will also reduce the spillage of heating oil in these communities. The latter is a serious problem in virtually every community.
- Biomass utilization in remote communities will enhance the self-reliance of remote communities and make them less vulnerable to fluctuations in world oil prices.

All of these factors are very favourable, but many barriers to biomass energy development remain to be overcome. These barriers include:

- Lack of knowledge about the relative merits of biomass energy compared to other energy options that people hear about. (Wind, solar, small scale hydro, connection to the power grid, etc.)
- Lack of trust of outside experts.
- High initial costs of biomass systems relative to oil heating systems.
- Absence of funding mechanisms that can accommodate high initial costs.
- Few companies that build or sell biomass systems in Canada.
- Aboriginal bands have many pressing issues on their agendas. Biomass and energy matters in general have a low priority.

Biomass energy in remote communities in Canada has tremendous potential. To be successful, all of these barriers must be addressed.

Potential utilization of woodfuels in Finland

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1 Introduction

Even today Finland is one of the leading countries in the use of woodfuels. The energy content of wood derived fuels used in 1995 was 4.74 million tons of oil equivalent (toe). More than half of the wood-derived fuels was waste liquors from pulping industry (2.78 million toe) and the rest was mainly waste wood from the forest industries (1.11 million toe) and firewood (0.85 million toe). The share of wood-derived fuels was 15.0 % of the total primary energy consumption, 31.7 million toe (Asplund 1997).

From the point of wood resources Finland still has excellent opportunities for increasing the use of woodfuels in energy production. The main barrier for the utilization of these resources is the high price compared to the price of alternative fuels.

In 1994, the Finnish Government established objectives for the promotion of bioenergy. The aim is to increase the use of bioenergy by about 25 % from the present level by 2005. The increment corresponds to 1.5 million toe per year. The research and development work to decrease production costs is considered to be an important factor towards achieving this goal.

2 Production potential of woodfuels

2.1 Logging residues from final cuttings

Helynen & Nousiainen (1996) have estimated the technical and economic aspects of the potential production of chips from logging residues according to forest management plans. The estimate assumes that logging residues are harvested only from spruce-dominant clear-cutting areas and that for ecological and technical reasons, only 80 % of these areas are suitable for logging residue harvesting. When using present harvesting methods it has been estimated that 60 % of the logging residues from a final cutting area is recoverable. According to these assumptions the annual production potential of logging residue chips is 3.67 mill. m^3, which is 28 % of the total amount of logging residues from final cutting areas (Table 1).

According to Hakkila & Nurmi (1997), the technically feasible logging residue harvest potential is 8.6 mill. m^3/year. The difference between these two estimates is due to differences in the calculation assumptions. Hakkila and Nurmi assume a higher harvesting yield. Furthermore, regeneration cuttings other than clear-cuttings and logging residues from pine-dominant stands have been included in their calculations.

Table 1. Additional production potential of woodfuels in Finland (Helynen & Nousiainen 1996, Hakkila & Nurmi 1997).

Production potential	mill. m^3/year	Mtoe/year
Forests		
Logging residues	3.67	0.65
First thinnings (excluding bark)	3.57	0.61
Precommercial thinnings	1.15	0.20
Unproductive stands	0.81	0.14
	9.20	1.60
Forest industry		
Bark	..	0.7—1.1
Wood waste	..	0.3—0.4
Waste liquors	..	2.2—3.8
Total	..	3.2—5.3

2.2 Processing residues and whole-tree chips from early commercial thinnings

It would be possible to integrate pulpwood and woodfuel production in early commercial thinnings. The potential harvest of additional needles, branches and tops is 3.6 mill. m^3/year. The harvest potential of woodfuel from precommercial thinnings and unproductive stands is almost 2.0 mill. m^3/year (Table 1).

3 Woodfuel production

3.1 Logging residues

Logging residue chips are the cheapest form of wood fuel produced directly for energy use. Under Finnish conditions, the two main production methods in use are quite similar. The only difference is in the location of the chipping process. In one method chipping takes place at the road-side and in the other at the felling site (Fig. 1 and 2).

Both the *terrain chipping* and the *road-side chipping* methods demand the piling of logging residues in conjunction with the cutting of timber. By slightly adapting the cutting method, such piling does not complicate the timber harvesting. After piling, the forest haulage of logging residues can be done either in the form of chips or uncomminuted logging residues. If the logging residues are not comminuted at the felling site, they are normally comminuted at the road-side using a big drum chipper, but they could also be comminuted at a larger terminal. In the both alternatives, the comminuted logging residues are transported to the user by a chip truck.

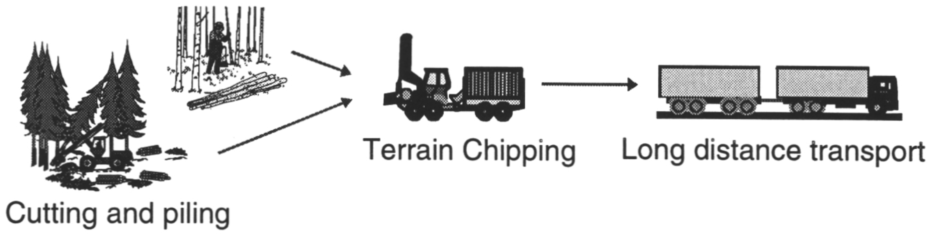

Figure 1. Production of logging residue chips with terrain chipping method.

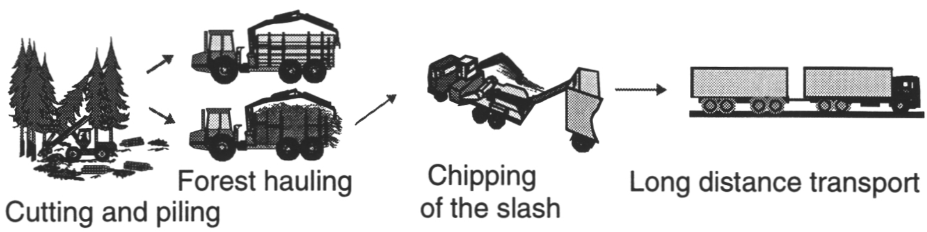

Figure 2. Production of logging residue chips with road-side chipping method.

The production cost of logging residue varies considerably depending on the quality of piling, chip yield and forest haulage and road transportation distances. When the harvesting area is good and the distances are short, it is possible to reach a competitive price level of 40—45 FIM/MWh for the logging residue chips (Table 2, Vesisenaho 1997).

3.2 Integrated methods in early commercial thinnings

By integrating woodfuel and pulpwood production in early commercial thinnings, it is possible to lower the production costs of both woodfuel and pulpwood. Two methods have been developed for the processing of tree-sections or whole-trees from early commercial thinnings. Until now, these new methods have not been widely used, though it has been estimated, that they would be competitive compared to the normal log-length method. The most used integrated production method for pulpwood and woodfuel has been the drum debarking of tree-sections.

Table 2. Production costs of logging residue chips (FIM/MWh).

	Chipping Place	
	Roadside	Terrain
Piling of logging slash	0—2	0—2
Forest haulage (100 m)	10—12	—
Chipping	16—18	25—30
Transportation (40 km)	10	10
Overheads	5	5
Total	41—47	40—47

Chain-flail delimbing-debarking

In a Finnish application of integrated harvesting, a mobile chain-flail delimbing-debarking unit is equipped with a hammer crusher for woodfuel. This integrated production method is suitable for bunch-processing of small-sized wood. With this method, it is possible to simultaneously produce debarked stemwood for the pulp industry and chips from branches and bark for heating purposes with the same equipment efficiently.

The method is based on the utilization of a separate delimber-debarker at the roadside or terminal. The trees to be processed are felled, bucked and piled into bunches either manually or mechanically. The undelimbed bolts are transported to the processing site as tree-sections.

The unit delimbs and debarks the trees by flaying them with steel chains, and the processing waste is crushed using the machine's hammer-crusher, after which the waste is blown into the container of the chip-truck, sited just behind the unit. The productivity of debarked bolts is approximately 25—30 m^3/E_{15}-h and for the energy fraction 5—7 m^3/E_{15}-h when processing Scots pine.

Another chain-flail technique based application used in Finland is a combination of chain-flail technique and drum debarking. The chain-flail technique is used for delimbing of the bolts and a small debarking drum is used for debarking of the bolts. With this method it has been possible to reach a lower bark content than when only using the chain-flail method.

MASSAHAKE-method

In the MASSAHAKE method, the fuel fraction and the pulp chips are separated by a multiphase process. The method is able to accept chips from many types of wood material; undelimbed or delimbed, small or big trees and high bark content wood chips.

Compared to other methods, the special feature of the system is to loosen the bark which is attached to the thick wood chips. The fine fraction is mainly removed by mechanical screening, although some light outer bark, especially in birch whole-tree chips, and other large and light fuel particles are removed using a pneumatical sorter. Finally, the quality of the pulp chips is guaranteed by employing an optical sorter. The rejected material from the optical sorter can either be used for fuel or recycled back to the bark loosening process to increase the yield of pulp chip.

Because the fuel fraction has been homogenised it is suitable for fuel at power plants as such without the need for further treatment. The heating value of the fuel fraction is higher than with whole-tree chips because of higher portion of outer-bark of birch. When chain-flail delimbing is employed, an effective crusher or a drum-chipper is required for processing the branches into fuel.

4 Consumption potential of woodfuels

The potential consumption of biofuels in Finland has been estimated by Helynen & Nousiainen (Helynen & Nousiainen 1996, Helynen 1997 and Nousiainen et al 1997). In these estimations, different scenarios have been composed up to the year 2010. They are based on factors of vital importance to the consumption and production of wood energy. In this paper, two scenarios concerning the potential consumption of biomass based fuels are presented.

4.1 Residential heating and agriculture

There are about 1.0 million fireplaces in detached houses and farms and about 350 000 fireplaces in electrically heated residences. It would be possible to increase the utilization of woodfuels in these fireplaces by about 2.0 million m^3. The present consumption of woodfuels in fireplaces is about 5.5 million m^3/year (1.1 Mtoe) (Helynen 1997).

In the basic scenario, it has been assumed that the energy produced using biomass will remain at the present level, but the use of fuels will decrease due to the increased efficiency in heat production. In the maximum scenario, the use of firewood in fireplaces will increase significantly (Helynen & Nousiainen 1996).

4.2 District heating

Nowadays, peat is widely used for heat production in district heating plants and in combined heat and power (CHP) plants inland. At coastal locations and close to the natural gas network, coal and natural gas are often more competitive alternatives than woodfuel. Peat accounts for about 25 % of the total fuel consumption in district heating, whereas the share of woodfuels is only 6 %.

In the basic scenario, it has been assumed that where the annual heat load is greater than 10 GWh district heat production will be based on the use of biomass,. When the annual heat load is greater than 45 GWh, it has been assumed that small scale power plants will be constructed during the evaluation period.

In the maximum scenario, the energy production in heating plants of greater than 5 GWh heat load will be based on the use of biomass. The assumption for small scale power plants is the same as in the basic scenario. The IGCC (integrated gasification combined cycle) technology is assumed to be commercial for biomass after the year 2000, which enables twice the power-to-heat ratio compared to a conventional 'steam boiler-steam turbine' plant.

4.3 Forest Industry

Currently, forest industries consume over 75 % of the total available wood-derived fuels. These woodfuels (e.g. waste liquors from chemical pulping and wood waste from the debarking process) are produced mainly as by-products.

Table 3. Basic assumptions for the scenarios in the chemical forest industry.

	Basic scenario	Maximum scenario
Production growth	3 %	4 %
Heat saving	2 %	4 %
Electricity saving	—	6 %
Price of electricity	At present level	Increases clearly
Competitiveness of biofuels	Improves somewhat	Improves clearly
Construction of IGCC-plants	—	7

Nowadays almost all solid fuel boilers at pulp and paper mills are based on fluidized bed combustion technology which allows multi-fuel use and wide variations of fuel particle size and moisture. The conversion of several grate and pulverized fuel fired boilers to fluidized bed combustion boilers during last 15 years has made it possible to use a wider variety of biomass in many boilers.

Because the share of by-products, as well as the need for energy, depends on the pulping method, changes in product categories and the development of production capacity have a great influence on the use of biomass-based fuels in the forest industries. On the other hand, the use of purchased biomass depends directly on the competitiveness compared to alternative fuels. The introduction of new energy production technology will also significantly increase the potential utilization of biofuels for power production.

The basic assumptions for the scenarios of woodfuel use by the forest industries are presented in Table 3. In the maximum scenario IGCC-plants will be constructed and the competitiveness of biofuels will improve significantly. Furthermore, heat and electricity will be saved a lot in the processes.

In the basic scenario, it is assumed that the structure of pulp production will develop as in the past. In the maximum biofuels scenario, the production of chemical pulp is assumed to increase significantly faster than the production of mechanical pulp.

4.4 Condensing

A low share of biomass-based fuels are employed in condensing power production. In Finland only one 150 MW_e peat-fired power plant has been in operation since 1989. Some of the largest biomass-based CHP-plants have also been equipped with turbines having a condensing section, which is utilized when low heat loads limit power production. Peat reserves would allow the construction of a few new condensing plants. Generally, biomass resources are a limiting factor when considering the competitiveness of condensing power production (Helynen 1997).

4.5 Consumption potential

In the basic scenario, it is assumed that the consumption potential of biomass-based fuels will increase from 5.58 Mtoe/year to 8.37 Mtoe/year by year 2010 (Table 4). In the maximum scenario, it is assumed that the use of biomass-based fuels will increase to 10.73 Mtoe/year; the main part of the increase taking place in the forest industries.

In the basic scenario, the increased use of biofuels in the forest industries is based on the assumed increase in production. Therefore, the amount of waste liquors and wood waste in heat and power production will increase, but the amount of purchased biofuels will remain at a low level. In the maximum scenario, it is assumed that the use of purchased biofuels will also increase significantly.

Table 4. Consumption potential of biomass-based fuels in 1992—2010, Mtoe/year (Helynen 1996, Helynen & Nousiainen 1995, Nousiainen et al. 1997).

	1992	2000	2010
Basic scenario, Mtoe/year	1.11	1.04	1.00
Residential heating and agriculture	0.80	1.23	1.35
District heating	3.47	4.56	5.41
Forest industry	0.09	0.10	0.12
Other industry	0.11	0.44	0.49
Condensing			
Total	5.58	7.37	8.37
Maximum scenario, Mtoe/year			
Residential heating and agriculture	1.11	1.23	1.41
District heating	0.80	1.26	1.51
Forest industry	3.47	5.39	6.83
Other industry	0.09	0.16	0.12
Condensing	0.11	0.59	0.87
Total	5.58	8.63	10.73

Table 5. The consumption potential of biomass-based fuels in different scenarios in the forest industries in 1992—2010, Mtoe/year (Nousiainen et al. 1997).

	1992	2000	2005	2010
Basic scenario, Mtoe	2.22	2.95	3.26	3.57
Waste liquors	0.89	1.15	1.25	1.35
Wood waste	0.36	0.46	0.46	0.49
Purchased biofuels				
Total	3.47	4.56	4.97	5.41
Maximum biofuels scenario, Mtoe				
Waste liquors	2.22	3.23	3.67	3.82
Wood waste	0.89	1.24	1.41	1.47
Purchased biofuels	0.36	0.92	1.24	1.54
Total	3.47	5.39	6.32	6.83

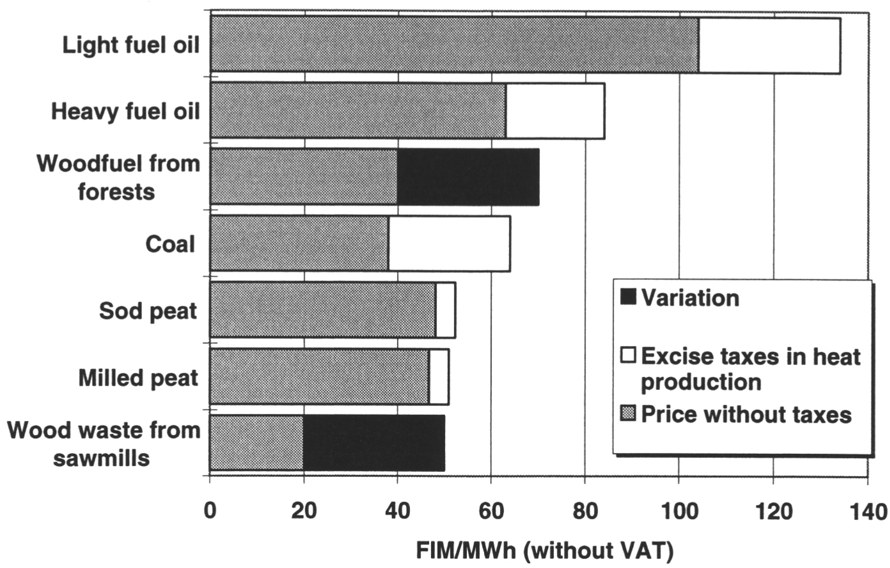

Figure 3. Consumer prices of different fuels in Finland in June 1997 without VAT (Polttoaineiden... 1997).

5 Competitiveness of woodfuels

5.1 Fuel prices in Finland

The prices of fuel used for heat production in Finland are given in Figure 3 (Polttoaineiden... 1997). From 1.1.1997, the consumer prices of fuels for heat production include excise taxes, but not fuels for electricity production. For the time being, woodfuels do not have a fixed market price. The price of woodfuel varies considerably depending on the production method and transportation distances. In small district heating plants, the price of woodfuel may be as high as 70 FIM/MWh, whereas in big power plants the price of by-products from sawmills may be as low as 20 FIM/MWh.

5.2 Competitiveness in heat and power production

In Finland natural gas, where it is available, is the most competitive fuel in both heat production and electricity generation, as well as in combined heat and power production. Heavy fuel oil also continues to be cheaper than solid fuels in heating plants. The fixed costs of oil-fired energy production plants are lower than those of solid fuel plants.

Wood fuels seem to be the most competitive in small heating plants and small-scale power plants. The competitiveness of wood fuels in larger plants will probably be limited by the supply of sufficient volumes from distances short enough to keep the price of wood fuels competitive (Kosunen & Leino 1995).

The Ministry of Trade and Industry grants aid for investments in heating and power plants when these investments involve an opportunity for the increased use of biomass-based fuels. This investment aid increases the competitiveness of wood fuels significantly both in separate heat production and in combined heat and power production.

5.3 Socio-economic effects of woodfuels

In heat and power production, the price of domestic fuels could be higher than the price of non-domestic fuels, if all socio-economic effects, such as direct and indirect employment and disposable incomes in the local economy, are taken into consideration.

The equivalent prices for domestic fuels compared to coal are given in Fig. 4. Wood chips could cost up to 11 FIM/MWh more in condensing power plants and 22 FIM/MWh more in combined heat and power production, if the price of coal is 28 FIM/MWh at the coast (Mäenpää & Männistö 1995). Inland sites raise the price of coal by 6 FIM/MWh.

6 Conclusions

The production potential of woodfuels enables a 45 % increase in use of woodfuels. If the potential was fully utilized, woodfuels would account for 2.16 Mtoe/year, which is 22 % of the present primary energy consumption.

The main consumption potential of woodfuels is in the forest industries where the fluidized bed boilers make it easy to increase the use of woodfuels, as different fuels (separately or mixed) can be used in these boilers.

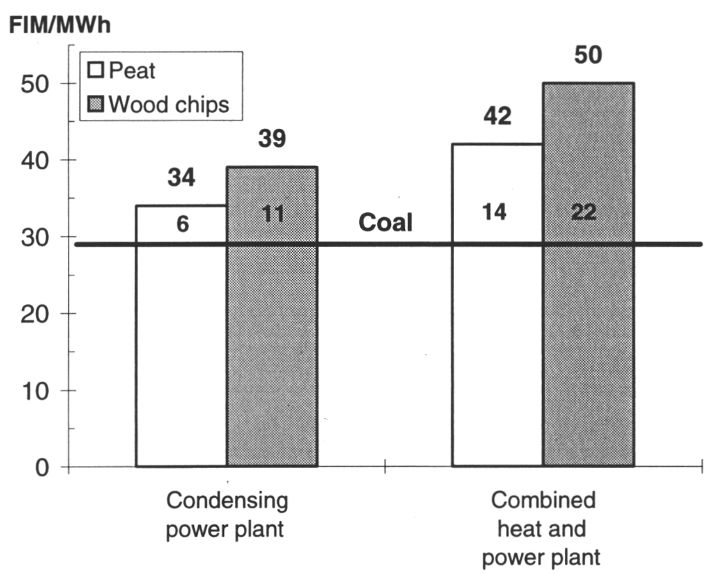

Figure 4. Equivalent prices of domestic fuels and the price difference compared to hard coal without taxes (redrawn from Mäenpää & Männistö 1995).

With new integrated production methods, it is possible to produce woodfuels at a competitive price. This is important when increasing the use of woodfuels as the selection of a fuel is almost always based simply on its price. From the viewpoint of the national economy it would be economical to pay even 11—22 FIM/MWh more for woodfuels compared to coal.

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State of the art in energywood development in Holland with special attention to the marketing concept of 'green energy'

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1 History of Dutch forestry

The development of the woodland area in Holland during the last centuries is very interesting. Once Holland (Holtland=Woodland) was almost totally covered with forests. Overgrazing in the middle ages and overcutting in the period of the golden age (1600—1700), for instance for ship building, resulted in large moving sand dunes and forming of enormous heathlands in the eastern part of the country.

So in the middle of the 19th century only 4 % of the land surface was covered with woodland. After this time we can distinguish 5 different stages in the development:

1. Reforestation of moving sand dunes in 1860—1900. Main tree species Scots pine. Founding of the State Forest Service in 1899.
2. Reforestation of heathlands in 1920—1940 as a part of the big employment program. Main species pine, spruce, larch (mining industries).
3. Afforestation of 20 000 ha in the new polders (land reclamation in the former Zuiderzee) in 1950—1990. Main species poplar, ash and oak. The proportion of land for forest and nature is in the first polder 5 % but in the most recent polder almost 35 %!
4. Founding of Urban Forest Areas near the big cities in the western part of the country mainly for recreation purposes from 1980 till now. After starting the establishment of recreation areas with a low amount of forests in the 1970s (Twiske and Spaarnwoude near Amsterdam), woodland now plays a central role in the recreation areas simply because it is more cost-effective for recreation.
5. Afforestation of surplus agricultural land since 1985 especially in the northern part of the country. Recently the decrease in the area of forests has been some 1000 ha annually.

In a densely populated country, forestry is closely related to social developments. The main objectives in forestry are changing according to public opinions.

Before the second world war the main objectives were production of timber especially for mining industry, controlling moving sand dunes, improvement of employment and use of heathlands which were left without any function after the change in the old agricultural system due to the introduction of fertilizers.

After the second world war both nature conservation and recreation became more and more important. Nowadays the production function is not the main reason for forestry. More attention is given to the reduction of greenhouse gases and conserving groundwater areas.

2 Timber market for Dutch wood

As much as 92 % of the timber is imported. Holland lacks industries capable of using low value wood. There is only one pulp mill using 200 000 m^3 of wood per year. Because of long transport distances to foreign sawmills in Germany, Belgium and sometimes in Sweden, Dutch roundwood can not be sold with a positive stumpage price. Consequently, during the last years the annual cut has decreased from 1.5 million m^3 to 1.1 million m^3.

3 Energy policy

- The two existing nuclear power plants will be closed in 2004.
- Holland has a large field of natural gas, enough till 2050. More fields, mostly small ones, are still being found.
- Gas and coal imported Australian, are the main fuels for the electricity plants. For heating the main fuel is gas.
- House heating systems are common. In the beginning of the century most cities had an city heating system, but after the exploring of the natural gas these outdated systems were closed. After the energy crisis, district heating systems started to come back, especially in new city quarters.
- Holland is both an exporter and importer of natural gas.
- After the oil crisis in the 1970s, Holland decided to become more independent in its energy supply.
- The government decided to increase the proportion of sustainable energy to at least 10 % by 2020. At present the amount is only 1 %, mostly wind energy.
- The production and distribution of electricity are separated by law. The energy distributing companies are free to buy the electricity where it is most profitable. For me as a citizen that means that yesterday my electricity may have been produced in Germany, last night in Holland, and tomorrow it may be produced in a nuclear power plant in France.
- There is an overcapacity in electricity production. Some coal fired power plants are already closed.
- After 1995 research in using biomass for energy production has been strengthened, with special interest in municipal waste, including wood waste.
- To get the production of wind energy more profitable the electricity companies pay a double price for it. Private persons have the possibility to deliver their surplus production from wind mills for that higher price. So investments in private wind mills are becoming more interesting.

4 CO_2-policy

CO_2 is a hot political issue in Holland. Sea level rising requires higher dykes, and we have just had two years with excessively high water levels in the rivers.

The Dutch environmental policy is more or less successful in most environmental issues such as acid rain and overfertilization. The emissions of ammonia, nitrate and phosphate have been reduced, but there is one big exception: the CO_2 emissions. The official governmental policy is to reduce the CO_2 emission level by 3 % by 2000 compared to the level of 1990. Recent measurements show, however, a dramatical increase: +3,9 % in 1995 and +0.5 % in 1996.

The Dutch CO_2 policy is not successful at this moment. The main factor responsible for the increase is the economic growth: more traffic and a higher energy demand, both resulting in increased use of fossil fuels.

Holland always tried to be a leading country in environmental issues, but now its international image is in danger. That is why the government decided last year to double the efforts, and established an extra budget of 750 million fl. (1 fl. = 0.50 USD, April 1998) for the coming 5 years for both research and investments in CO_2-friendly techniques.

5 Combining the facts

Holland has a serious CO_2 problem, intends to rise the share of sustainable energy to 10 % by 2020, and there exists a surplus of unmerchantable wood of approx. 1 million m^3 per year. So it is attractive to combine these facts because wood-based fuels are CO_2 neutral and sustainable.

The main question is: how much wood is available for energy production, and what is the cost? There are three main resources for woodfuels:

— Growingstock in the forests (only 70 % of the annual increment is utilized)
— Logging residues
— Waste wood

In the Netherlands, not only wood and logging residues from forests are of interest, but also woody biomass from gardens and city parks. Waste wood from buildings has a disadvantage that it is often contaminated with paint and other chemicals. Therefore it can only be burned in special plants. Waste wood excluded, about 500.000 odt of wood is available for energy production annually.

At this moment there are no plants using wood for energy production. Three options of combustion are available:

— Cofiring wood in coal fired plants. Pilot tests have shown that it is possible to mix up to 30 % pulverized wood in coal fired plants. There are 9 of these plants, with a total capacity of 4200 MW.
— Stand alone wood fired plants with conventional techniques, including both small scale (up to 15 MW) district heating plants and medium scale (up to 50 MW) power plants.
— Stand alone plants using new techniques (gasification).

At this moment the following projects based on the use of wood are ongoing. The first plants will be in operation in 1999:

1. District heating plant (7 MW) in Lelystad
2. Gasification pilot plant (4,4 MW) in Apeldoorn
3. Power plant (50 MW) in Cuyk
4. Power plant with gasification (32 MW) in Diemen

6 The problem of the market price

From the viewpoint of bio-energy, the fossil fuel based energy is too cheap. The cost is 7—8 ct/KWh for conventional electricity, 14—17 ct for windenergy, and 16—20 ct for biomass energy. So energy from biomass is 2—2½ times as expensive as conventional energy. There are two main questions:

— What is the reason?
— Who is paying the difference?

1. *The reason.* Why is the energy so cheap? First: very cheap fuel is available, such as coal from Australia. Second: there is overcapacity of energy production in western Europe. Electricity is produced where the costs are low. Third: countries give their own industry advantages in the international competition through low or no taxes on energy.
2. *The paying.* There are in fact only to options. It is the government who pays, or it is the consumers. Indirectly the consumers are always paying.
   The best solution in the long term is paying by the consumers so that the price includes all environmental costs. Therefore it is necessary that the European integration is completed. The governments have to take the responsibility to make wood-based energy competitive.

7 Dutch possibilities

For the energy producer, the following possibilities to lower the costs of bio-energy and make this energy competitive are available:

— Grant scheme on investments within the framework of the CO_2-policy. The total amount of money is 750 million fl. for the coming 5 years
— Special programs of the EU (Joule, Thermie) on new technology
— Dutch tax rules

Since 1996 there is an energy tax on fossil fuels of 3.2 ct/kWh. However, companies pay the tax only for the first 50 000 kWh annually (to avoid disadvantages in international competition). For households the first 800 kWh are free of tax. The energy tax is politically controversial as long as the surrounding countries do not have one.

People who invest money in special funds for green projects such as afforestation, sustainable energy and nature development get tax benefits. The interest rates for green projects are 1 to 1½ % below the official market rates. There is a lot of interest in this funding, but there is one big problem: more money is available than there are suitable projects. In fact there is a surplus of more than 500 million fl., and the funds have the obligation that at least 70 % of the money should be invested in green projects. During the last two years there have been mainly investments in wind energy projects. Fortunately, two big bio-energy projects are coming with a total investment of more than 200 million fl.

8 The marketing concept of 'green energy'

Not only the producer has possibilities for lowering cost of bio-energy, also the distributor can do something. In 1995 the first company started to sell green energy. The concept works as follows:

People pay 4,7 ct/kWh more for their energy, but are free of the energy tax, so that they pay for green energy 4.7 ct more for the first 800 kWh and only 1.2 ct/ kWh for the greater part. They get for their money two quarantees:

— The company buys at least an equal quantity of sustainable energy as it sells to its clients.
— All the extra money the company gets from the green energy is used for research and development in sustainable energy, monitored by an independent commission. All clients get a report of the efforts and results.

There are presently 5 companies, covering 80 % of the market, who have introduced this product under different names: nature power, ecopower, green power etc. Some companies only use clean wood fuels, whereas some use all kinds of renewables, including waste wood.

The company in my region has several different rates: 25, 50 or 100 %, so that also people with little money can participate. It is the free choice of people to do it or not. Of course companies have a marketing concept to make it for people attractive to pay 200 fl/year more for the same. Companies use wellknown people such as famous sportsmen to advertise the concept: I chose for the environment, what did you do? The clients get a special newsletter, and they also get a special sticker to make themselves recognizable.

Why do people choose this more expensive product? Some answers from common customers:

— To keep the nature green
— Because of my children wanted it. They found it important for their future
— Green power is necessary.
— Because it is environmental friendly

How many people did choose this concept? The two companies who started in 1995 and 1996 have presently 9600 and 7000 households as their client. That means approx. 1 % of the market.

Some companies and communities have chosen this product as well. The first business client was a big one: the van Melle company, who did accept a ½ million fl./year higher electricity bill! A breakthrough was the decision made this summer by the Departments of Economic Affairs and Environment to take a 20 % share of their total energy use in green energy.

Recently a poll was held regarding the national budget for 1998. People could give a score for different political issues such as government information on internet, more longer shopping time in evenings or on Sundays, energy tax and green energy. Green energy got the highest rating.

9 Conclusions and further developments

Electricity companies expect the share of green electricity to grow to 10 % of the market. They are investing in additional capacity to produce green energy. For the year 2000 the target is 4—5 %, of which 50 % is based on the use of biomass.

Wood from Dutch forests can supply only 1 or 2 % of the market (excluding waste wood). One of the options is import of roudwood from other European countries. This is in the first place a price problem for the European market as a whole. In my opinion it would be better to look for possibilities for exporting green power rather than fuelwood.

Short rotation forestry (SRF) is not an important option, although it is possible to plant some thousands of hectares. But Holland is a small country, and land is a scarce and expensive commodity. Only when we can make the product multifunctional SRF may have a chance.

The development of green energy may follow the history of the non-phosphate detergents. In the 1970s we had a serious problem of water pollution, when high phosphate and nitrate loads caused a hypertrofic situation in surface waters. Dephosphating of municipal waste waters was very expensive. In 1970 the first non-phosphate detergents came in the market. In the beginning, only environment-minded people did buy this expensive product. The situation changed when the government decided to make the non-phosphate option at least not more expensive than the others. And what happened? Within a few years all detergents are non-phosphate.

What I will say with this case is that you always need a group of people to make new development visible in their life. The number of these people is less important than their motivation: they must be believers! This is necessary to convince the majority of the population that something can be done for the environment, and that doing that gives a good feeling without spending too much money.

Appendix 1. Facts about the Dutch forests.

Area	
Total land surface	3.4 million ha
Woodland	335 000 ha = 10 %
Main tree species	
Broadleaved species	40 %
Coniferous species	60 %
Scots pine	39 %
Oak	16 %
Larix	6 %
Birch	6 %
Douglas fir	5 %
Poplar	5 %
Spruce	4 %
Beech	3 %
Others	16 %
Ownership of Dutch forests	
Private	41 %
State Forest Service	31 %
Local Communities	15 %
Nature conservation (NGO's)	11 %
Others	2 %
Growing stock, increment and harvest	
Growing stock	51 million m^3 (182 m^3/ha)
Annual increment	2.7 million m^3 (8.1 m^3/ha)
Annual harvest	1.1 million m^3

Timber procurement systems of the southeastern United States

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1 Introduction

The forests of the United States are of great importance to the forest products industry, landowners, and economy of the nation. In addition to the raw materials to build homes, and paper and paperboard products, they provide a variety of opportunities for recreation, aesthetic enjoyment, watershed management, and soil conservation. But, timber products usually provide the greatest financial return to the landowner.

The forests of the United States were the source of 506.3 million cubic meters of industrial roundwood during 1991 (Smith et al. 1994). The distribution of this wood to various products in shown in Table 1. These volumes are harvested from both public and private lands. For the past several decades, the greatest volume of roundwood has been produced in the Western region of the U.S. In this region, federal land ownership exceeds 53 percent of the timberland area (USDA Forest Service, 1988). These public lands have historically been the major source of raw materials for the forest products industry in the western region.

More recently as harvest volumes from public lands in the Western region have decreased, the southern region has become the supplier of nearly one-half of all industrial roundwood. The southern region comprising 13 states from Texas to Virginia is shown in Figure 1.

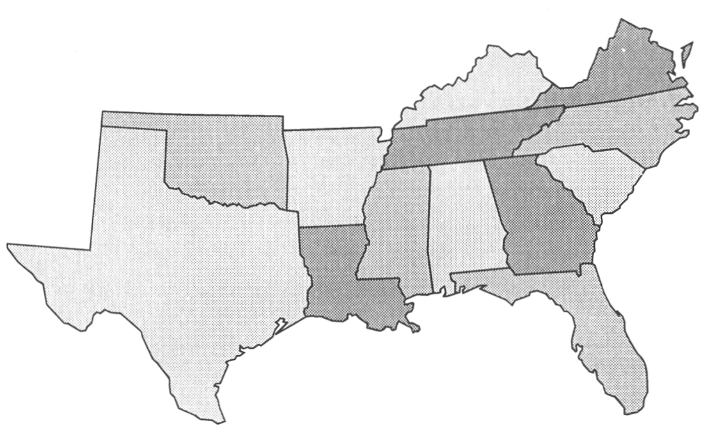

Figure 1. States comprising the Southern region U.S.

Table 1. Roundwood consumption in the U.S. in 1992.

Product	United States m^3 (000's)	South m^3 (000's)
Sawlogs	208 027	95 012
Pulpwood	142 895	96 113
Veneer logs	38 614	22 509
Fuelwood	90 183	24 120
Other	26 550	6 008
Total	506 269	243 762

The timberland ownership patterns in the south are dramatically different than the western region. Historically, private ownership exceeds 89.7 percent, of which less than 19.6 percent is owned by the forest products industry (Smith et al. 1994). The non-industrial, private forest owners (NIPF) own the remaining land. Most forest industries must purchase raw materials on the open market, as their own lands usually provide insufficient raw materials to support their manufacturing requirements. Based on this land ownership pattern, various procurement strategies have evolved to obtain wood furnish to support mill requirements.

2 Procurement of primary products

Wood procurement patterns for companies vary based on a variety of factors, such as area of land ownership or control, availability of public and private stumpage, availability of loggers, and cost to procure wood fiber. There are four approaches that are most widely utilized by the forest products industry to procure wood in its primary form. Some companies use only one approach, most use at least two, and some use all four avenues to obtain raw materials.

2.1 Company-owned lands

The first approach is to harvest wood from company owned lands or lands leased from private owners for the primary purpose of producing wood. This approach provides the most stability and gives the company a volume of wood at a predictable cost and availability. In the south there are very few companies that are able to rely solely on harvesting timber from their own lands to support their needs. The land area required and cost of owning and managing these lands is sometimes not as economical when compared to purchasing wood from other sources, but the necessity for a "captive" source of wood fiber forces most companies to be land owners. Companies that follow this approach may require a raw material of a quality or species that is not readily produced by other landowners, or desire to have maximum access and control over their raw material. Sometimes they have the luxury of having had a far-sighted owner many years ago who saw land and timber as a good investment.

2.2 Gatewood procurement

The second approach, gatewood procurement usually involves the minimal amount of effort and investment. Gatewood also termed market wood, or free-wood involves purchasing wood at the mill gate from independent loggers. A price is usually advertised for the material delivered to the mill gate. There may be different prices for different grades, and the prices may be adjusted to manage wood yard volumes. Producers of gatewood are often farmers and small independent loggers who work and live relatively nearby the mill. The price offered by the mill is strongly influenced by local supply and demand. Mills that rely on this approach often find that they must increase the gatewood price significantly to attract wood producers during wet, winter weather, and must control their inventories accordingly.

The gatewood approach usually requires no capital investment in raw materials and there also are usually no company employees involved in the process until the wood arrives at the mill yard. This makes the cost of the wood procurement activity the lowest of all methods, but it also can produce irregular and unpredictable volumes of raw materials for the mill.

2.3 Internal procurement organization

The third approach to wood procurement involves using company employees, usually procurement foresters to appraise timber stands on the lands not owned by the company. In the southern U.S., this most frequently is carried out on NIPF lands through a negotiated or sealed-bid sale. If the timber meets the required specifications for size, quality, location, and accessibility, the procurement forester will negotiate a stumpage price for the timber, or submit a sealed bid in competition with procurement foresters from competing companies. In the negotiated sale, the landowner is usually at a disadvantage since he is normally an infrequent seller of timber, but is selling on the market to a professional timber buyer. Landowners who want to realize the true market value of their timber offer their timber for sale on a sealed-bid basis.

A major advantage to this approach is that companies can control the quantity of timber that they have in inventory on the stump. This allows some degree of certainty that the mill will have an adequate supply of raw material at all times. Mills in the south usually maintain a inventory of 6 to 12 months on the stump. Accessibility and proximity to the mill is also of concern. Procurement managers desire some stumpage be accessible on ground conditions that allow wet weather logging. Proximity to the mill is also important to minimize transportation costs, but procurement distances can exceed 200 kilometers by truck or 650 kilometers by barge. This approach also helps the procurement manager to better control the quality of timber delivered to the mill. Field foresters who are knowledgeable of the quality of timber required to manufacture the company's products must go to the effort required to locate stumpage of the required quality.

Disadvantages of this approach center mainly around cost and efficiency. A procurement forester is required to appraise each timber stand. When the landowner sells on a sealed bid basis, there are usually multiple buyers competing to buy the timber. There will only be one winning bid, all others will have done their work for nothing. A success rate of 1-in-10 is not infrequent, so much appraisal work is a cost that shows no direct return. Also, many times a mill may be approaching a dangerously low inventory, so the procurement forester must submit a bid which is high enough to buy the timber, but not so high above the second highest bidder that a large sum of money is "left on the table." If several bidding mills are in a similar low inventory situation, the cost of stumpage can exceed the justified value delivered to the mill gate. There is also the potential problem of under-cut of the appraised volume. Since the timber stand is cruised on a sample basis, the actual harvest may not be equal to the volume apparently purchased.

Frequently, a mill organization is not vertically integrated to the extent that all raw materials from the purchased stand can be used at their mill. Usually all products are purchased, and then the buyer must market the material that does not meet their specifications to a manufacturing facility of another company. For example, a mill that only produces pulp must re-sell higher cost sawlogs to someone else. This can mean realizing a profit or a loss on these materials, depending on markets and location.

2.4 Wood dealer

A final common approach to wood procurement involves the use of a middleman to procure, harvest, and deliver raw materials to the mill. This approach, the wood dealer system has been in use in the south for more than fifty years. A wood using facility using this approach contracts with a wood dealer or broker to deliver a specified volume of wood or logs at specified intervals for an agreed upon price. This price is usually higher than the gatewood cost, but frequently is less than the cost of using internal procurement employees.

The wood dealer purchases stumpage through negotiations with landowners or through the bid process. After the wood dealer purchases the timber, he may harvest the tract using his own logging crew, or more usually makes a contractual arrangement with an independent logging contractor. To facilitate diversification, the wood dealer usually markets wood to several mills and must ensure that the timber purchased meets acceptable mill standards.

The wood dealer system provides the using mill with numerous advantages over the previous systems discussed. The problems associated with harvesting the timber are shifted to the wood dealer. Dealing with landowners, loggers, transporters, governmental regulators and others becomes the responsibility of the wood dealer. The number of direct employees required to procure stumpage is usually significantly reduced, as the wood dealer employs these individuals rather than the mill. The using mill can contract with as small a number of wood dealers as it feels comfortable. Theoretically, one wood dealer who could supply the mill's raw material requirements would make the procurement manager's job simplest. But there is "strength in numbers," so several wood dealers are usually contracted to supply mill requirements to provide some cushion in case one dealer cannot meet his contractual obligations. The mill also has a smaller capital investment in raw material on the stump. The wood dealer is responsible for maintaining an inventory to meet his required deliveries, which is usually a smaller volume divided among several wood dealers.

Most timber tracts that are purchased have a variety of products and species in the stand; energywood, pulpwood, sawlogs, and veneer logs, of both hardwood and softwood species may all be present on the same sale. As a middleman, wood dealers often broker the different products to appropriate outlets so as to obtain the highest value. They are not tempted to send a higher value product, such as small sawlogs to a lower value use such as pulpwood. This allows the wood dealer to obtain the best value from the timber sale, thus increasing his profitability.

Wood dealers also often have another advantage when buying wood. They are usually local residents to the procurement area and are better able to negotiate sales directly with a landowner, thus taking the purchase out of the competitive bidding arena, and frequently buying at a lower price than would be dictated by the market.

Some disadvantages of this system are that the buying mill has less control over the raw material quality. This is especially important if the using mill requires a specific product of a specific grade, such as high quality, hardwood veneer logs. The mill is also dealing with a knowledgeable market expert. The wood dealer knows the current market value much better than the landowner who only sells timber infrequently. Perhaps the most obvious disadvantage is that a middleman handling cost must be added to the cost of the product. This cost varies dependant on supply and demand, and is usually negotiated on some specified time period, monthly, quarterly, or annually.

3 Production of energywood

Assuming there is a market available, energywood can be procured by any of these procurement methods. It may be the primary product, but is more frequently produced as a by-product during processing of another forest product. Most biomass fuels are sold on a delivered basis, so as transportation distance increases, the economic justification of using energywood becomes more difficult. Transportation of forest products in the south currently ranges from $0.08 to $0.10 per ton/mile.

3.1 Primary product

Energywood can be procured and produced in the woods as the primary product. This material is frequently small size, or unmerchantable for other higher value products. The wood fiber is customarily chipped in the woods to allow more efficient handling from the woods through the energy production process. This approach provides some advantages to the landowner, such as removing material that would be left after a conventional harvest and possibly increase the cost of site preparation. Removal of this material during a stand improvement harvest also removes vegetation that competes with higher value crop trees.

However, manufacture of energywood from this source is usually of a higher cost than that procured from other, secondary sources. Whole tree chips can currently be purchased in the southeast typically in a range of $12 to $16 per ton (Muehlenfeld 1997).

3.2 Secondary – in woods

Energywood procured as a secondary product from in woods processing is usually produced from the delimbing/debarking function of a whole tree chipping operation. It can also result from "barkless" logs, which are debarked in the woods and debarked a second time at the mill to insure minimum bark content for paper manufacture. The volume of energywood produced from this process, 25 to 30 percent of the total volume is often too small to produce and deliver economically. This material is usually left in the woods as a waste to be handled during the site preparation process, or distributed over the temporary road system to reduce soil erosion.

In this process, the energywood must be processed through a grinder or hog to facilitate handling. This added cost for a small volume of material may make the conversion of energywood as a secondary product in the woods cost prohibitive.

3.3 Secondary – intermediate processing facility

A procurement approach that is becoming more widely employed is the use of intermediate processing and consolidation facilities. Pulpwood is purchased at a secondary facility, and chipped for efficient shipment via rail or barge transport. This process is primarily designed to produce wood chips for pulp manufacture. As a consolidation point, a large volume of material is accumulated at a stationary site. The bark produced from the debarking operation is a "waste" material that must be disposed of, usually as energywood. Disposal in a landfill would be excessively costly, therefore the bark is hogged and usually sold by the chipmill operator to nearby waste-fired steam production facilities. A typical current price range for hog fuel is $6 to $10 per ton in the south (Muehlenfeld 1997)

3.4 Secondary – final processing facility

The source of energywood that most frequently occurs from the procurement process is that biomass produced at the final processing facility, pulpmill, sawmill, or panel mill. Inherent in the delivery of logs and pulpwood, production of bark, fines, sawdust, and shavings creates a disposal problem or an opportunity for energy production. Since there is a large amount of material at a single location, this biomass has been used for production of energy by these mills for a number of years. Dependent on the economies of scale, the energy produced may be used internally, or sold as a co-generated energy product.

4 Volume of energywood

The volume of forest biomass produced on the 86.15 million hectares (212.8 million acres) of forestland in the southeastern states averages 6.28 tonnes per hectare (17.1 tons/acre). Of this total, forest biomass available for energy use is 0.122 tonnes per hectare (0.333 tons per acre) (Muehlenfeld 1997). The source of energywood from this area is potentially available from logging residues, cull trees, and wood processing mill residues.

Logging residues in this region amount to 37.09 million tonnes (40.87 million tons) annually and average 0.039 tonnes per hectare (0.106 tons per acre). These residues can be reclaimed through the use of whole tree chipping operations. Cull trees amount to 33.72 million tonnes (37.16 million tons) annually and account for 14.1 percent of the standing forest biomass at a volume of 0.036 tonnes per hectare (0.097 tons per acre). These cull trees can only be practically used when harvested simultaneously with growing stock during conventional harvesting operations. Therefore most cull trees become wildlife habitat and eventually decompose to be incorporated into the soil as organic matter.

Wood processing mill residues include chips, bark, sawdust, slabs, shavings, edgings, trim ends, and chip fines. The amount produced varies based on the efficiency of the mill, but averages from 10 percent of log volume at a pulp mill to 55 percent at a sawmill. Muehlenfeld (1997) estimates that a total of 45.32 million tonnes (49.94 million tons) of these residues are produced annually in the south. Most of these residues are currently used for production of pulp, composite building materials and energy. Muehlenfeld reports that a survey conducted in Mississippi revealed that as little as 10 percent of this material is unused, the remaining 90 percent are committed to other uses.

5 Conclusion

Wood procurement systems are adapted to meet each company's needs. Land ownership patterns, raw material availability, level of competition, and economics are some of the factors that contribute to the development of a wood procurement system. Wood procurement systems developed primarily to obtain mill furnish also can be effectively used to procure energywood. This energywood can be obtained from primary sources in the woods, or from secondary sources in the woods or at the mill.

Procurement systems may employ a variety of approaches. Company owned or controlled lands to provide a captive source of wood fiber, the low investment gatewood approach, a more controlled internal procurement organization, or the wood dealer approach may be used singularly or in any combination to minimize cost and maximize control of the raw material supply

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Harvesting systems for multiple products An update for the United States

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1 Introduction

As expected, currently and for years to come, the demand for energy will increase, especially for transportation. Other increases will be for natural gas for residential and industrial use, and for renewables as a response to environmental awareness. However, for the short term, economics dictate energy source selection and use; bioenergy has not been competitive. There are the extraneous factors such as environmental constraints and reduction of subsidies in the Conservation Reserve Program that might accelerate the use of biomass for energy. There may come more incentives to change to bioenergy.

The deregulation of the electric power industry is forcing the industry to become more competitive (DOE/IEA 1997). Congress is considering repealing or extensively modifying laws that would strengthen the relative position of large utilities and large, well-capitalized nonutility generators, and it would potentially weaken the position of the renewable energy industry. Proposed responses include the promotion of continued commercialization of renewable energy technologies by specifying minimum levels of renewable-generated electricity at the State level. In addition, electric utilities are using a voluntary approach, the use of "green pricing" programs, as a way to promote the use of renewable energy.

As far as forestry, there is much potential for furnishing bioenergy, but very little application (Bioenergy 1996). As an example, bioenergy use in the South is 1.6 quads, which is 56 percent of Nation's use. This is still a very insignificant amount; only 6 percent of energy consumption in the South was wood, and wood was only used to produce about 2.4 percent of the electricity. This clearly does not align with potential for bioenergy production. By using residues and using forestry and agricultural energy products, the bioenergy potential is 4 to 7 quads.

Useful Energy Conversion Factors:

1 Btu = 1.055.056 joules(J)
1 quad = 1 quadrillion Btu of energy
= 1 x 10^{15} Btu of energy
= 40.82 million metric tons of coal
= 54.43 million metric tons of oven-dried hardwood
= 27.1 cubic meters of crude oil

The range of utility of woody biomass is very wide across the Nation, and varies because of many factors. The forest industry is probably the largest user as well as the largest generator of woody biomass. Pulp and paper mills, which are high users of woody biomass in co-generation, also can produce excess wood residues that are even a disposal problem. Only a few buy market residues and have procurement systems to obtain the needed boiler fuels.

2 Use of biomass

The Nation's total energy supply provided by biomass (predominately wood, but includes wastes and alcohol fuels) has been increasing for the past 5 years; currently up to 3.0 quadrillion Btu (Table 1). Of the total 1996 energy consumption of 93.8 quads, biomass was only 3.2 percent of the source. Biomass energy consumption was 41 percent of the total renewable energy sources. When excluding hydropower, a renewable energy resource that is considered as "conventional," biomass accounted for 87 percent of the remaining renewable energy consumption in 1996. Wood pellets is a fast-growing biomass fuel market. In the residential and commercial sectors, an increase in residential wood use for heating resulted in a 10-percent increase in renewable energy consumption in 1995. U.S. pellet fuel production increased by 18 percent between the 1993—94 and 1995—96 heating seasons (DOE/IEA 1996).

In 1996, the residential/commercial sector used biomass for 90.8 percent of the renewable energy consumed; almost all was wood for heating (Table 2). Almost 84 percent of the renewables used in the industrial sector was biomass. A substantial amount was probably used for generating heat instead of electricity. Very little biomass was used to generate electricity in the electric utility.

Renewable electricity generation rose to 465 billion kilowatt-hours in 1996 (Table 3). Biomass accounted for almost 14 percent of the source of the generation; almost 97 percent within the industrial sector. Biomass was used very little in the electrical utility sector, although there was a slight increase from 1995 when it had made a significant decrease.

Table 1. U.S. Renewable energy consumption by Source, 1992—1996 (Quadrillion Btu).

Energy Source	1992	1993	1994	1995	1996
Conventional hydroelectric power[a]	2.852	3.138	2.958	R3.471	3.911
Geothermal energy	0.367	0.381	0.381	0.325	0.354
Biomass[b]	2.788	2.784	R2.838	R2.946	3.017
Solar energy[c]	0.068	R0.071	R0.072	0.073	0.075
Wind energy	0.030	0.031	0.036	0.033	0.036
Total renewable energy	6.106	R6.404	R6.285	R6.847	7.393

[a] Hydroelectricity generated by pumped storage is not included in renewable energy.
[b] Includes wood, wood waste, peat, wood sludge, municipal solid waste, agricultural waste, straw, tires, landfill gases, fish oils, and/or other waste.
[c] Includes solar thermal and photovoltaic.
R = Revised data.
Sources: 1992—1996: Energy Information Administration (EIA), Annual Energy Review 1996, DOE/EIA-0384(96) (Washington, DC, July 1997).

Table 2. Renewable energy consumption by Sector and Energy Source, 1992—1996 (Quadrillion Btu).

Sector and Source	1992	1993	1994	1995	1996
Residential/Commercial					
Biomass	0.645	0.592	0.582	0.651	0.644
Solar	0.060	R0.062	R0.064	R0.065	0.066
Total	0.705	R0.654	R0.646	R0.706	0.709
Industrial[a]					
Biomass	2.042	2.084	R2.138	R2.184	2.279
Geothermal	0.179	0.204	0.212	0.207	0.231
Conventional hydroelectric[b]	0.097	0.118	0.136	0.152	0.172
Solar	0.008	0.009	0.008	0.008	0.009
Wind	0.030	0.031	0.036	0.033	0.036
Total	2.357	2.446	R2.530	R2.584	2.727
Transportation					
Biomass[c]	0.079	0.088	R0.097	R0.104	0.074
Electric Utility					
Biomass	0.022	0.020	0.020	0.017	0.020
Geothermal	0.169	0.158	0.145	0.099	0.110
Conventional hydroelectric[b]	2.511	2.766	R2.583	R3.053	3.419
Solar and wind	*	*	*	*	*
Net renewable energy imports[d]	0.263	0.271	0.309	R0.284	0.333
Total	2.065	3.217	R3.012	R3.453	3.883
Total renewable energy Consumption	6.106	R6.404	R6.285	R6.847	7.393

*Less than 0.5 trillion Btu. R = revised data.

[a] Includes generation of electricity by cogenerators, independent power producers, and small power producers.

[b] Hydroelectricity generated by pumped storage is not included in renewable energy.

[c] Ethanol blended into gasoline.

[d] Includes only net imports of electricity known to be from renewable resources (geothermal and hydroelectric).

Sources: See Table 1.

3 Harvest system

The most prevalent harvest system in the South is the tree-length system. Highly productive feller-bunchers are used to fell, collect, and bunch many small stems into piles. The trees are delimbed and topped in the woods either using a chainsaw or delimbing gate with chainsaws at the deck. Grapple skidders are used to extract the trees and the stems are usually loaded tree-length onto trailers. Improvements have been the addition of mechanical processors and slashers. The limbs and tops are left at the processing area, or carried back onto the stand by the skidder. Some feller-buncher/ skidder systems use a flail delimber/debarker and a chipper to produce clean chips at the deck (Stokes & Watson 1988 and 1996). Flail processing and chipping is potentially more economical for small diameter trees than delimbing and hauling tree-length wood. Another advantage is the potential biomass recovery. The limbs, tops, and bark can be hogged at the deck and used as fuel. Cut-to-length (CTL) systems are becoming more widely used. Harvesters are used for felling and processing at the stump.

Table 3. Electricity generation from renewable energy by Energy Source, 1992—1996 (MWh).

Source	1992	1993	1994	1995	1996
Industrial Sector[a]					
Biomass	R53 606	R55 745	R57 391	56 975	62 107
Geotherm	R8 577	R9 748	R10 122	9 911	11 014
Hydroelectric	R9 446	R11 510	R13 226	14 773	16 711
Solar	R746	R896	R823	824	908
Wind	R2 916	R3 052	R3 481	3 185	3 507
Total	R75 293	80 954	85 046	R85 669	94 249
Electric Utility Sector (Net Generation)[b]					
Biomass	2 092	1 990	1 988	1 649	1 967
Geothermal	8 103	7 570	6 940	4 744	5 233
Conventional Hydroelectric	243 736	269 098	247 070	R296 377	331 035
Solar	3	4	3	4	3
Wind	*	*	*	11	10
Total	253 936	278 663	256 003	R302 786	339 149
Net Imports	24 583	25 496	28 844	26 648	31 673
Total Renewable Generation	R353 814	R385 114	R369 894	R415 105	465 072

* Less than 500 MWh

[a] Includes cogenerators, independent power producers, and small power producers.

[b] Excludes imports.

R = Revised data.

Sources: Energy Information Administration, Form EIA-759, "Monthly Power Plant Report"; From EIA-867, "Annual Nonutility Power Producer Report"; and Electric Power Monthly March 1997, DOE/EIA-0226(75/03) Washington, DC, March 1997).

Table 4. Stands used for harvesting cost analysis.

Stand	Initial DBH	Initial TPH	Initial BA/HA	Harvested DBH	Harvested TPH	Harvested BA/HA	Whole Tonnes/HA	Merchantable Tonnes/HA
Thinning, 13—15 yrs	18.3	684	19	16.0	319	7	48.4	34.5
Thinning, 16—18 yrs	19.3	689	21	17.3	306	8	55.4	39.7
Clearcut, 23 yrs	20.6	650	23	20.6	650	23	178.7	137.6

Note: DBH is diameter at breast height in centimeters; TPH is trees per hectare; BA/HA is basal area in m^2 per hectare; Whole is harvested whole tree weight including wood, bark, limbs, tops and foliage in tonnes per hectare; Merchantable is harvested merchantable weight in tonnes per hectare to a 10 centimeter top.

4 Stand descriptions

Three loblolly (*Pinus taeda*) stands were selected as typical pine plantations to analyze the productivity and cost of the three selected systems. Table 4 summarizes the composition of the representative stands used for a range of structure and removal levels. The stand information was only for pine trees 13 cm, DBH, and larger; these were considered merchantable. The 13—15 year old stand, as an early thinning, had an initial basal area of 19 m^2/ha and a removal of 7 m^2/ha. The 16—18 year old stand was considered to be a late thinning and had an initial basal area of 21 m^2/ha. A total of 8 m^2/ha were removed. In the thinnings, every fifth row was harvested and the rest were removed by selection. The clearcut stand had 23 m^2/ha harvested. Merchantable tonnes per hectare were calculated to a 10-cm top.

5 Utilization

A study was conducted at a local pulpmill in Alabama to estimate the recovery and utilization for the three representative stands. Five tree-length truck loads of loblolly plantation pine were processed through a tree-length (longwood) drum debarker to determine merchantable chip recovery. Additional laboratory work was completed to determine chip quality and size distribution. The same procedure was used to determine the recovery of cut-to-length wood. Four loads of random length wood were processed on the same longwood yard as the tree-length wood was processed. One load of the CTL wood was processed at a shortwood drum, after being slashed into 1.5-m lengths.

The authors have completed several studies on the recovery of loblolly pine plantation wood using a flail delimber/debarker and chipper (Flowers et al. 1992, Stokes & Watson 1988 and 1994, Watson et al. 1992). This published information concerning the recovery of products from a flail/chipper was used in this analysis.

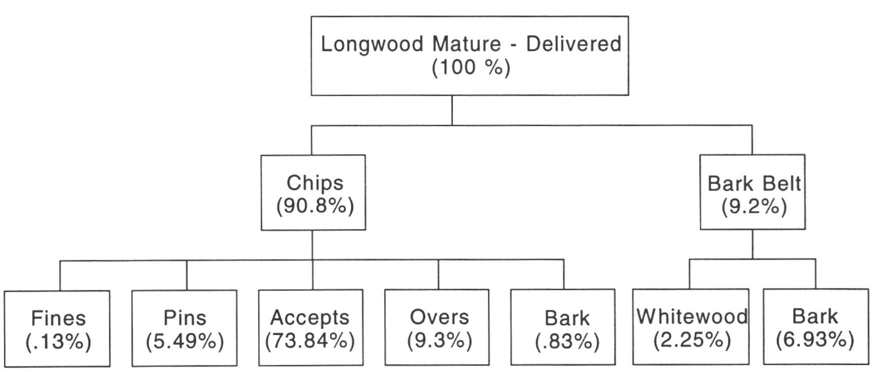

Figure 1. Utilization of tree-length wood processed through tree-length drum debarker.

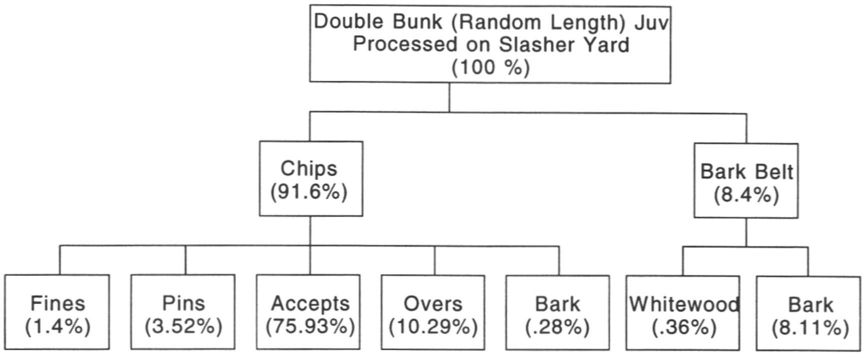

Figure 2. Utilization of cut-to-length wood slashed to 1.5 m lengths and processed through shortwood drum debarker.

The wood flow and utilization of various harvesting products are shown in Figures 1—4. The wood flow recovery for the tree-length and cut-to-length are for the roundwood delivered to the mill, drum debarked, chipped and screened for merchantable chips to the digester. The wood flow for the chips produced in-woods with the flail/chipper includes the whole tree converted to chips and then screened for merchantable chips to the digester.

In this analysis, recovery at the forest was assumed the same for the tree-length and CTL options. Only 71.3—77.0 percent of the total standing biomass was delivered to the mill. Almost 91 percent of the delivered tree-length wood resulted in chips (Figure 1). Over 9.2 percent became residue, or bark by-products that are usually used in the boilers. As more satellite chip mills have been established, this by-product has become more of a waste problem than a readily available fuel source. When the CTL wood was slashed and processed through the shortwood drum, almost 92 percent of the roundwood was converted into chips (Figure 2) and the rest was bark residue. When the CTL wood was processed through the longwood drum without slashing, there was a lot of breakage that resulted in more bark residue. Over 12 percent went into the bark pile for this option (Figure 3). All three alternatives had some additional residues generated after screening.

Figure 4 illustrates the wood flow and recovery for the flail/chip process. Over 60 percent of the whole tree that goes through the flail goes to the chip van and 39.4 percent is left on site. Some of the residues are spread across the site, but much is piled at the deck as a result of the flail processing. Sometimes this material is hogged and hauled to the mill for energywood. When screened at the mill, recovery of acceptable chips is 82.1 percent and only a small percent of residues are generated at the mill.

Mills handle the overs in many ways and for this simplistic analysis, overs were added to the accepts. These recovery percentages for the three harvesting systems (cut-to-length had two processing options) were used to convert the stand data into clean, acceptable chips to the digester (Table 5) and to determine points along the wood flow where residues are generated. These recovery figures should be used with caution since they are based on a small sampling. Also, the problem of breakage associated with processing CTL wood in a longwood drum may only be associated with the test mill.

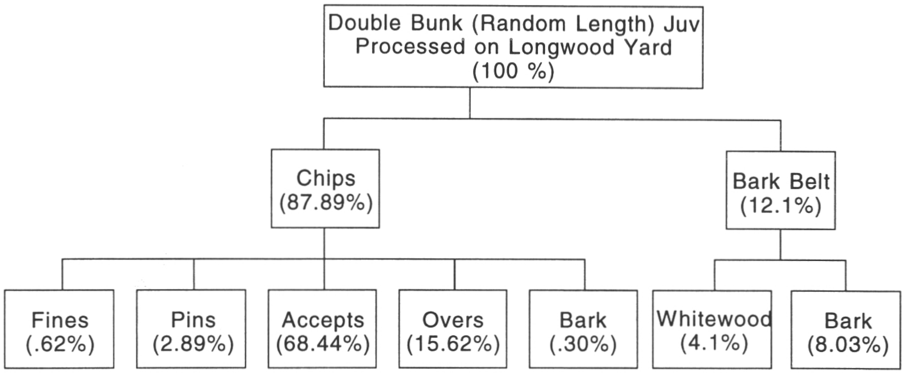

Figure 3. Utilization of cut-to-length wood processed through tree-length drum debarker.

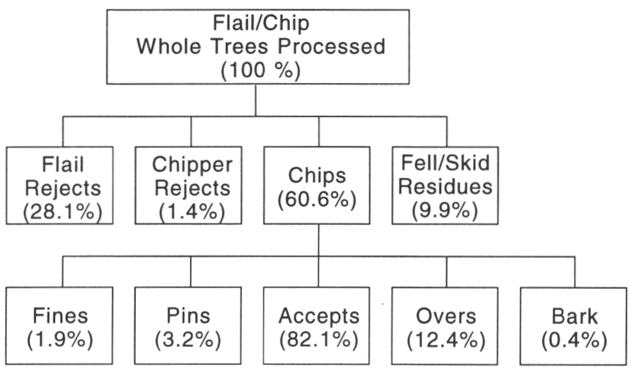

Figure 4. Utilization of whole trees processed through flail delimber/debarker and chipper.

In the early thinning, 13.9 tonnes/ha of residues were left on the site when roundwood was delivered to the mill. This analysis did not consider the unmerchantable pine or any hardwood on site. There could have been even more potential biomass left as a function of the thinning operations. This could also be true of the older thinnings which left 15.7 tonnes/ha on the site for tree-length and CTL systems. The flail system left an additional 5.2 tonnes/ha for the early thinning and 6.1 tonnes/ha for the older thinning. At the mill, 5.6—6.7 tonnes/ha, dependent on stand and wood type, were generated as bark residue. Only a small amount was generated by the screening process of the flail chips.

The clearcuts produced much more residual biomass for all the harvest systems. When hauling roundwood to the mill, it produced almost 22.4 tonnes/ha as drum debarker residues. These residues usually go to the boiler. The flail produced 70.4 tonnes/ha at the forest site.

The flail/chip system generates the most residues collected in one point. However, the added cost of processing and hauling lessen the use of this biomass in energy production. The roundwood systems generated usable residue at a mill facility and are readily available for energy production.

Table 5. Recovery of representative stands.

	Thinning, 13-15 yrs				Thinning, 16-18 yrs				Clearcut, 23 yrs			
	CTL		TL	FC	CTL		TL	FC	CTL		TL	FC
	1.5-m	NS			1.5-m	NS			1.5-m	NS		
	Tonnes/ha											
Residues at wood	13.9	13.9	13.9	19.1	15.7	15.7	15.7	21.7	41.0	41.0	41.0	70.4
Delivered Rdwd/Chips	34.5	34.5	34.5	29.4	39.7	39.7	39.7	33.6	137.6	137.6	137.6	108.3
Residual at mill	5.6	5.6	5.8	1.6	6.3	6.3	6.7	1.8	22.0	23.3	32.3	6.1
Merchant-able chips	28.9	28.9	27.8	27.8	33.4	33.4	33.0	31.8	115.7	114.3	105.4	102.2

Note: CTL is cut-to-length; TL is tree-length; FC is flail/chipper; Rdwd is roundwood. NS means that the CTL was not slashed and was processed in tree-length drum.

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New techniques and methods in an expanding wood-fuel market

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1 Present consumption

The total demand for energy in Sweden has been fairly steady for several decades at about 450 TWh per annum (Figure 1). This is a little surprising, given that the population has grown considerably during this period. The use of oil as a source of power has fallen sharply in favour of, above all, nuclear power and bioenergy. An interesting point is that bioenergy today provides more power than either hydroelectric or nuclear power, accounting for 87 TWh per annum (1996) and nearly 20 % of the total power generated.

Waste liquor from the pulp and paper industry, together with peat and waste-derived fuel, accounts for about half of the bioenergy supply, although energy wood is still the largest single source, accounting for about 44 TWh per annum in 1996 (Figure 2). The biggest consumers of energy wood are the industrial forest enterprises, domestic users and the district-heating stations. A small proportion is used to generate electricity. In the 1990s, the highest growth of 1.2–2.0 TWh per annum has taken place in the district-heating sector, and it is predicted a continued growth at a rate of some 1.5 TWh a year up to the year 2010. The total consumption of energywood today amounts to 20 million m^3 (solid) and includes raw materials direct from the forest, by-products from the forest products industry and a small quantity of recycled wood. This should be seen in the context of a total annual cut of some 60 million m^3 of roundwood for industrial consumption.

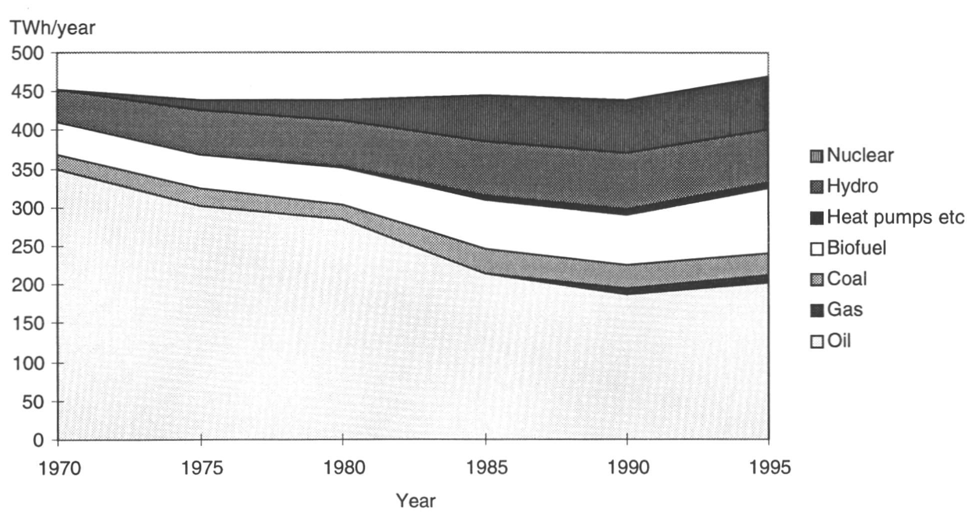


Figure 1. Total energy supply in Sweden 1970–1995.

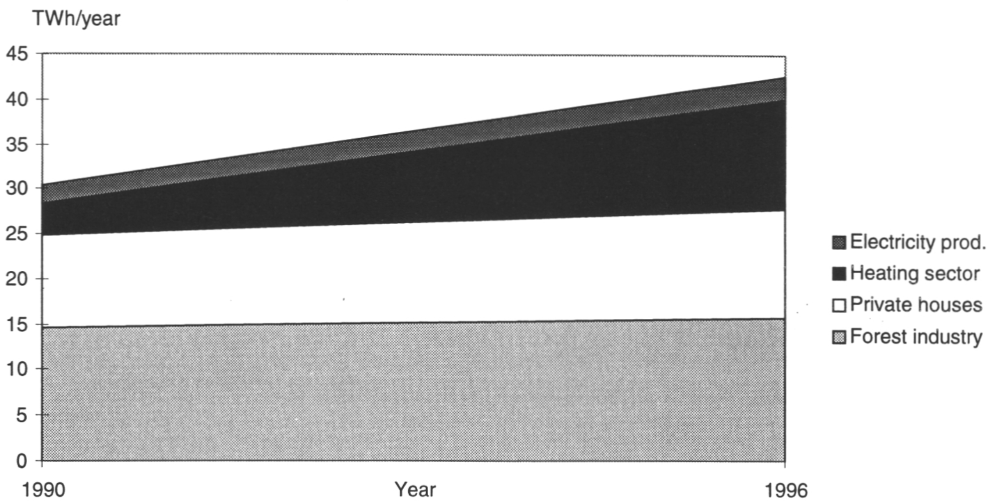


Figure 2. Energy-wood consumption 1990–1996.

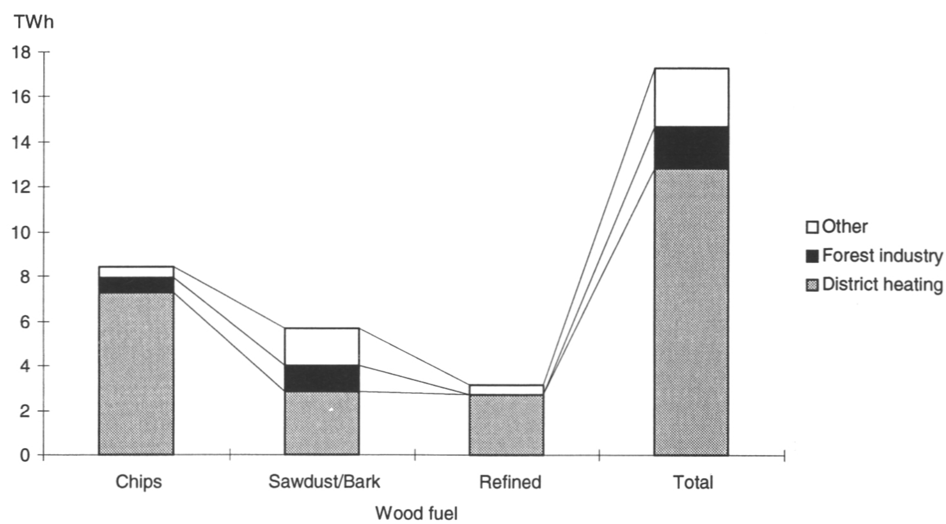


Figure 3. Energy-wood assortments on the open market in 1996. What's happening?

The energy wood that is available on the open market obviously consists largely of wood straight from the stand, in the form of chips and other comminuted biomass. We utilize today roughly 4 million m^3 of biomass, which consists mainly of logging residue from final felling. Bark and shavings from the mills account for a respectable share—some 30 %. A growing assortment is that of processed fuels in the form of pellets and briquettes, most of which are by-products from the sawmills (Figure 3).

2 What's happening?

The energy-wood sector is currently in a state of high activity. Increasing demand is having a variety of effects on the market and the design of supply systems. Above all, there is a heavy demand in the vicinity of large towns in some parts of the country, whereas demand is relatively weak in other areas. In consequence, we are forced to look for new stands further and further away from the consumer. New players and a greater cost-consciousness are generating new ideas and driving forward rationalization work at a keen pace. There is also an increasing awareness of the need, for ecological reasons, for well-thought-out recommendations as to where and how energy wood should be exploited.

Some of the effects of the expanding market

- Increasing demand in some regions
- Large systems
- New stands/resources being sought
- Longer haulage distances
- More players in the market
- More need for ecological recommendations
- Increased rationalization work

Rationalization work is focusing on the following developments:

- New techniques for utilizing energy wood from small-dimension thinning (in which only a tiny proportion of the resources were utilized in the past). Multitree-handling (MTH) felling heads constitute a key element in the logging systems.
- New technology for comminution of the raw material to give loads having a high energy content and, hence, cost-effective long-distance haulage. Baling is the latest development here.
- Large-scale, high-capacity chipping close to the combustion plant. Developments here are new Swedish mobile chippers as well as machinery imported from the USA.
- Methods to enable the proportions of pulpwood and energy-wood assortments to be varied with movements in the relative prices are being developed. The fluctuation in pulpwood prices has a decisive influence on profitability.

3 Developments in thinning

There are currently three interesting new felling heads and machine concepts, all of which are based on multitree-handling in the felling head to increase productivity in thinning (Figure 4).

3.1 FGS 500 B felling and bucking head

The FGS 500 B felling and bucking head, constructed by Bror Hult, is currently only available as a prototype, although it is undergoing practical trials at an industrial forest enterprise. In its present form, the felling head weighs approximately 600 kg, although it is expected to be lighter on a future version. It is equipped with a chain saw, which, after having felled a bunch of trees, can be turned to buck the bunch to a suitable length for forwarding to the landing. This makes for high flexibility, as the felled trees can be handled in two different ways at the edge of the striproad. In addition, of course, conventional forwarders can be used when the stems have been bucked in conjunction with felling, without the need for the machines to be equipped with longer booms or grapple saws. I should add here that the felling and bucking head is suitable for medium-duty single-grip harvesters having an adequate reach and good stability. A Timberjack 870 is being used as the base machine in the current trials. Since the felling head can also function as a loader, a future version of this type of machine could possibly both harvest the timber and extract it to the main haul road.

3.2 Steber 250 Beaver

Two Swedish companies, Allan Bruks and Steber, have unveiled a machine concept consisting of a small base machine, which is designed for use in narrow strips between striproads. The operator can choose from three optional boom lengths, to suit the width of operating envelope required (6.6, 7.5 and 8.7 m). At the longest outreach of course, the ability of the machine to hold trees upright in the felling head is limited and, so far, only the 7.5-m reach has been tested. To make it possible to carry out all thinning work from the striproad when the striproads are spaced at least 18–20 metres apart, the machine will partly leave the striproad, making short inroads into the stand for selective thinning between the roads. The felling head incorporates conventional shears, weighs approximately 300 kg and can handle trees up to 25 cm in diameter.

3.3 EnHar (Energy Harvester)

For thinning in the smallest-dimension stands, a group of companies led by Elmek Engineering has developed a felling head based on an idea conceived by a forestry contractor. The felling head weighs approximately 230 kg and can handle trees up to about 20 cm in diameter. The design of the head has eliminated one operating element, since the head can simultaneously cut and grip the trees. Cutting is done by means of shears that have slightly angled blades to reduce the power requirement. The way in which trees are accumulated in the head is also new. The upper grapple arms tilt back at the same time as they open to receive a new tree. Once the tree is held, the arms tilt forward and grip the bunched trees again.The machine is being launched mounted on a small, lightweight Rullen forwarder, which has been converted and equipped with a clam bunk instead. The machine is therefore designed for use on sites with wide striproad spacing and for operating in strips at right angles to the striproads, skidding large bunches of felled trees to the edge of the road.

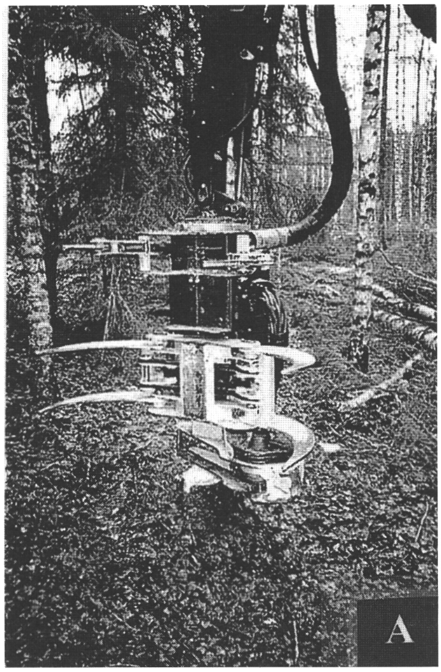
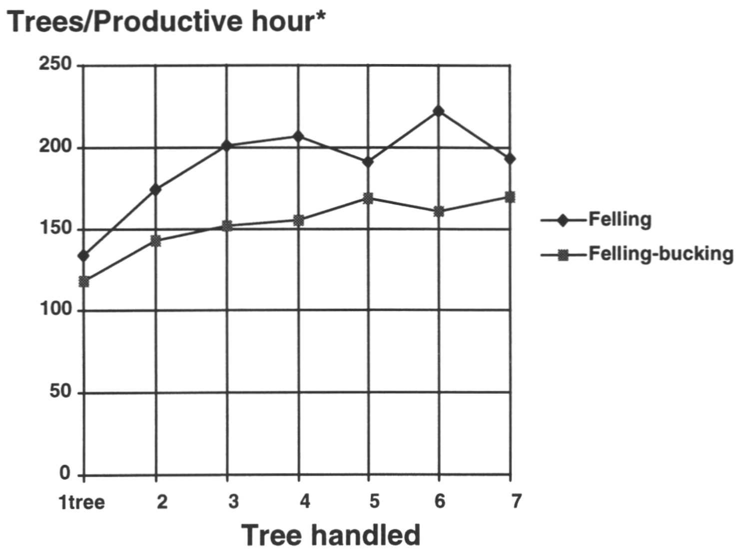


Figure 4. Three development projects in thinning.

A = FGS 500 B
B = Steber 250 Beaver
C = EnHar (Energy Harvester)



* Productive (G15) hour = Hour of productive machine time including downtime not exceeding 15 minutes per occasion.

Figure 5. Preliminary findings of time study on the FGS 500 B felling and bucking head. Approximate mean stem volume in study: 0.03 m^3 (solid i.b.). Hardwood-dominated stand.

3.4 Studies completed

So far, time studies have only been carried out on one of the machine concepts and these findings are still only preliminary. As regards the FGS 500 B felling and bucking head, results of studies made of the machine operating in small-dimension hardwood thinning point to productivity of about 200 trees per productive (G_{15}) hour (Figure 5). An average of 2.8 trees were handled per felling cycle, which represents a productivity level some 40 % higher than that achieved in single-tree handling. (We need to take into account here the fact that the productivity figures refer only to the number of trees per hour—no volume figures have been computed yet.) If the machine had also been used to buck the trees, productivity would have been some 20 % lower.

As mentioned earlier, no studies have been made of the other two machine types. However, EnHar's marketing literature claims that productivity is about 250 trees per productive (G_{15}) hour—which is a plausible figure given the design of the felling head and the fact that only the smallest trees are being handled.

3.5 Costs and revenue

An economic comparison between the most interesting systems of today for small-tree thinning shows that it is very difficult to get a positive net income when the mean-stem volume is below 0.040 m^3 solid under bark (Figure 6). All costs are not even included in these calculations, for example the costs of moving the machines between the logging sites. In the small-dimension stands, with mean-stem volumes below 0.035–0.040 m^3 solid u.b., it is most economic to use the whole trees for forest-fuel. The system with a strip-road operating chipper is slightly stronger than the tree-section system, but have some weaknesses what regards energy content and storage due to the fresh chips. In somewhat larger dimensions, more than 0.055–0.060 m^3 solid u.b., it is more economic to buck the pulpwood at a larger diameter than usual and leave the long tops to a strip-road operating chipper. In this analysis the top-diameter for pulpwood is 10 cm, even though I am not certain that it is the most optimal diameter. Anyhow, it is certainly important to increase the knowledge about how to adjust the bucking diameter and the assortments to the price fluctuations that occur.

4 Developments in final felling

Probably the main innovation in the removal of logging residue from final felling is the baling machine from Bala Press. I shall here leave the task of describing the baling machine to Barrie Hudson, who has the findings of the latest assessment of the machine. But a lot is happening also in the fields of comminution technology and logging methods.

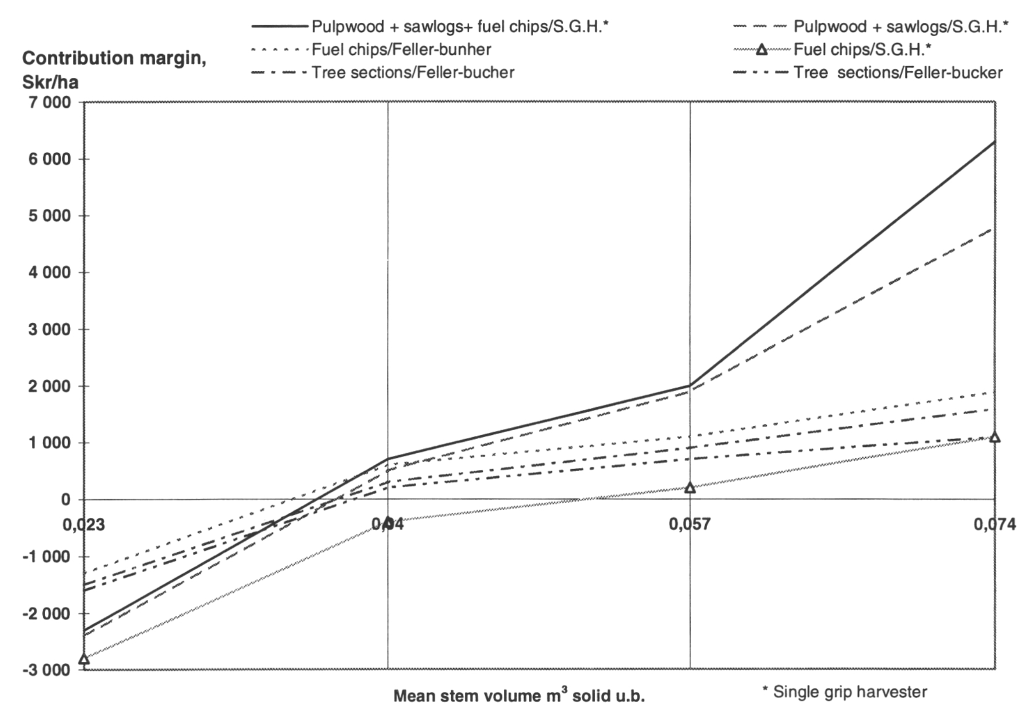


Figure 6. An economic comparison between some thinning systems. Exclusive costs for moving machines between logging sites, administration etc.

4.1 Large-scale comminution

There is a marked trend in Sweden for comminution to take place late in the flow, close to the consumer. The main reason for this is to keep comminution costs as low as possible. This structural change to system, of course, makes new demands on the machinery, which must have a high capacity and be capable of handling a variety of raw material. A standard requirement (in Sweden, at least) is that the comminuted material shall not contain any long slivers. Most of the users prefer to receive chipped rather than crushed wood, as they see this as a guarantee that the material will be free from contaminants.

Both the manufacturers and the chipper contractors have heavy-duty, high-capacity machines available. A recently launched machine is the Bruks 1004 CT (Figure 7), which is the largest mobile chipper built. It is a drum chipper, which has an intake opening measuring 113 × 67 cm and a 500-hp engine. The side-tipping chip bin has a capacity of 30 m^3, which is the same as a container used for secondary haulage. It is intended that the machine will be modified so that it can chip baled logging residue as well.

Another recent development in Sweden has seen the forestry contractors importing large comminution machines from the USA. Biokross Norr, a company operating nationwide in Sweden, now offers a model PWG 1260 Tub Grinder from Diamond Z manufacturing (Figure 8). The machine is top fed and is primarily designed for bark and demolition timber. It grinds the raw material to fractions of various sizes and has magnets for separating out any bits of metal.

A recent addition to the product range of Biokross Norr is a CBI Magnum Force (Figure 9) designed to operate at large wood terminals. This machine has a horizontal feed and is therefore able to handle long pieces. The feed opening measures 150 × 120 cm, and the engine rating is more than 800 hp. This machine also has magnets for separating out metal contaminants. According to the contractor, the comminuted material resembles wood chips. The machine can be used to comminute logging residue, bales, demolition timber, bark and compost.

Figure 7. The Bruks 1004 CT.

Figure 8. Model PWG 1260 Tub Grinder.

Figure 9. The CBI Magnum Force.

4.2 Costs and revenue

A study of the costs in three supply systems for three assortments has shown that it is becoming increasingly difficult for the conventional haulage system, comprising removable containers for chips, to remain cost-effective. This is mainly because of the high costs incurred in comminution at the landing and in secondary haulage.

The study shows that the costs for systems handling uncomminuted or baled logging residue are substantially lower, even taking account of the extra materials-handling costs to be incurred by the user (Table 1). I should perhaps mention here that it is worthwhile for a forest owner in Sweden to utilize the logging residue when the price he can secure is in the range of 5–15 kronor per cubic metre or between 65 cents and $1.95 per cubic metre.

Table 1. Comparison of costs between chips and uncomminuted logging residue on the one hand and baled residue on the other for a haulage distance of 60 km. Skr/m³ loose volume.

Operation	Fuel chips	Logging residue	Bales
Extra cost in logging	1	1	1
Baling	–	–	28
Forwarding	22	22	11
Paperboard covering	3	3	–
Storage	2	2	3
Chipping at roadside	35	–	–
Management & admin.	5	5	5
Landowner (stumpage)	5–15	5–15	5–15
Total cost before haulage	73–83	38–48	53–63
Haulage 60 km	19	27	16
Admin. profit and risk	10	10	10
Comminution	–	15	12
Total cost	102–112	90–100	91–101

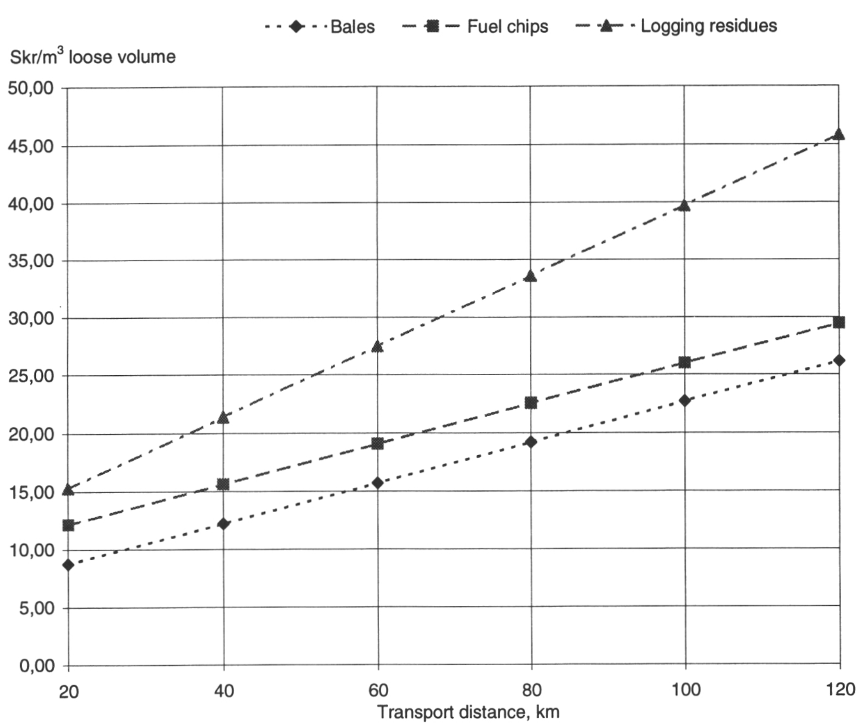


Figure 10. Haulage costs.

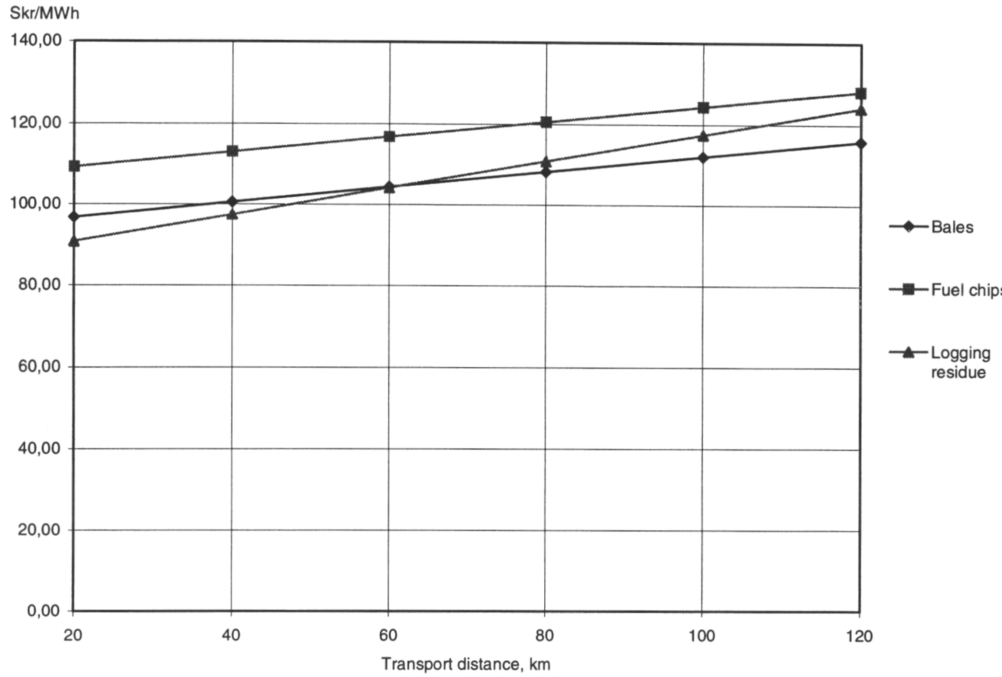


Figure 11.Total cost delivered free to user (Skr/MWh).

It is interesting when we compare systems to look at how the haulage distance influences the result (Figures 10 and 11). The container system is the most expensive option throughout the range, while uncomminuted logging residue is the most cost-effective over haulage distances up to about 60–70 km. Over greater distances, it appears that baling of the residue could be the cheapest system. If we compare the price of the raw material delivered free to the user (which is Skr113/MWh or $14.70/MWh in the analysis), it is clear that it is difficult to cover a payment to the forest owner of Skr10/m^3 loose volume ($1.30) if the haulage distance is greater than about 80–100 km what regards uncomminuted logging residue and bales. For chips in containers there will be problems already at 40 km distance. Thus, the average payment will probably be somewhat lower than Skr 10/m^3 in reality.

4.3 Larger-diameter tops as pulpwood bolts

It is an attractive option for a forest owner to be able to vary the diameter of the top in bucking and thus also the relative proportions of pulpwood and energy wood in a cut to suit the respective prices. But to do this, we need to know in advance how this will affect costs and revenue. Tentative findings from SkogForsk suggest that, for diameters of 6–10 cm, the impact on productivity is marginal, which implies that the costs for pulpwood and sawlogs would not be affected significantly if a bucking diameter within this range were chosen (Figure 12).

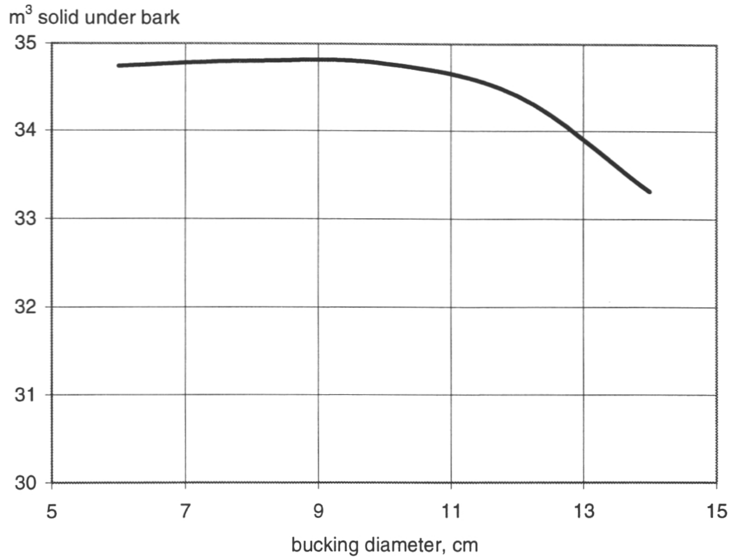


Figure 12. Preliminary study results showing the impact of different bucking diameters on the productivity of a single-grip harvester (m^3 per productive (G_{15}) hour).

Obviously, the other operations in the system will also be affected by whether short or long tops are left. We intend to investigate these effects in more detail and also to find out what sort of revenue figures are obtained for the different options. To summarize; there is much more to do what regards both techniques and methods in the whole chain from the forest to the consumer.

UK industry - baling and storage of forest residues

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1 Introduction

A major cost element in the supply of wood fuel from both forest residues and short rotation coppice is in the transport from the point of production to the end user plant. Recent trials carried out in the UK and Sweden (Hudson 1996, Andersson & Hudson 1997) indicated that a substantial reduction in the transport costs of forest residues can be achieved by compressing the residue prior to transport by the use of baling techniques. A combination of baling to reduce transport costs, allied to large scale comminution at the end user plant, offers considerable potential for cost savings in the supply of wood fuel. The opportunity to store wood fuel in bale form prior to comminution could minimise dry matter losses, and ventilation through the bale could encourage quicker and even drying.

Two industry led trials carried out in the UK in 1997, partly funded by the UK Department of Trade and Industry, are summarised in this paper:

Uk industry wood fuel baling, management and logistics. Baling of both short rotation coppice and forest residues was carried out to establish the logistics and the management practices involved in the introduction of the baling element into the short rotation coppice supply chain and into whole tree conifer harvesting operations (Hudson 1997).

Uk industry wood fuel baling, storage trial. Bales produced in trials carried out in 1996 were stored, uncovered on a forest landing, over a period of 12 months from July 1996 to June 1997 to determine moisture content and energy value changes with time (Hudson & Hudson 1997).

2 UK industry wood fuel baling, management and logistics

Part 1 of the trial was carried out in north England over 2 working days, 17 to 18 March 1997. Bales were produced from both willow and poplar short rotation coppice crops, transported to the site from a number of harvesting trials sites (Table 1).

Part 2 of the trial was carried out on a Sitka spruce clearfell harvesting site in south Scotland. The trial was conducted over 3 working days, 19 to 21 March 1997. The harvesting system was motor manual felling and whole tree extraction by cable crane. The whole trees were mechanically delimbed and crosscut on the forest road and landings, and the residues stacked on the edge of the road and landing. Normally these residues are disposed of over the downside of the forest

Table 1. Trial material.

Trial part	Lot no	Clone	Yield (odt/ha)	Moisture content (%)	Total weight (tonnes)	Age (years)	Base diameter (cm)	Length (metres)
1	1	Willow	-	58	3.35	3	2 to 5	4 to 5
1	2	Poplar	-	56	3.35	5	6 to 15	5 to 6
1	3	75.028/2	4.1	64	6.46	5	6 to 15	5 to 6
1	4	75.028/3	4.1	64	3.56	5	6 to 15	5 to 6
1	5	71.009/1	4.1	60	4.02	5	6 to 15	5 to 6
1	6	71.015/1	6.8	60	4.02	5	6 to 15	5 to 6
1	7	Dors kamp	6.7	54	7.62	5	6 to 15	5 to 6
1	8	Willow	-	58	9.34	3	1 to 5	3 to 5
1	9	Boelare	6.4	56	6.55	5	6 to 15	5 to 6
2	10	Sitka spruce	-	62	40	n/a	n/a	n/a

road. For the purposes of the trial some 40 tonnes of Sitka spruce residues were retained along the road and landing edge to enable them to be fed into the baler using the integral loader on a forwarder mounted baler (Table 1).

2.1 Methodology

The equipment comprised a Bala Press baler complete with own 67 kW diesel engine pack, slew mounted on an ÖSA 250 forwarder equipped with integral loader and grapple for loading residues and offloading completed bales. Bale transport/weighing was carried out using a six wheel Foden rigid timber transport lorry and trailer complete with integral loader and grapple mounted at the rear of the rigid unit.

The materials to be baled, both coppice stems and forest residues, were picked up by the operator using the integral grapple mounted on the forwarder and dropped onto the feed table of the baler. The ability of the baler to slew to allow a multi-directional feed was useful in having to avoid moving the machine when picking up material. After the formation of the 1200 mm diameter bale, the baler automatically wrapped the bale in a conventional layer of 'net wrap' used to wrap agricultural bales. The bales were then unloaded from the baler using the grapple loader and placed on the ground to one side of the baler to allow weighing and movement to the stacking area on site.

Weighing of all bales was carried out using the load cell fitted to the lorry mounted grapple loader. Moisture content analysis was carried out to determine moisture content measured on a wet basis. Time studies were carried out by SkogForsk personnel throughout the baling operations.

Costs of baling were calculated using the computer based FCA Machine Cost System (cash flow basis). Production costs were calculated per green tonne (/gt), per oven dry tonne (/odt) and per bale (/b) based on the capital investment of the baler mounted on a carrier base, operating costs including net wrap at a cost of £1.00 per bale, labour costs and overhead costs. Costs included a risk and profit motive for the baler owner/operator based on 10 % of the £200,000 capital investment of the equipment over a 12 month period. The time trials were conducted with zero rest allowance, the costs were calculated using the FCA Machine Cost System (cash flow basis), based on 15 % rest allowance (rest period 10 % and 5 % maintenance).

2.2. Results

Short rotation coppice

A total of 163 bales of SRC material were produced over the two days of the trial. Baling of the Willow and Poplar SRC took place from the nine separate stacks in the yard.

The operator had no problem handling and feeding the small size willow coppice stems (lots 1 and 8), but problems did occur in the baling leading to the production of 'log basket' bales with the willow stems forming an outer ring with a hollow centre, the flexible stems were not compressed sufficiently to attain economic bale weights. Bale weights were 349 kg for lot 1 and 340 kg for lot 8. Baling costs were low per bale, £4.06 for lot 1 and £3.91 for lot 8, however the low bale weights meant high costs at £11.62 and £11.49/gt respectively.

Baling the poplar stems became more difficult as individual stem size increased. The baler operator had to manoeuvre the stems to ensure that feeding could take place, the larger butt size making feeding difficult, this had the effect of increasing baling time such that production fell in the worst case as low as 12 bales/hr, 5.3 gt/hr. Average bale weights were higher in the poplar ranging from 378 kilograms (kg) to 486 kg. Productivity of the baler ranged from 5.3 gt/hr (1.9 odt/hr, 12 b/hr) to 7.9 gt/hr (3.5 odt/hr, 21 b/hr). Production costs for the baling of poplar ranged from £9.99/gt (£22.70/odt, £3.78/b) to £14.85/gt (£41.25/odt, £6.80/b).

The role of the centralised baling depot was to give a system analysis of primary transport to the central depot, bale at the central depot and secondary transport to the end user. System costs are given in Table 2, primary and secondary transport is based on a 100 kilometre distance, with baling costs based on 15 % rest allowance.

Table 2. System costs - primary transport/bale/secondary transport.

Primary transport		Bale		Secondary transport		Total	
£/gt	£/odt	£/gt	£/odt	£/gt	£/odt	£/gt	£/odt
10.37	20.74	12.29	24.58	7.41	14.82	30.07	60.14

Primary transport was via articulated timber lorries which loaded at the coppice collection sites and unloaded at the central baling depot with the use of their integral mounted crane and grapple. The coppice material was stacked in the central baling depot. The baler worked along the rows of stacked coppice material, placing the bales to one side ready for transport to the end user.

Secondary transport was via a rigid timber lorry and trailer with integral mounted crane and grapple. A total number of 30 bales were loaded onto one lorry, at an average weight of 429 kg, giving a total load weight of 12.87 tonnes. This is within 8 tonnes of maximum load weight permitted for this class of lorry unit. In previous trials it was possible to carry a total number of 40 bales by using articulated lorries with flatbeds, with an average bale weight of 429 kg, a total load weight of 17.16 tonnes can be obtained. This is within 7 tonnes of permitted weight for this class of lorry unit.

Forest Residues

A total of 74 bales were produced over the two days of the trial. The introduction of the baling element into the whole tree harvesting system was accomplished without undue disruption of the roundwood harvesting. Two cable crane units were working on the site. The roadside processor moved between the two cable crane units delimbing and crosscutting roundwood from the stack of whole trees, building up bins of residues at each cable crane unit. The baler was introduced into the harvesting system moving in after the processor at each cable site to bale the freshly accumulated residues. The bales were moved from the harvesting site to a landing below the harvesting site and stacked for later onward transport.

The baler had no problems in dealing with the spruce residues. Average bale weight was 542 kg, productivity was 9.5 gt/hr, 4.5 odt/hr, 18 bales/hr. Production costs were £8.35/gt, £4.53/bale, 38p/kWh (Table 3).

2.3 Discussion

Moisture content of the SRC was in the fifties and lower sixties. Moisture content of the Sitka spruce residues was 53 %. The weight variation of the completed bales was a factor of the amount of material inserted into the bale, and the level of compression achieved. Given a bale size of 1200 mm diameter and 1200 mm width, the volume of each bale was 1.36 m^3. The SRC willow material did not compress and produced the lowest bale density at an average of 254 kg/m^3 at an average bale weight of 344 kg. Baling the SRC poplar averaged a bale density of 334 kg/m^3 at an average bale weight of 453 kg. The spruce residue had the smallest piece size of the material, and the needles and twigs were the most compressible of the materials baled, the resultant density was highest at 399 kg/m^3 at a bale weight averaging 542 kg.

The SRC poplar material was the most difficult to bale, the productivity was the lowest as individual stem size increased and additional handling was necessary, there was an overall longer cycle time and productivity was some 25 - 30 % lower than in the spruce. The productivity of baling spruce forest residues was the

Table 3. Results summary - parts 1 and 2.

Lot no	Bales in trial	Av bale weight (kg)	Moisture content (%)	Energy content (MWh)	Productivity at G^{o} (gt/hr)	(odt/hr)	(bale/hr)	Production costs based on G^{15} (£/gt)	(£/odt)	(£/bale)	(p/kWh)	Density (kg/m³)
1	11	349	58	0.60	6.8	2.9	19	11.62	27.67	4.06	0.68	257
8	27	340	58	0.59	6.9	2.9	20	11.49	27.36	3.91	0.67	250
2	8	378	56	0.69	7.9	3.5	21	9.99	22.7	3.78	0.55	278
3	8	486	64	0.67	6.9	2.5	14	11.49	31.92	5.59	0.84	358
4	11	458	64	0.63	5.3	1.9	12	14.85	41.25	6.8	1.08	337
5	8	485	60	0.78	5.8	2.3	12	13.71	34.28	6.65	0.85	357
6	8	476	60	0.76	6.5	2.6	14	12.15	30.38	5.78	0.76	351
7	15	441	54	0.86	6.9	3.2	16	11.49	24.98	5.07	0.59	325
9	16	451	56	0.83	5.7	2.5	13	13.88	31.55	6.26	0.76	332
10	74	542	53	1.18	9.5	4.5	18	8.35	17.77	4.53	0.38	399

G^{o} zero rest allowance
G^{15} 15% rest allowance

highest. From an analysis of cycle time, the actual baling takes little time, taking 50 centiminutes (cmins) of a total cycle time of 340 cmin, i.e. less than 20 % of total time. Wrapping takes the same time, 50 cmin, regardless of the baled material. The cost of the net wrap material is high, at £1.00/bale, accounting for some 20 % of total bale cost.

The introduction of a primary transport/bale/secondary transport through a central depot, does not offer an economic solution with the low density and weights of bales that were being obtained. Despite the advantage of the scale of the central baling depot, this does not outweigh the higher transport costs incurred in both the primary and secondary transport.

Comparing the data to the 1996 trial it is noticeable that:

- Willow bales are heavier (a factor of moisture content), but baling time is lower.
- The machine productivity in spruce residues is *exactly* the same at 342 cmin, bale weight was slightly higher (542 kg at 53 % moisture content compared with 484 kg at 28 % moisture content).
- Overall baling productivity seems to have improved slightly.

The cable crane site which was used in part 2 of the harvesting trial site posed few problems with the baler working from the bins of residues at roadside, and moving between the two cable crane systems. Although no problems were incurred on this particular harvesting site, there is the potential for problems to occur. With the baler working on site, the whole harvesting system is 'hot', therefore the baler is dependent on the extraction and processing machines. Another problem is the scale of operations, although access on this particular site posed no great problem especially with the fact the baler could move between the two cable crane systems, with one larger cable crane system working on a site with limited access, problems would be incurred. One way to overcome this would be to make the system 'cold', this would mean the residues could be left to accumulate on site and baled at a later date.

This 'cold' system would enable the baler unit to be mounted on a rigid lorry base. This system would have the advantage of reducing the capital cost from £200,000 to approximately £150,000, thereby reducing bale costs from £8.35/tonne (£4.53/bale) to £7.12/tonne (£3.86/bale). The baler would enter a site when cable crane extraction had finished, and the residues would be baled and the bales left at roadside ready for collection by timber lorry.

If the baler was to alternate between cable crane sites, stacking space for completed bales would be limited, therefore requiring either immediate uplift by lorry to the end user, or an additional second hand rigid lorry unit to move bales to a lower landing ready for stacking. This system would give the same productivity but the transport cost would increase. To keep the baler supplied with residues, it would have to work in conjunction with two large cablecrane systems, each system extracting 100 tonnes roundwood per day, 33 tonnes of residue per day, these two systems would also have to be within economic transport distance of each other.

If baling of the residues was to occur after all harvesting operations had been finished, the amount of residues required to feed the baler on a daily basis would not be a problem. The longest time in producing a bale is incurred whilst waiting for the bale to form and for the net wrap to be tied. Therefore it might be possible to mount two baling units on one rigid lorry system, with the feeding of the bale chambers being done alternatively with the use of the integral loader and grapple. This would mean a capital cost of £250,000, productivity of 130 tonnes per shift with a price per tonne of £4.72 (£2.56/bale). With this system the baling unit would be able to travel greater distances to bale residue material. The greater quantities on each site would enable the system to be more economic, productivity levels would be easier to meet as less time would be spent on road travel. In this system with all extraction and processing having been completed, the industrial roundwood will also have been removed from site, allowing room for stacking of bales at roadside ready for collection.

3 UK industry wood fuel baling, storage trial

Storage and drying of wood fuel, both in comminuted and uncomminuted form, has major implications in the utilisation of available energy. Storage is one of the more difficult tasks in the wood fuel supply chain. The storage has to be conducted in such a way as to prevent significant dry matter losses which result in reductions in net energy content.

The greatest demand for wood fuel for heating purposes occurs in the winter months. This can lead to an imbalance in supply with demand greatest at the time of the greatest risk to interruption of supplies due to weather conditions (Thörnqvist 1988). Storage of large volumes of wood fuel, in the provision of buffer stocks, has a financial cost, but is necessary for stable supplies and to balance seasonal factors (Heding 1990). The importance of moisture content as both a feedstock parameter, and as a determinant of the value of the wood fuel, raises the significance of means of achieving a reduction in moisture content as part of the storage process. Storage of wood fuel presents a number of problems, there is a risk of spontaneous combustion, dry matter losses and health risks from fungal spores.

Successful storage depends upon minimising dry matter losses, which in turn depends on restricting the microbial activity, by removing, or at least curtailing, the supply of water and nutrients essential for microbial activity (Jirjis 1992). Control can be exercised by reducing the initial moisture content of the material to be stored, and by storing, where possible, uncomminuted material with intact cell walls removing the nutrient feed source. Covered storage helps to reduce moisture content gain from precipitation, and uncompacted material provides an air flow preventing high temperature levels forming. Nylinder (1981) reported the results of a comparative study of storage of forest residues in the form of chips, hog fuel, baled processed residues and unprocessed residues. Moisture content, dry matter losses and energy change were recorded over a winter storage period for each material stored. In comparison with the other forms of storage the unprocessed residues had the greatest moisture content loss, the lowest dry matter loss and a positive change in energy value.

3.1 Methodology

Storage of the residue bales was carried out over a 12 month period in north east Scotland. The bales were stored, 3 bales high, in the open in stacks simulating a real life storage situation in a commercial operation minimising ground area and bale surface open to rain penetration. The trial site had a south westerly aspect, open on all sites except to the north east which was in tree cover, at an elevation of 150 metres above sea level. Weather data for the trial site was obtained from the Meteorological Office weather station located at Dyce Airport, Aberdeen, 12 miles south east of the storage trial site.

A total of 141 bales were transported to the site in July 1996, 109 bales of Lodgepole pine residues and 32 Sitka spruce residue bales. Each bale was made to a length and diameter of 1200 mm and wrapped individually in light plastic "net wrap" material. Three stacks were formed so as to utilise the given space and to allow air flow around and throughout the stacks.

Although each bale was tagged at the time of baling, some tag numbers became washed out over the 12 months of the trial. At each weighing the number of bales with identifiable tags became less (Table 4).

The bales were weighed and labelled at the harvesting trial sites prior to transport to the storage trial site. At this time, samples of residue material were taken and moisture contents (measured on a wet basis) calculated by an outside contractor. Doubt was expressed at the time as to the accuracy of the moisture contents results, and a second analysis was carried out. The moisture contents taken at this time are recorded in Table 5 (column titled "Initial mc incorrect").

The bales were then weighed at the storage site in November 1996 and February 1997 with a final weighing in June 1997. Throughout the storage trial the bales were weighed with a loadcell mounted on a forwarder trailer. During each weighing of stack 3 the position and bale numbers within the stack were recorded as they were moved to the forwarder trailer. This allowed the weight loss variation within the stack to be seen.

Table 4. Stack data.

Stack No	Species	State of residue at time of baling	Total bales	Number of bales with identification tags remaining at the end of the trial
1	Sitka spruce	Dry	32	16
2	Lodgepole pine	Dry	34	27
3	Lodgepole pine	Fresh	75	21

After the final weighing was conducted, 2 bales with identification numbers were randomly selected from each stack, to be chipped to enable the overall final moisture content for each stack to be determined. Each bale was chipped with the use of an Erjo tractor-mounted chipper. The chips were blown into an agricultural trailer where they were thoroughly mixed by hand and a 25 kilogram (kg) bag was filled, sealed and numbered. The remainder of the chips were then dumped. This was carried out for each of the 6 bales.

The moisture contents were obtained by taking 2 x 2 kg samples from each 25 kg bag, and dried in a conventional electric oven at 105 degrees centigrade. The samples were weighed after 24 hrs in the oven, the weight was recorded and then weighed for a further 12 hrs to check that there was no further weight change. The loss in weight during oven drying was deemed to be moisture loss.

3.2 Results

The following results are based on an average for all bales within each stack:

The greatest weight loss occurred in the initial period July 1996 to November 1996 for all 3 stacks, with stack 3 Lodgepole pine 'fresh' incurring the greatest losses, an average of 181.3 kg (31.3 %), with bales in stack 1 Sitka Spruce 'dry' incurring the second greatest loss, 133 kg (28.7 %) and finally bales in stack 2 Lodgepole pine 'dry', incurring the least weight loss 63 kg (14.8 %).

The least overall weight loss for all 3 stacks was in the middle period of November 1996 to February 1997. Bales in stack 3 lost an average 27.3 kg (7 %), bales in stack 1 lost 22.5 kg (6.9 %) and bales in stack 2 again incurred the least losses with a loss of 17.3 kg (4.8 %).

Weight loss increased again in the final period February 1997 to June 1997. Bales in stack 3 lost an average of 40.4 kg (10.8 %), bales in stack 1 lost 22.6 kg (7.4 %) and bales in stack 2 lost 21 kg (6.1 %).

The average bale weight loss over the whole 12 month trial period for stack 1 was 178.5 kg (38.4 %), bales in stack 2 lost 101.4 kg (23.8 %) and bales in stack 3 lost 249.1 kg (43.2 %).

Moisture content

The original moisture content of the residue bales was calculated by an outside contractor. At the time it was thought from past experience these moisture contents were underestimated, as stack 1 Sitka spruce ‘dry’ was calculated to have had an initial moisture content of 28 %, stack 2 Lodgepole pine ‘dry’ initial moisture content 23 % and stack 3 Lodgepole pine ‘fresh’ 35 % (Table 5, column “Initial mc error”). From previous storage and drying trials within the UK, it had been established that freshly harvested Lodgepole pine residues were found to be in the region of 50 % (Mitchell *et al.* 1990). There appeared therefore to be an underestimate of perhaps between 5 and 15 % across the three stacks.

The moisture contents for each stack at the end of the trial as at June 1997 were obtained from the oven drying results. These moisture contents were averaged from the 2 samples from the 2 chipped bales from each stack to determine the specific bale moisture content (Table 5). The average moisture content for stack 1 was 17.2 %, stack 2 — 16.4 % and stack 3 — 18.9 %.

By assuming a dry matter loss of 8 % per annum (Jirjis 1996), it was possible then to calculate back over the period of the storage trial to obtain an estimated average moisture content at the time of baling. Stack 1 had an estimated initial moisture content of 41.2 %, stack 2 — 28.9 % and stack 3 — 46 %. (Table 5). On the basis of weight loss and on the assumption of the 8 % dry matter losses per annum, moisture content change was then calculated for each stack at each weight measurement point in the storage trial (Table 5 and Figure 1).

Energy variation

Over the 12 month period, energy content calculated for the average residue bale in each stack remained relatively constant with stack 1 losing a total of 0.10 MWh/bale, Stack 2 losing 0.12 MWh/bale and stack 3 losing 0.11 MWh/bale (Table 6). The calculations for energy content have taken into account the assumed dry matter loss of 8 % per annum used in the moisture content calculations.

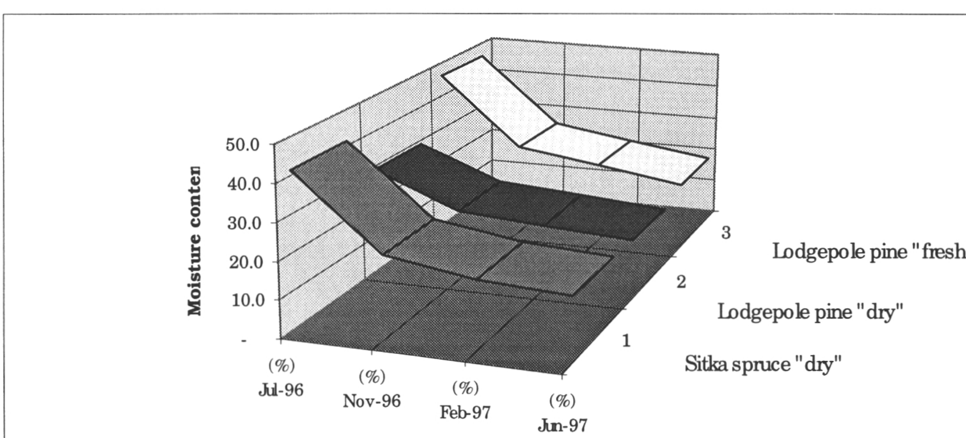

Figure 1. Moisture content change.

Although the energy content figure per bale dropped over the trial period, it must be noted weight loss also occurred, this translates to a net energy gain *per tonne* over the trial period (Table 7).

3.3 Discussion

Results indicate moisture content losses across all stacks. The greatest moisture content loss was in the initial drying period July 96 to November 96, the rate of drying then flattened off over the middle and final storage periods. Overall moisture content changes, given the caveats of 8 % dry matter losses and that the recalculated moisture contents at the time of baling are correct, were significant with stack 1 reducing from 41.2 % to 17.2 %, stack 2 from 28.9 % to 16.4 %, stack 3 from 46 % to 18.9 %.

The rate of moisture content change indicated links both with climatic conditions, as recorded over the period of the trial, and the moisture content of the bales at the start of the trial.

From recording the results of individual moisture contents of the bales within stack 3 at each weighing, it was found that there was no direct pattern between bale position within the stack and moisture content loss, and differing moisture content losses within the stack are due to the individual properties of the bale at the time of baling (initial moisture content, original weight and density).

Energy content measured per bale remained relatively constant falling slightly in stack 1 from 1.34 MWh to 1.24 MWh, in stack 2 from 1.51 to 1.39 MWh, and in stack 3 from 1.49 to 1.38 MWh. However, energy content when measured per tonne increased considerably, in stack 1 from 2.90 MWh/tonne to 4.38 MWh/tonne, in stack 2 from 3.63 to 4.42 MWh/tonne, and in stack 3 from 2.59 to 4.24 MWh/tonne.

4 Conclusion

The baling technology is proven and reliable with productivity in the range of 12 — 21 bales/hr, in spruce residues the productivity was 18 bales/hr. Bale weights ranged from 340 kg to 542 kg, determined by the moisture content, type, size and the degree of compressibility of the material baled. Bale density varied from a low of 254 kg/m^3 in willow to a high of 400 kg/m^3 in Sitka spruce.

The movement of SRC material to central processing sites for preparation prior to onward transport to the end product user has very limited potential, but baling of SRC material has problems. Larger diameter poplar does not bale well, the diameter and length of individual pieces presents handling problems for the baler operator and slows down feed speed to such a level that low production does not make baling an economic proposition. The flexibility of willow stems does not allow cost effective weights to be achieved. The low weight is a result of the stems forming an outer ring forming the "log basket" effect.

Table 5. Dry matter and moisture content change.

Stack	Bale no	Initial wt	DM	Initial mc	Initial mc	mc error	DM loss *	Final wt	Final mc	Final DM		
		Jul-96			incorrect			Jun-97				
		(kg)	(kg)	(%)	(%)	(%)	(kg)	(kg)	(%)	(kg)		
1	225	504.0	274.1	45.6			40.3	278.0	15.9	233.8		
	224	596.0	295.6	50.4			47.7	304.0	18.5	247.9		
Av Stack		**461.4**	**271.3**	**41.2**	28.0	32.1	**36.9**	**282.9**	**17.2**	**234.3**		
2	133	493.0	327.8	33.5			39.4	353.0	18.3	288.4		
	111	460.0	358.6	22.0			36.8	376.0	14.4	321.8		
Av Stack		**416.0**	**295.9**	**28.9**	23.0	20.3	**33.3**	**314.0**	**16.4**	**262.6**		
3	14	546.0	313.9	42.5			43.7	317.0	14.8	270.2		
	62	676.0	353.9	47.7			54.1	389.0	22.9	299.8		
Av Stack		**574.2**	**310.0**	**46.0**	35.0	23.9	**45.9**	**325.4**	**18.9**	**264.0**		
* assumed at 8 % per annum												
Stack	Jul-96			Nov-96			Feb-97			Jun-97		
	Weight	Dry matter	Moist cont	Weight	Dry matter	Moist cont	Weight	Dry matter	Moist cont	Weight	Dry matter	Moist cont
	(kg)	(kg)	(%)	(kg)	(kg)	(%)	(kg)	(kg)	(%)	(kg)	(kg)	(%)
1	461.0	271.3	41.2	328	255.9	21.98	305	249.3	18.25	282.9	234.3	17.2
2	416.0	295.9	28.9	352	282.1	19.87	335	275.0	17.91	314.0	262.6	16.4
3	574.2	310.0	46.0	392.9	290.8	25.97	365.6	283.0	22.60	278.0	225.6	18.9

Table 6. Energy change per bale.

Stack	Jul-96 Weight (kg)	Moisture Content (%)	Energy Content (MWh)	Nov-96 Weight (kg)	Moisture Content (%)	Energy Content (MWh)	Feb-97 Weight (kg)	Moisture Content (%)	Energy Content (MWh)	Jun-97 Weight (kg)	Moisture Content (%)	Energy Content (MWh)
1	461.4	41.2	1.34	328	22	1.33	305.5	18.3	1.32	282.9	17.2	1.24
2	416	28.9	1.51	353	19.9	1.48	335.6	17.9	1.45	314.6	16.4	1.39
3	574.2	46	1.49	392.9	26	1.50	365.6	22.6	1.47	325.2	18.9	1.38

Table 7. Energy change per tonne.

Stack	July 96 Energy Content		Nov 96 Energy content		Feb 97 Energy content		Jun 97 Energy content	
	MWh /bale	MWh /tonne	MWh /bale	MWh /tonne	MWh /bale	MWh /tonne	MWh /bale	MWh /tonne
1	1.34	2.90	1.33	4.05	1.32	4.32	1.24	4.38
2	1.51	3.63	1.48	4.19	1.45	4.32	1.39	4.42
3	1.49	2.59	1.5	3.82	1.47	4.02	1.38	4.24

The introduction of a baling element into whole tree cable crane harvesting of Sitka spruce did not present a problem. The ability of the baler to move about the forest road to work in tandem with the processor enabled it to fit into the harvesting system with a minimum of disruption. Space for stacking of the completed bales was limited and will require an additional transport element into the site unless the bales can be moved directly away from the site to the end product user. If movement of the bales is within the site, but onto a lower unused landing there is a case for the introduction of a low cost second-hand rigid lorry for bale movement only. There is also the opportunity for this vehicle to be used to move produce away from the foot of the cable crane sites.

The emphasis in former trials on baling systems has been on the system being ‘hot’. This has several disadvantages. Firstly in that the baling system is dependent upon the extraction and processing systems and there is the need for an additional transport element to keep roadsides clear of bales to enable stacking of industrial roundwood. If the system was to become ‘cold’ there would be no interdependence between harvesting systems, and the possibility of being able to stack bales at roadside for drying. There is considerable scope for the baler to be mounted on a second hand rigid lorry unit, which could reduce total capital cost. When the baler is in operation, the operator is idle whilst waiting for the bale to form and the netting to be applied. If two baling units were mounted on one lorry unit, there would be no idle time waiting for the bale to form and be netted, and productivity would increase with a reduction in production costs. With a lorry mounted unit the system becomes more flexible, reducing costs of moving between sites.

Given the difficulties of baling both small diameter willow and the larger diameter poplar SRC there are no evident advantages from the introduction of baling into central processing sites. Further work is necessary to establish the potential for baling SRC at the point of production, perhaps integrating cutting and baling into a single simultaneous operation.

There are no logistical or management problems in the introduction of baling into whole tree harvesting operations. There is the potential for environmental gain from the removal of residue bins from whole tree harvesting sites. There are evident advantages in the use of baling for increasing the density of uncomminuted residue material both for ease of handling and onward transport of Sitka spruce residues. There is scope for the development of a lorry mounted baler, and some additional research into bale chamber design to increase production. There is still work to be done to establish the logistics and management of “cold” baling in conjunction with a lorry mounted baler and integration with storage of the baled material.

The storage trial indicated that the moisture content of baled residues stored externally on a well ventilated forest landing over a 12 month storage period, fell to within a range of 16.4 to 18.9 %. Energy content when measured in terms of weight increased markedly.

Lack of knowledge of actual dry matter losses during the trial period does to some extent offset the value of the actual results. However, there was no visible sign of fungal attack associated with dry matter losses and no apparent rot in any of the bales at the conclusion of the trial. The assumption of 8 % dry matter losses would thus appear to be reasonably conservative. Notwithstanding the loss of dry matter through fungal or other losses, there was loss of material resulting from the repeated handling of the bales, this again somewhat reduces the accuracy of the results given also the apparent error in moisture content determination at the time of the start of the storage process.

Notwithstanding these caveats there was a remarkable reduction in moisture content and the residues were exceptionally dry at the conclusion of the trial. The results from this trial would tend to indicate that external storage of baled residues would markedly reduce moisture content with a minimum outlay in terms of cost, other than the interest on capital invested in the bales during the storage period, and the minimal cost of the in-forest storage sites. Transport costs of the bales after storage, when measured in terms of energy content, is reduced. The concept of baling residues to minimise disruption to harvesting operations, reduce moisture content and increase the density of transport and reduce transport costs, would appear to offer considerable potential.

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Fuelwood characteristics and nutrient release from Norway spruce logging residue during storage at the forest landing

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1 Introduction

The share of woodbased fuels of the total energy consumption is some 15 % in Finland. This is the highest in all industrialized countries. The figure includes black liquor and other industrial wood wastes. According to the 8th National Forest Inventory the average annual volume increment of stemwood during 1986-94 was 77.1 Mm^3/a (Metsätilastollinen vuosikirja 1995). The total growth of the above ground woody biomass, branches and foliage included is some 110 Mm^3/a. Of this volume 29 Mm^3/a is logging residue (Hakkila & Fredriksson 1996).

Possible but rather restricted areas of utilization for this reserve are pulp and paper products, panel products, chemicals and fodder. However, due to the low quality of this non-commercial wood the most likely form of utilization is fuelwood. Unfortunately the oil price is a dictating factor for the expansion of fuelwood utilization.

One of the more difficult tasks in biomass harvesting is how to manage the storage of the material. It is known from previous studies that long-term storage of comminuted biomass will amount to significant dry matter losses, reductions in net energy content and cause health risks among the users (Bergman & Nilson 1966, Gislerud 1974, Thörnqvist 1987, Nurmi 1990, Thörnqvist & Jirjis 1990). Nevertheless, it is necessary to use buffer storages at latitudes where winter will prevent contractors from supplying heating facilities during the most severe winter conditions.

When dead organic matter lies on the forest floor it looses nutrients through leaching and decay. Hence the nutrients will stay on the site and are available to the flora. When the nutrient rich residue is piled on the landing the question is whether the nutrients end up in concentrated form in surface waters or not. The primary aim of this particular study was to find out if nutrients are released during storage on a landing and the second aim was to find out if moisture content can be governed by covering the piles.

2 Material and methods

The study material was composed of spruce logging residue from six different clearcut sites. At each site the residue was collected and forwarded to the landing within three weeks of logging. This took place late August and early September

1995. To study the possible benefits of covering the residue piles two storage piles were formed at each landing. One was covered with a multi-layered timber wrapping paper supplied by Wisapak of Finland under the trademark of Forest Wrap while the other one was left uncovered. Hence, a total of twelve piles were included in the study. The maximum pile height was 5 meters. To learn about the effects of storage time the piles were dismantled at three occasions, four piles at a time. The piles were sampled before and after each stage of the study (Sept. -95, Jan. -96, June -96, Jan. -97) for moisture- and ash content, relative needle mass and a number of elements (P, K, Mg, Ca, Mn, B, Na, S, Al, Cu, Fe, Zn, Mo, Cd).

3 Results and discussion

3.1 Moisture content

The moisture content of live spruce crown is about 55 % (Hakkila 1989, Nurmi 1997). The residue material used in this study had been on the clearcut in piles created by a single grip harvester for two to three weeks after the round wood harvest. As a result the average moisture content had decreased to 41.2 % (s= 10.6, n= 238) prior to forwarding. As shown by Figure 1 the stored material had gained moisture by next January 1996 (45.0 %, s= 6.8, n= 58). Moisture content was reduced during the following summer. At that time the moisture was down to 33,7 % (s= 6.3, n= 36). During the last winter of the study the moisture content was up again at 43.1 % (s=7.6, n= 56).

When trees are felled and branches removed changes in moisture content may take place and wood, bark and foliage will eventually come to an equilibrium moisture content with the environment. The rate at which changes take place are governed by temperature and relative humidity of the ambient air. Hence, spring and summer are the most favourable drying seasons when the vapor pressure deficit is highest. In winter time when the deficit is < 1 mb and residue is frozen no drying takes place. It follows that the moisture content of non-comminuted residue will fluctuate with the season as shown by Figure 1. It should also be noted that the final moisture content was not as low as if the material had been dried on the clearcut area (Nurmi 1997).

No difference was found between the covered and uncovered piles. This result is different from those attained in Sweden where covering was found to have a positive effect on the fuel stock quality (Jirjis & Lehtikangas 1993). The reason for the difference in results can most likely be contributed to the pile size. In the Swedish study the pile height had been 2.7 meters whereas in this study the piles were almost twice that height. It can be concluded that when the pile height gets bigger the cover provides less protection. Another advantage of the greater pile height is the reduction in costs. However, if cost is no limiting factor and protective cover is used then the piles should not be greater than three meters in height.

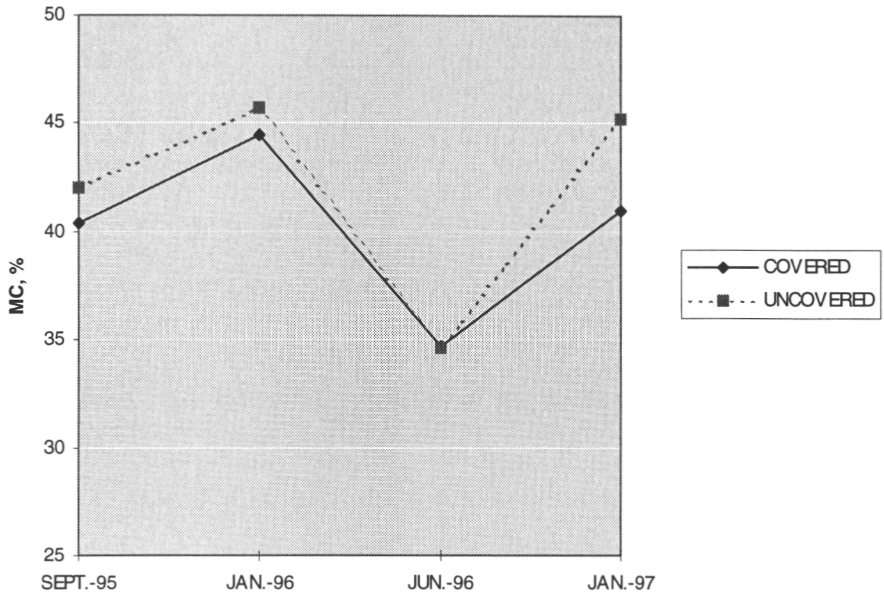

Figure 1. Changes in moisture content over time in spruce logging residue when stored in covered and uncovered piles at the landing.

3.2 The nutrient concentrations of logging residue

The percentage of foliage in green Norway spruce residue from regeneration cuttings is about 30 % of the oven dry biomass. Also the majority of the nutrients found in logging residue are concentrated in the needle mass. There is even a slight indication that the concentrations of elements like potassium (K) and calsium (Ca) first increase just to decrease with extended storage. It could be that these elements are just slower in release than some other elements (P, Mg, Mn, B). This would increase their concentration temporarily. Similar phenomena have earlier been observed by Granhall and Slapokas (1984). Heavier elements (Fe, Zn, S, Al) are released very slowly and they actually show an increase of concentrations (App. 1 and 2). An exception to the rule is copper which is readily released in minute amounts. Sodium (Na) contained by the fuel is thought to be responsible for some of the corrosion in combustion equipment. Small concentrations of this element (17—34 ppm) were found in the needle mass but no conclusions could be drawn whether storage would decrease the amount of sodium in the fuel or not. Heavy metals like cadmium and molybdenium appeared in such small quantities that they were actually detected only in handful of samples making it impossible to determine the actual amounts present. Whether covering the piles has an effect on the nutrient release is yet to be discovered.

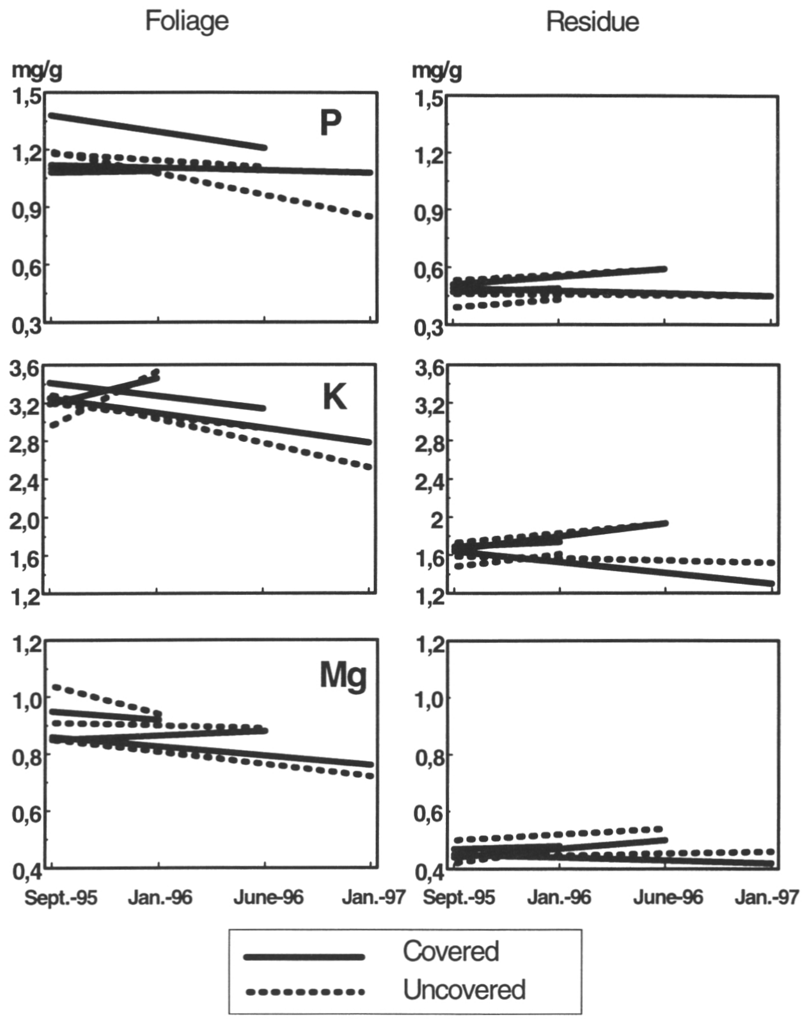

Figure 2a. The phosphorus, potassium and magnesium concentrations as a function of time.

When looking at the figures showing the nutrient concentrations in logging residue (wood, bark and foliage included) two things can be noted. First, the concentrations are much lower than in the needle mass and second, in the case of most nutrients there is no distinct trend over time. The reason for this second observation is that the residue starts loosing foliage once seasoning takes place. It follows that the samples recovered from the pile contain a wide range of needles making it more difficult to interpret the results.

3.3 Ash content of logging residue

Only the mineral elements are present in ash. The primary elements, carbon, hydrogen, oxygen and nitrogen are lost when material is exposed to high temperatures.

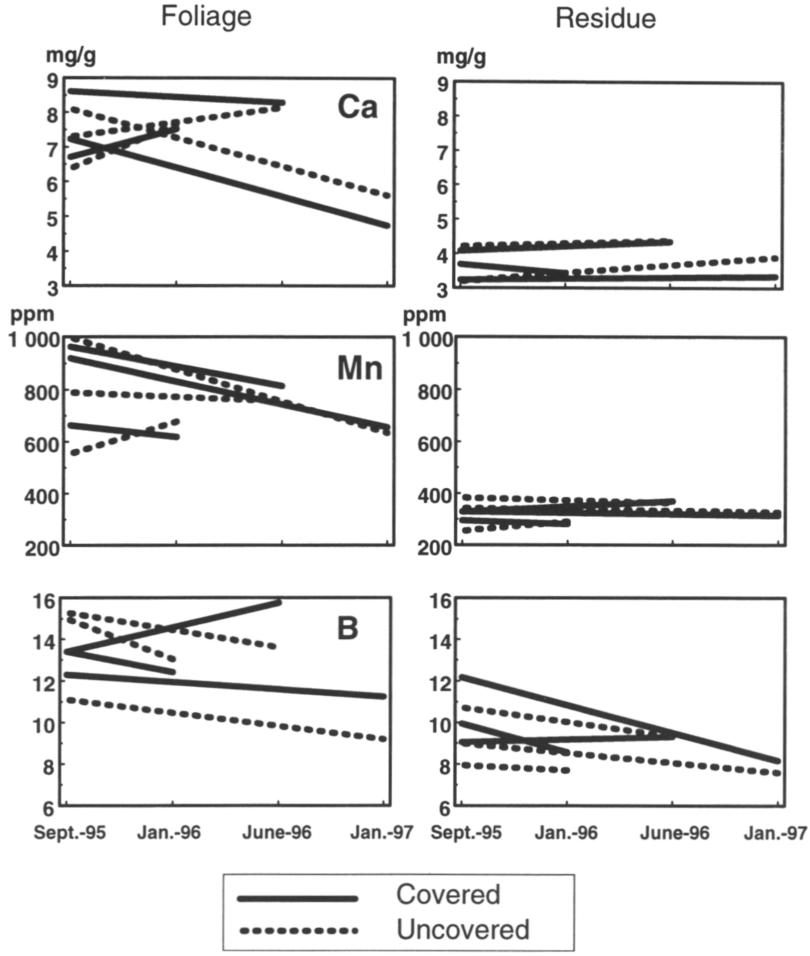

Figure 2b. The calsium, manganese and boron concentrations as function of time.

The ash content of Norway spruce stem- and branchwood varies from 0.30—0.63 % of the dry mass. Branches including bark has an ash content of 1,88 %. The higher percentage is caused by the bark as it contains ash in excess of 3 %. The ash content of foliage is the highest of all three components. Different studies give values from 4.20 to 5.13 % (Hakkila & Kalaja 1983, Voipio & Laakso 1992).

The ash content of the needles found in the storage piles at the beginning of this study varied from 4.2—4.9 % which is in accordance with previous studies. With time the ash concentration increases slowly both in the needle mass and the whole residue mass as well (Figure 3). The most likely reason for this phenomena is the loss of carbohydrates by leaching and volatilization (Kramer & Kozlowski 1979). This loss can also be seen as a loss of relative needle mass as seen on Figure 4. Similar losses have been recorded earlier on spruce needles when the residue material has been stored both on clearcut and on landing (Nurmi 1997).

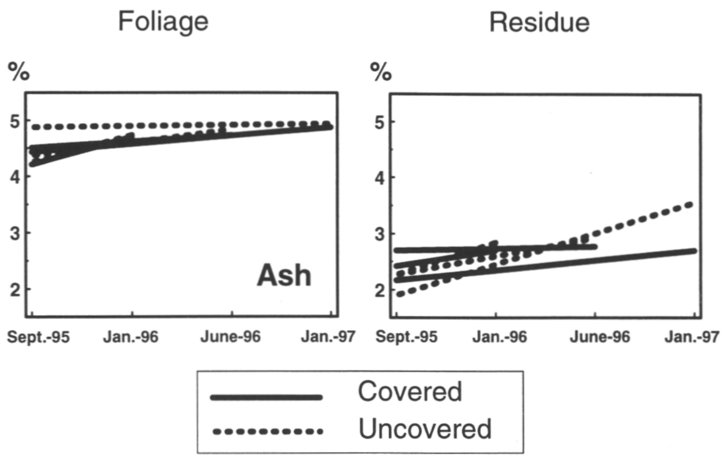

Figure 3. Ash content in spruce logging residue as a function of time.

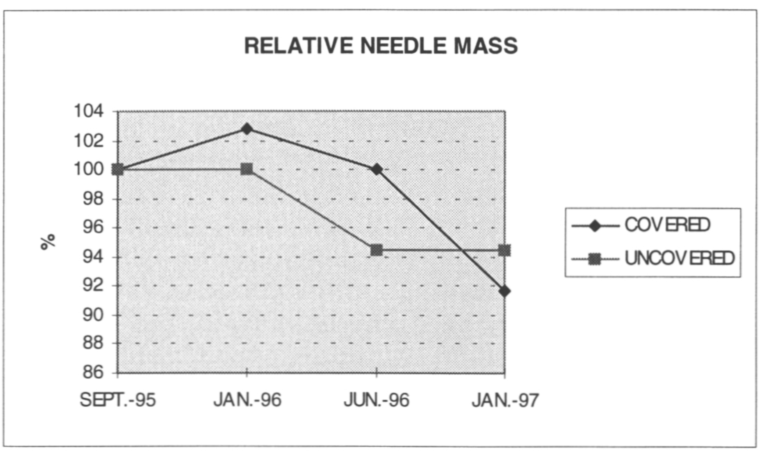

Figure 4. The relative needle mass as a function of time.

4 Conclusions

Logging residue is the most abundant source of biofuel available in Finland at the moment. However, to improve the quality of fuel stock to suit most of the district heating plants in Finland it is necessary to season the material. This can be done either on the clearcut in piles created by the single grip harvester or on the landing. When done on the landing, drying is not as good as it would be on the clearcut. The significant benefit of seasoning the material at the landing is the greater recovery of material. Most of this would be needle mass which would be lost if seasoned on the clearcut.

The release of nutrients is slow from the storage piles. Phosphorus, magnesium, manganese and boron seem to have been released sooner than other elements found in wood ash. When storage time increases the release of potassium and calcium also takes place. Heavier metals are released very slowly. Seasoning does not seem to have an effect on the sodium concentration.

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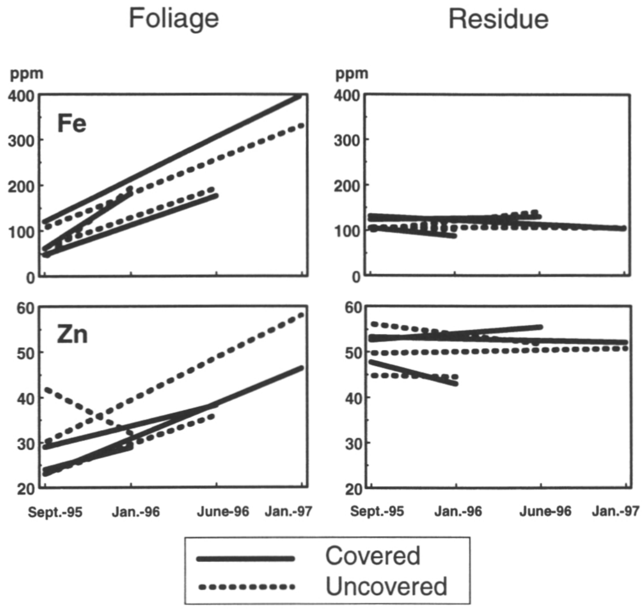
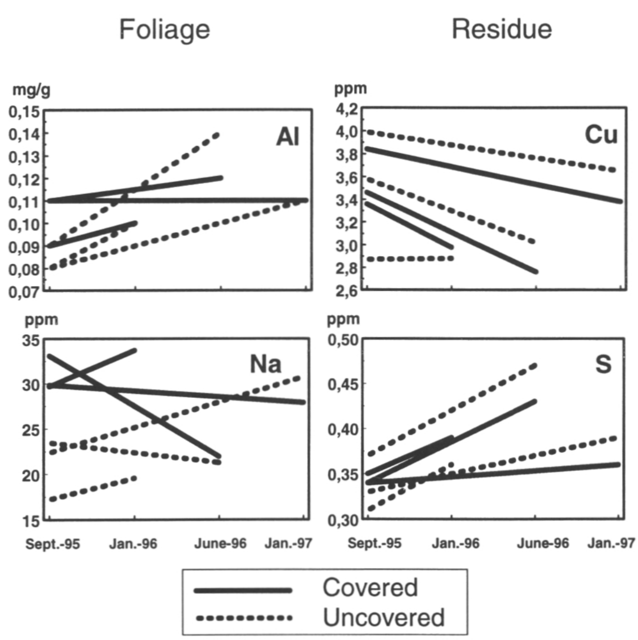
Appendix 1. The iron and zinc concentrations as a function of time.



Appendix 2. The aluminum, copper, sodium and sulphur concentrations of logging residue as a function of time.



Standards for wood fuels, or the lack there-of

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1 Introduction

Wood fuel is a wide concept. Wood fuels range from wood dust via chips to chunk to firewood. As such we are talking about a product from the lengths of under 1 mm up to 250 mm. Above 250 mm we are talking about solid firewood, which of course is a wood fuel, but which is hardly used for large scale applications.

The few standards which exist refer only to chipped wood. Wood which has passed through a shredder is not included. Only clean forest wood is being referred to, while a vast amount of recycled wood could be, and is, used for energy purposes.

Wood for fuel is increasing in many countries. In Austria, Denmark, Sweden and Finland it is very usual, while in countries like the Holland, Italy and the UK it is emerging. However without the right political incentives wood for energy is still expensive in comparison to fossil fuels.

An international market is being created for chipped wood fuels, especially from e.g. the Baltic countries because of the low costs of the wood and labour.

Since wood fuels are taking a more and more important role and the amounts of wood fuels are increasing, the need for international standards is increasing rapidly. Also the fact that utility companies are entering the market is important in this respect. The utility companies are used to buy only defined fuels for which international standards are available (coal, oil, natural gas).

No international standards exist for wood fuels, and also nationally there is a clear lack of standards. Several organisations have occupied themselves the last few years with a search for standards:

In Holland the ECN carried out a project called "Characterisation of Biomass Fuels" (Curvers & Gigler 1996).

In the UK, ETSU carried out an inventory of standards for biomass fuels in 1997 within the European AFB/NETT project. The results have not been published yet.

In France, students made a project on size classifaction of wood chips. The report is called "Caractérisation du combustible bois déchiqueté: granulométrie et foisonnement" (Gourman et al. 1997)

A European Project within the FAIR programme is starting soon. This project is called "Standardization of Solid Biofuels in Europe" and is being co-ordinated by the University of Stuttgart in Germany. The project is under negotiation and has not yet started.

In Denmark a national project has been granted to look into the problems of size classification of wood fuels. This pilot project will include a literature study and study trips to Sweden, Germany, Holland, Austria and the USA. Interest in the problems of standards for wood fuels is increasing.

2 Existing standards

Austria is the only country which has a comprehensive set of standards for wood fuels. In Sweden a standard exists for size classification of fuel chips. In Denmark a voluntary agreement exists between the producers and the consumers of fuel chips.

In Germany many DIN standards exist, which can be used for wood fuel also, as size classification, moisture content, ash content etc., however no clear standards exists for wood fuel.

Also many of the ASEA standards apply to wood, but again no clear standards for wood fuels exist.

Many standards occupy themselves with describing precise procedures, but very few translate these procedures into specifications.

2.1 Austria

Önorm M 7132: Energiewirtschaftliche Nutzung von Holz und Rinde als Brennstoff. Begriffsbestimmungen und brennstofftechnologische Merkmale (The energetic use of wood and bark as fuel. Definitions and fuel technical properties)

Önorm M 7133: Energiehackgut. Anforderungen und Prüfbestimmungen (Energy chips: Requirements and Test Procedures)

In the first standard, wood fuels are defined in detail and all variations of wood fuels are described. General information about wood density and other wood properties are given.

The second standard is more interesting, since it defines different classes of wood fuels. These classes are arranged according to the following parameters:

Moisture content
Size
Specific dry weight
Ash content
Extraneous bodies

Moisture contents

As a first criteria moisture content is used. For wood fuels five classes are defined:

- W20 Moisture contents lower than 20 % (air dried energy chips)
- W30 Moisture contents 19 %<MC<30 % (storable energy chips)
- W35 Moisture contents 29 %<MC<35 % (reduced storable energy chips)
- W40 Moisture contents 34 %<MC<40 % (moist energy chips)
- W50 Moisture contents 39 %<MC<50 % (fresh harvested energy chips)

To be noted about this classification are the names of the classes and that there is no class for chips with a moisture content of over 50 %. This is usual for green chips, but also chips which have been stored outdoors under unfavourable conditions can have such high MC.

The determination of the MC is following the German DIN norm 52 183. (103 °C until constant weight). This German standard also specifies that, if one suspects larger amounts of volatiles in the wood, one has to dry at 50 °C under vacuum.

Size classification

The next step in the classification is the size of the chips. There are three classes, which have specific demands attached to them. The classes are:

- G30 Nominal length 30 mm (Fine chips)
- G50 Nominal length 50 mm (Middle chips)
- G100 Nominal length 100 mm (Large chips)

To each of these classes demands have been attached on the amount of chips on each of the screens. These demands are specified in table 1.

The size classification procedure should be carried out according to the German standard DIN 66 165 parts 1 and 2. This is a very detailed and complex description which is valid for all screening methods and equipment.

Table 1. Size classification according to Austrian standard.

Total 100 %		G30 Fine	G50 Middle	G100 Large
Oversize max. 20 %	Cross section max. cm^2	3	5	10
	Length max. cm	8,5	12	25
	Screen slot mm	16	31,5	63
Main part 60 to 100 %	Screen slot	2,8	5,6	11,2
Undersize max. 20 %	Screen slot	1	1	1
Fines max. 4 %				

In table 2 the wire mesh sizes for each class are given.

Table 2. Wire mesh sizes in mm, Austrian standard.

G30 Fine chips	16 mm	2,8 mm	1 mm	bottom tray
G50 Medium chips	31,5 mm	5,6 mm	1 mm	bottom tray
G100 Large chips	63 mm	11,2 mm	1 mm	bottom tray

Specific dry weight

The next step in the classification is the specific dry weight of the chips. There are three classes:

- S160 Low specific dry weight, less than 160 kg/m^3 (Spruce, poplar, willow)
- S200 Medium specific dry weight, at least 160 and less than 200 kg/m^3 (pine, larch, birch, alder)
- S250 High specific dry weight of more than 200 kg/m^3. (Beech, oak, robinia)

The specific dry weight is determined according to the German DIN 51 705 standard.

Ash contents

There are only two classes:

- A1 Low ash contents, or less than 1 %
- A2 Increased ash content of more than 1 %, but less than 5 %

Ashes are determined according to the German DIN 51 719 standard.

Extraneous bodies

Foreign bodies such as stones, metal objects and such, as well as the addition of combustible extraneous materials (such as sanding dust) is not permitted.

2.2 Sweden

In Sweden a standard exists for size classification of wood fuels (SS187174) as well as one for determining the ash contents of biofuels (SS187171).

The Swedish standard SS187174 specifies that a screen should be used with the following round holes:

- 45 mm
- 22 mm
- 3 mm
- bottom tray

The trays have to be shaken for 4 minutes with 160 rpm and a stroke length of 70 mm. Trays should have a size of 397x650 mm. The material to be screened should be predried to 10-20 % MC at max. 65 °C.

No demands are attached to this standard, it just describes the procedure. Many standards are available which refer to pulp chips.

2.3 Denmark

As stated before no standard exists, but a voluntary agreement between the producers and the consumers exist. This agreement forms the basis for all contracts in Denmark.

The size classification of chips is carried out according to the Scandinavian standard SCAN-CM 40:88, which describes the requirements for screening pulpwood chips.

In Denmark two types of chips have been described, with a third being under consideration. These types are: fine chips and large chips. The name for the third one is still to de determined. The classes and the demands are listed in Table 3. The determination of moisture contents is carried out at 105 °C until constant weight is reached.

3 Conclusions

Apart from Austria, no country has a set of standards to describe wood fuels. Even though this standard has three size classes, it is still too limited to encompass the whole range of wood fuels from wood floor to firewood. The standard might be suited as a guideline for the producers and consumers of fuel chips, but it is not suited to describe a wood fuel for research purposes.

The Austrian standard often refers to German DIN standards for procedures to follow. It will probably fit the Austrian circumstances well, but the standard is not very suitable for other countries like Denmark. E.g. the range of moisture contents is too limited and the size classification is rather crude.

There is still a demand for an international standard, which in the manner of the Austrian one, can be applied to wood fuels in general in a wide range from wood dust to firewood. This standard should describe the application of general procedural standards to wood fuels as far as possible. The standard should also include wood fuels produced from recycled wood and as such describe demands on the contents of glue, paint, plastics, glass, metals etc.

Table 3. Danish demands on fuel chips.

Screen	Name	Fine chips	Large chips
45 mm round holes	over large	< 5 %	< 15 %
8 mm slits	over thick	< 25 %	< 40 %
7 mm round holes	accept	> 40 %	largest possible
3 mm round holes	pins	< 20 %	< 15 %
bottom tray	dust	< 10 %	< 7 %
twigs 10-20 cm	diameter > 1 cm	< 2 %	< 12 %
twigs > 20 cm	diameter > 1 cm	< 0,5 %	< 6 %

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Standards

SCAN-CM 40:88 Massaflis Flissållning (pulpchips, screening)
SCAN-CM 39:88 Massaflis Torrhalt (pulpchips, dry matter contents)
SCAN-CM 43:89 Massaflis Torr-rådensitet (pulpchips, dry bulk density)
SCAN-CM 42:89 Massaflis Barkhalt (pulpwood chips, bark contents)
SCAN-CM 41:89 Massaflis Provtagning (pulpwood chips, sampling methods)

Önorm M 7132: Energiewirtschaftliche Nutzung von Holz und Rinde als Brennstoff. Begriffsbestimmungen und brennstofftechnologische Merkmale (The energetic use of wood and bark as fuel. Definitions and fuel technical properties)

Önorm M 7133: Energiehackgut. Anforderungen und Prüfbestimmungen (Energy chips: Requirements and Test Procedures)

DIN 51718 Prüfung fester Brennstoffe: Bestimmung des Wassergehaltes und der Analysenfeuchtigkeit (Testing of solid fuels: Determination of the moisture contents and the moisture of analysis sample)

DIN 51705 Prüfung fester Brennstoffe: Bestimmung der Schüttdichte (Testing of solid fuels: Determination of the bulk density)

DIN 51719 Prüfung fester Brennstoffe: Bestimmung des Aschegehaltes (Testing of solid fuels: Determination of ash contents)

DIN 52183 Prüfung von Holz: Bestimmung des Feachtigkeitsgehaltes (Testing of wood: Determination of moisture contents)

DIN 66165 Partikelgrösseanalyse: Siebanalyse Teil 1: Grundlagen (Particle size analysis; sieving analysis; fundamentals)

DIN 66165 Partikelgrösseanalyse: Siebanalyse Teil 2: Durchführung (Particle size analysis; sieving analysis; procedure)

DIN 3310 Analysesiebe; Anforderungen und Prüfung. Analysesiebe mit Metalldrahtgewebe (Identische mit ISO 3310-1) (Test sieves; Technical requirements and testing. Test sieves of metal wire cloth. Identical with ISO 3310-1 1990)

SS187174 Biobränslen och torv - Bestämning av fraktionsfördeling (Biofuels and peat - Determination of size distribution)

SS187171 Biofuels. Determination of ash content

Wood fuel harvesting - the role of IEA Bioenergy

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1 Introduction

In 1996, Harvesting Activity of Task XII/IEA Bioenergy agreed that a state-of-the-art review on wood fuel harvesting would be carried out. This report is based on interviews of the representatives of Canada, Denmark, Sweden and United Kingdom, a national report on Finland (Hakkila & Fredriksson 1996), and questionnaires answered by representatives of the Netherlands, New Zealand and Norway. Commission of the European Communities - also member in the Harvesting Activity - was excluded from this survey.

This report

- briefly describes the history of harvesting related cooperation within IEA Bioenergy,
- discusses the potential, utilisation, harvesting, environmental, employment and policy issues, as well as barriers related to wood fuel harvesting,
- describes the main developments during past ten years, and
- discusses the advantages and disadvantages of IEA Bioenergy cooperation.

Wood fuel generally would consists of traditional firewood, wood harvested for energy from conventional forestry and short rotation plantations, wood residues used for energy purposes, lignin burned at chemical pulp mills and regained wood from e.g. the construction industry. This report concentrates mainly on wood fuel harvested from conventional forestry, but some information is provided on the other wood fuels as well.

Conversion factors:

	odt	MWh	m^3 (solid)
1 odt (oven-dry tonne)	1	4.72	2.36
1 MWh	0.21	1	2.1
1 m^3 (solid)	0.42	0.48	1

2 A short history of harvesting related cooperation within IEA Bioenergy

2.1 What is the IEA?

The International Energy Agency (IEA) is the energy forum of 23 industrialised countries, all of which are members of the Organisation for Economic Cooperation and Development (OECD). IEA was founded in 1974 by 21 member governments agreeing to share remaining oil supplies in the event of severe oil supply disruption, and to coordinate their energy policies.

The following "Shared Goals" were adopted by IEA Ministers at their 4 June 1993 meeting in Paris:

- Diversity, efficiency and flexibility within the energy sector
- Joint response to oil supply emergencies
- Environmentally sustainable provision and use of energy
- Encouragement and development of environmentally acceptable energy sources
- Improved energy efficiency
- Continued research, development and market deployment of new and improved energy technologies
- Undistorted energy prices
- Free and open trade and secure framework for investment
- Cooperation among all energy market participants

In research and development, the IEA promotes collaboration between member governments. The IEA helps member countries to set up collaborative projects for research, development and demonstration of energy-related technologies.

2.2 Bioenergy Agreement

In 1978, the first bioenergy component, the Forestry Energy Agreement, was added to the IEA's R&D cooperation. The collaboration was initiated by Canada, Ireland, Sweden and the USA. Later, the agreement was joined by Austria, Belgium, Denmark, Finland, Norway, New Zealand, Switzerland and the United Kingdom. Both Switzerland and the United Kingdom withdrew some time later, the UK only temporarily. Four Programme Groups, initially Planning Groups, were established (IEA Forestry Energy … 1987):

1. Growth and Production
   — short rotation forestry: species selection, evaluation, breeding, clonal propagation, production biology, management and tending, protection, ecological consequences
2. Harvesting, Processing and Transport
   — harvesting and plantation establishment in short rotation forestry
   — recovery of wood fuel from conventional forestry: harvesting of forest residues, integrated harvesting systems, harvesting of small trees

— processing: database of wood fuel conversion equipment (comminution, drying, screening, aggregation and densification), storage, drying, handling, evaluation methods, ecological consequences

3. Conversion
   — thermal conversion: combustion, direct liquefaction
   — biological conversion: pretreatment of lignocellulosics, conversion of C-5 sugars
4. Systems Analysis (discontinued 1982 as a separate group)
   — joint activities of groups 1, 2 and 3: systems analysis models

In the Forestry Energy Agreement, forestry energy was defined as the use of short rotation forestry biomass and forestry residues to produce clean fuels, petrochemical substitutes and other energy intensive products. In 1986 the scope of the Agreement was widened from forestry energy to bioenergy.

2.3 Wood fuel-related tasks within IEA Bioenergy

The following harvesting-related tasks have been or are being finalised under IEA Bioenergy since the year 1986:

- Task III: Development of improved methods for harvesting, processing and transport of forest biomass for energy from conventional forests (1986—88)
- Task VI Biomass supply from conventional forestry (1989—91)
- Task IX Harvesting and supply of woody biomass for energy (1992—1994)
- Task XII Biomass production, harvesting and supply (1995—97)

Table 1 summarises each countries' participation in the cooperation. Each Activity has typically arranged one meeting or workshop each year, often jointly with some other Activities. The leaders and budgets of the Activities are summarised in. The budgets are only indicative, since current exchange rates have been used to convert Swedish crowns (1986—94) and Canadian dollars (1995—97) into US dollars without deflation. The objectives of the current harvesting-related activities are listed in Table 3.

Table 1. Participation in harvesting-related Tasks and Activities.

Task, *Area*, Activity	AUS	CAN	DEN	FIN	FRA	ITA	NL	NZ	NOR	SWE	SWI	UK	USA	CEC
III (1986—88)														
Harvesting whole trees		x						x		x		x	x	
Harvesting early thinnings		x	x	x				x	x	x		x	x	
Nutritional consequences		x						x		x		x	x	
System analysis		x								x		x		
Standardised evaluation		x						x		x			x	
Chunkwood		x	x	x					x	x			x	
Drying and storage		x							x	x		x	x	
Measurement and evaluation		x								x		x		
VI (1989—91)														
Conventional forestry		x				x				x		x	x	
Integrated harvesting		x	x	x		x		x	x	x	x	x	x	
Harvesting small trees and forest residues		x				x		x	x	x	x	x	x	
Wood preparation, drying and storage		x	x			x			x	x		x	x	
Measurement and evaluation of wood fuel		x		x			x			x		x	x	
Environmental impacts of harvesting		x						x		x	x	x	x	
Economics of wood energy supply systems		x				x			x	x		x	x	
IX (1992—94)														
Mechanisation for short-rotation forestry		x										x	x	
Integrated harvesting systems		x	x	x				x	x	x		x	x	
Harvesting small trees and residues		x		x					x	x		x		
Environmental consequences		x						x		x		x	x	
Storage & drying		x							x	x		x	x	
Transport & handling								x				x	x	
Technoeconomic studies		x							x			x	x	
XII (1995—97)														
Conventional forestry														
Forest management		x	x	x					x	x		x		
Harvesting		x	x	x			x	x	x	x		x		x
Short rotation forestry														
Production systems	x	x	x	x			x			x		x	x	x
Pests		x								x		x	x	
Stock improvement & characterisation		x								x		x	x	
Agricultural energy crops														
Liquid biofuels					x	x								
Lignocellulosic solid fuels			x		x	x	x			x				
Interfacing & system studies														
Feedstock preparation & quality			x							x			x	
Environmental issues		x	x	x				x		x		x	x	
System studies										x			x	

Table 2. Leaders and annual budgets for harvesting-related Tasks and Activities.

Task, *Area*, Activity	**Operating Agent**, Activity Leader	**Annual Budget,** 1000 USD*
III (1986—88)	**S. Andersson, Sweden**	**179**
Harvesting whole trees	C. Goulding/A. Twaddle, New Zealand	26
Harvesting early thinnings	P. T. Brenöe/P. D. Kofman, Denmark	10
Nutritional consequences	W. J. Dyck, New Zealand	26
System analysis	G. Lönner, Sweden	13
Standardised evaluation	W. B. Stuart, USA	13
Chunkwood	B.-O. Danielsson, Sweden	13
Drying and storage	O. Gislerud, Norway	20
Measurement and evaluation	M. Nylinder, Sweden	13
VI (1989—91)	**S. Andersson, Sweden**	**225**
Conventional forestry	J. Richardson, Canada	16
Integrated harvesting	J. B. Hudson, United Kingdom	33
Harvesting small trees and forest residues	B. Stokes, USA	17
Wood preparation, drying and storage	N. Heding, Denmark	26
Measurement and evaluation of wood fuel	J. Nurmi, Finland	16
Environmental impacts of harvesting	W. J. Dyck, New Zealand	31
Economics of wood energy supply systems	H. Knutell, Sweden	31
IX (1992—94)	**J.E. Mattson, Sweden**	**208**
Mechanisation for short-rotation forestry	D. Culshaw, United Kingdom	20
Integrated harvesting systems	J.B. Hudson, United Kingdom	40
Harvesting small trees and residues	J.-F. Gingras, Canada	26
Environmental consequences	T. Smith, New Zealand	26
Storage & drying	R. Jirjis, Sweden	16
Transport & handling	A. Twaddle, New Zealand	13
Technoeconomic studies	C. P. Mitchell, United Kingdom	22
XII (1995—97)	**L. Zsuffa/G. Page, Canada**	**570**
Conventional forestry		
Forest management	J. Richardson, Canada	44
Harvesting	P. Hakkila, Finland	66
Short rotation forestry		
Production systems	S. Ledin, Sweden	88
Pests	D. Royle, United Kingdom	37
Stock improvement & characterisation	G. Tuskan, USA	44
Agricultural energy crops		
Liquid biofuels	M. Wörgetter, Austria	51
Lignocellulosic solid fuels	U. Jorgensen, Denmark	44
Interfacing & system studies		
Feedstock preparation & quality	J. E. Mattson, Sweden	58
Environmental issues	T. Smith, New Zealand	44
System studies	R. Graham, USA	44

* Exchange rate SEK 1 = USD 0.13, CAD 1 = USD 0.73 (October 2, 1997), not deflated

Table 3. Objectives of harvesting-related Task XII Activities.

Area, Activity	Objectives
Area 1 Conventional Forestry	
1.1 Forest Management	• Develop silvicultural strategies and forest management practices for managed and unmanaged low-quality stands • Increase the availability and reduce the cost of wood for fuel. • Develop systems for production of wood for fuel from birch plantation
1.2 Harvesting	• Exchange information and conduct cooperative R&D on: • Harvesting, on-road transport, preparation, handling and storage of wood fuels • Develop harvesting decision support system • Promote commercialisation of new technology
Area 2 Short Rotation Forestry	
2.1 Production Systems	• Tackle non technical barriers • Update SRF production systems handbook • Produce computerised handbook • Investigate black locust for biomass production • Exchange information on SRF mechanisation • Exchange information and conduct cooperative R and D on disposal of sewage sludge and waste waters • Exchange information on relations between production and mechanisation systems
Area 4 Interfacing and Systems Studies	
4.1 Feedstock preparation and quality	• provide the means of evaluating optimal fuel up-grading options • measure the efficiency of supply with respect to the conversion process • develop optimal internal handling systems which aid the development of cost-effective systems
4.2 Environmental Issues	• Evaluate the environmental sustainability of intensive biomass production systems • Evaluate the environmental sustainability of utilising biosolids (wastewater sludge and wood ash) and effluents to increase the productivity of conventional and SR forestry systems • Develop environmental guidelines for deployment of bioenergy technologies and supply
4.3 Systems Studies	• Enhance and extend existing systems models of bioenergy supply and use in order to investigate critical factors in the supply chain conduct comparative analysis of bioenergy systems • Investigate non-technical barriers to the deployment of biomass production and supply systems • Seek innovative and effective solutions to barriers • Facilitate discussion among bioenergy system modellers with the intent of improving bioenergy systems models and reducing redundant modelling efforts

3 Wood fuel reserves

The role of the forests vary a lot in the countries participating - or having participated - in harvesting-related IEA Bioenergy Activities (Table 4). The available amount of wood fuel is naturally related to the future developments in the forestry practices, energy sector, pulp industry and sawmilling industry.

In **Canada** the easiest and most economical source of wood fuel would be the unutilised mill residues (Table 5). The annual estimates are based for following assumptions:

— precommercial thinning and cleaning: 150 000 ha, 40 odt/ha
— logging residues: 1 million ha, 3.3 odt/ha (30 % of available residues)
— thinnings: 16 200 ha, 20 odt/ha
— unutilised residues: CANMET Database 1992

According to another estimate, by CANMET, the availability of logging residues would be as high as 21 million odt. This estimate is likely to include thinning and clearing wood and to refer to all residues produced.

Table 4. Basic country information (population 1996, other data 1994, source: FAO Database 1997).

Country	Forest & woodland area		Industrial roundwood production			Land area	Population
	mill. ha	ha/cap	mill. m^3	m^3/cap	m^3/ha	mill. ha	millions
Canada	453.3	15.3	183.1	6.2	0.4	922.1	29.7
Denmark	0.4	0.1	1.8	0.3	4.3	4.2	5.2
Finland	23.2	4.5	46.1	9.0	2.0	30.5	5.1
Italy	6.8	0.1	4.5	0.1	0.7	29.4	57.2
Netherlands	0.3	0.0	0.9	0.1	2.8	3.4	15.6
New Zealand	7.7	2.1	17.1	4.7	2.2	26.8	3.6
Norway	8.3	1.9	8.6	2.0	1.0	30.7	4.3
Sweden	28.0	3.2	56.1	6.4	2.0	41.2	8.8
Switzerland	1.2	0.2	3.9	0.5	3.3	4.0	7.2
UK	2.4	0.0	8.0	0.1	3.3	24.2	58.4
USA	296.0	1.1	408.9	1.5	1.4	915.9	269.4
Total/Average	827.6	1.8	739	1.6	0.9	2032.4	464.5

Table 5. Technically available wood fuel potential in Canada.

Wood fuel source	mill. odt/yr
Precommercial thinning and clearing	6.0
Logging residues	3.3
Wood fuel fraction from thinnings	0.3
Unutilised mill residues	8.0
Total	17.6

Table 6. Technically available wood fuel potential in Finland (Hakkila & Fredriksson 1996)

Wood fuel source	mill. odt/yr
Precommercial thinning and cleaning	0.5
Wood fuel fraction from thinnings	1.2
Logging residues	3.8
Unproductive stands	0.3
Total	5.6

Denmark is a small country with a limited forest area, but manages to provide a relatively high amount of industrial roundwood and wood fuel. The forest area is expected to increase by 10 % by the year 2010. A characteristic of Danish forestry is Christmas tree and greenery production. This accounts for less than one percent of the country's forest area but provides 30 to 40 percent of forestry income!

The wood fuel potential in Denmark is estimated to be 0.32 million odt, which assumes that 50 % of stemwood in diameter classes below 20 cm is used for energy together with 50 % of all residues.

In **Finland**, logging residues would be the main source of additional wood fuel (Table 6). Practically all mill residues are already used as raw material or as a source of energy.

It is estimated in precommercial thinning and cleaning that wood fuel harvesting would be feasible in one third of the stands and three quarters of the biomass could be harvested. In thinnings, the minimum top diameter for pulpwood is assumed to be 5 cm (currently 7 cm), and the top is recommended to be left in the forest. Should the top diameter of pulpwood remain at 7 cm, an additional 0.8 mill odt of biomass would be available for fuel. Logging residues are assumed to be collected from pine and spruce dominated stands with stemwood yield of at least 400 m^3 and 200 m^3, respectively. A 15 percent reduction has been made for ecologically sensitive areas. Studies indicate that some 70 percent of the residues are recovered. In case all the residues are being seasoned, the potential is reduced by some 30 percent due to the loss of needles. There are practically no short rotation plantations in Finland.

In the **Netherlands**, the technically available wood fuel totals 0.7 million odt (Table 7). In addition, there are some 100 ha of short rotation forstery plantations.

In **New Zealand**, all industrial wood, some 17 million m^3 annually, comes from plantations, which cover 1.5 million hectares. The area of plantations is increasing. For the year ending 31 March 1996, new plantations accounted for 74 000 ha. The industrial stemwood harvest is expected to rise to about 30 million m^3 shortly after the turn of the century. The technically harvestable wood fuel potential is 9.1 million odt (Table 8). Biomass from precommercial thinnings in steep terrain is not expected to be available.

Table 7. Technically available wood fuel potential in the Netherlands.

Wood fuel source	mill. odt/yr
Precommercial thinning and cleaning	0.3
Wood fuel fraction from thinnings	0.2
Clearcuts	0.1
Logging residues	0.2
Total	0.7

Table 8. Technically harvestable wood fuel potential in New Zealand.

Wood fuel source	mill. odt
Precommercial thinning and cleaning	2.1
Fuelwood fraction from thinnings	0.5
Clearcuts	6.5
Total	9.1

Table 9. Wood fuel potential in Sweden according to Swedish University of Agricultural Sciences (SLU) (Trädbränsle 1997).

Wood fuel source	1998	2005
	mill. odt/yr	
Logging residues (final fellings & thinnings)	11.2	16.4
Pulpwood-sized wood from thinnings	2.5	5.0
Residuals etc.	2.6	3.0
Industrial byproducts	3.4	3.4
Regained wood	0.8	0.8
Total	20.5	28.6

The forests of **Sweden** amount to 28 million hectares. The annual growth of stemwood is 100 million m^3 and that of total biomass above ground some 130 million m^3 (solid). The main tree species are Scots pine, Norway spruce and birches. Logging residues represent almost a half of the available wood fuel potential (Table 9).

The figures for 1998 take into account the current ecological restrictions, while the problems related to compensating application of fertilisers and ash are expected to be solved by A.D. 2005. Opinions regarding the wood fuel potential vary considerably. According to the estimates of the Swedish forest industries, the potential in 2005 is less than half (40 %) of the SLU estimate above (Trädbränsle 1997).

There are some 16 000 ha of short rotation coppice plantations in Sweden, 90 percent of which have benefited from subsidy mechanisms. In 1996, some 1 000 ha were harvested with the total energy content of 100 GWh.

There is an increasing interest in the export of regained wood mainly from the construction industry in Germany and the Netherlands. In these countries there are very few energy plants capable of burning solid wood fuels and landfill fees are high. Denmark and Sweden are the principal importing countries. The largest Swedish importer, COCAB in Norrköping, imported some 376 GWh worth of regained wood in 1996 (Trädbränsle 1997).

There are 2,4 million ha of forests in the **UK** representing 10 percent of the country's land area. The main commercial tree species is Sitka spruce which accounts for half of the total annual wood production of 8 million m^3. Other commercial tree species include conifers such as Scots, Lodgepole and Corsican pine, Norway spruce, European and Japanese larch, Douglas fir, as well as deciduous species such as oak, beech, ash and birch. It has been estimated that the total available wood fuel potential in the UK is 1.14 million oven-dry tonnes annually (Table 10).

The share of residuals, i. e. clearing wood, is estimated to be 5 % of the total amount of residues and residuals. Environmental and operational constraints have been taken into account by region as suggested by Forest Enterprise. Additional clear felling consists of premature felling of poor-quality stands, for example. Industries using small roundwood are in the process of increasing the minimum top diameter from 7 to 10 cm thereby releasing an increased amount of logging residues for fuel purposes. Bark quantities are assessed on the basis of estimated production as well as the current and projected other uses of bark. An operational constraint of 75 % has been used for broadleaf woodlands. Arboricultural residues refer to tree removals and pruning in urban and semi-rural areas, as well as adjacent to railways and roads (UK Industry… 1997). So far, thinning operations have not been considered as a potential source of wood fuel in the UK.

Table 10. Wood fuel potential in the UK (UK Industry… 1997).

Wood fuel source*	1998	2013
	1000 odt/yr	
Logging residues and residuals	309	661
Additional clear felling	39	52
Top diameter increase	15	33
Available bark	78	260
Butt reducer chips etc.	16	35
Broadleaf woodlands	203	203
Arboricultural arisings	484	484
Total	1144	1728

* Explanations in text.

4 Utilisation of wood fuels

4.1 Liquors in chemical pulping

In countries producing large amounts of chemical pulp, the burning of the cooking liquor is an important way of utilising wood-based energy. In fact it is mainly the lignin of the wood that is burned while cooking chemicals are largely recycled.

In both Sweden and in Finland, for example, the use of process liquor was some 31 TWh in 1996, equal to 6.5 million odt of wood in each country. The excess energy which is not required in the pulping process itself is typically used by a near-by paper mill or community or transformed into electricity. In New Zealand, the burning of cooking liquor is equivalent to 1.3 million odt.

4.2 Solid wood fuel

The use of solid wood fuels is summarised in Table 11.

Table 11. Annual solid wood fuel consumption (1000 odt).

	Traditional firewood	Small-scale boilers	Power and heating plants	Forest industry	Total
Canada	840	700		700	2240
Denmark			118 (+80*)		118 (198*)
Finland	2200	100	420	2730	5430
Netherlands	40			40	80
New Zealand	550	NA	NA	920	
Norway	920		210	1050	2180
Sweden	2520**		2600	3740	8860
UK	420	21	(400*)	187	628 (1028*)

* Target of current development projects
** Includes small-scale boilers

In **Denmark**, there are between 50 and 100 small-scale boilers (< 0.5 MW) and some 30 power and heating plants utilising some 100 000 odt of forest chips and some 18 000 odt of wood residues. The Danish government has decided that an additional 80 000 odt should be used for generating electricity by the year 2000.

In **Finland**, some 38 percent of the 1,4 million small houses use wood as the principal source of energy. Traditional firewood accounts for 96 percent and chips for 4 percent. In saunas alone some 1.1 million m^3 of wood (0,5 million odt) is burned annually.

In 1995, wood fuel directly harvested from forest for heating plants accounted for only 260 000 m^3 (110 000 odt) or not more than one percent of the total consumption of wood based fuels - despite all the promotion and large expectations. There are some one hundred heating plants utilising forest fuel in Finland. The number of plants is, however, increasing. A new 0,3 TWh plant in

Forssa uses some 110 000 odt of wood fuel, the majority of which is bark and mill residues and the rest, some 20 percent, logging residues.

Forest industries are the main user of wood based energy. Until now, however, there has been little interest in harvesting wood fuel as a separate process. UPM-Kymmene has recently launched a two-year project to study the use of logging residues in energy production at their Kaipola mill. The annual use is expected to be 80 000 MWh (17 000 odt). Different harvesting system alternatives will be tested during the project. Other UPM-Kymmene mills are also studying the possibilities of using logging residues.

In **Sweden**, the capacity of wood fuel co-generators in district heating stations is expected to rise from the current 6.9 TWh to 34 TWh by the year 2010 (1.4 million odt and 7.1 million odt, respectively). The production of electricity in these plants is expected to be 22 TWh by year 2010. Some 2.5 million odt of wood is used for small scale heating. The boilers are typically old. Indeed, 85 % of them are more than 20 years old.

The new Government of the **UK** has set a target of providing 10 % of electricity from renewable energy sources by the year 2010. Only 2 % is currently produced through the national hydro and wind power. Under Non-Fossil Fuel Obligation (NFFO) three power plants based on short rotation coppice came forward after the 3^{rd} round and seven wood fuel based plants ranging from 6 to 18 kW after the 4^{th} round. The total target wood fuel consumption in NFFO 4 is 400 000 odt. In all plants the pyrolysis technology is likely to be utilised. NFFO Round number 5 is on its way.

4.3 Processed wood fuels

Wood fuel processing has become quite popular in Denmark and Sweden. In Sweden, for instance, pellets, briquettes and pulver already account for 18 percent of total production of commercial wood fuels. The industry is partly based on imported regained wood. A new pellet plant has been established on the west coast of Finland to serve the Swedish market.

5 Harvesting systems for wood fuel

In **Canada**, commercial harvesting of wood fuel is based mainly on roadside chipping of unmerchantable whole trees and logging residues. Some 100 000 — 150 000 tonnes (green) are shipped to the U.S. wood fuel market. There are some commercial firewood operations as well, but much of the firewood and small scale wood fuel is harvested by individual forest owners themselves.

In **Denmark**, 60 to 70 percent of wood fuel comes from thinnings and the rest equally from logging residues and land use conversion. Chipping is mostly carried out in the stand. A shuttle tractor normally takes the chips from the forest to a container or truck at the landing.

The **Finnish** systems are mainly based on chipping at the landing with truck mounted chippers. Some terrain chippers, such as Chipset and MOHA terrain truck chipper, are also in operation. Comminution also takes place to a limited amount at terminals or at heating or power plants.

Whole-trees, tree sections and logging residues are mainly transported to the roadside with forwarders. For logging residues, the forwarder may be equipped with a fork grapple and extended load room. For thinnings, the following chain flail techniques are used to some extent for delimbing and debarking tree sections:

— truck mounted chain flail chipper unit
— stationary chain flail, drum debarking and chipping unit
— truck mounted chain flail-crusher unit for production of wood fuel (delimbed and debarked logs transported as roundwood)

There is also a pilot plant for the separation of the fibre and fuel fractions from whole tree chips with grinder and screens, as well as pneumatic and colour separators.

In the **Netherlands**, some trials have been carried out with Danish equipment.

According to a survey carried out in **Sweden** in 1993, some 20 % of specialised wood fuel procurement was based on chipping in the forest, 45 % on chipping at the landing and 35 % on comminution in terminals and at plants. The share of terminal and end-user comminution has already increased and is expected to increase even more.

Harvesting logging residues has the best economy for the time being. The following guidelines have been established (Brunberg et. al. 1994):

— careful selection of the stands to be harvested placing special emphasis on ecological aspects
— harvesting method adapted to wood fuel harvesting
— transport of residues from the stand only after seasoning when the residues are at their driest
— forwarders equipped with extended load room and special grapple
— paper cover for piles to be stored at landings and at terminals
— when transporting uncomminuted material the load is compressed with large loader
— comminution takes place only just before burning, preferably at plant
— chips to be stored have a moisture content of less than 30—35 %

A new concept being applied is the baling of logging residues. There are currently two balers operating. Transport by railway is likely to become a practical alternative for transportation over longer distances (for a system analysis on baling, see Andersson & Hudson 1997).

The use of integrated harvesting systems for industrial wood and wood fuel, such as the tree section system, has declined since fossil fuels are still very competitive in the industrial sector, and distribution systems for delivering the wood fuel section to heating sector have not been developed. In the heating sector wood fuel and other biofuels are competitive due to the high environmental taxes levied on fossil fuels. However, at least two forest industry companies, Södra and SCA, have expressed their interest in energy production and thus continuing the use of the tree section system at a limited scale. The development possibilities lie in multi-tree handling and rough delimbing to reduce the amount of needles and to achieve a higher bulk density in transportation phase.

There is a high potential for wood fuel harvesting in thinning and clearing operations using, for instance, a single-grip harvester and a terrain chipper. The moisture content of the chips can, however create problems in storage and burning, since seasoning of conifers over the summer is illegal due to the risk of pest problems. Rough delimbing of the trees would leave most of the needles at the stand and thus reduce nutrient removals. Some 63 percent of the companies delivering wood fuel are connected to the forest industries, 20 percent to forest owners and 17 percent are independent (Hillring 1996).

In the new wood fuel based electricity generation programme in the **UK** some 20 % of the total of 400 000 odt of fuel is estimated to come from whole tree cable logging operations with single stem delimbers and baling of residues at the landing. Both whole-tree harvesting and the separate collection of residues are likely to be employed in ground-based operations providing some 40 % of wood fuel. The primary conversion of sawlogs (bark and butt reducer chips) and arboricultural material would each account for 20 % of the total.

In the UK, large scale studies have been carried out on harvesting systems. The use of feller/clam bunk skidder resulted in problems when the harvested volume exceeded 7 m^3/m of roadside frontage. The costs were 6.30 GBP/m^3 with tree size of 0.15 m^3/tree and transport distance of 100 m. The operation was more expensive in comparison to harvester and forwarder operation.

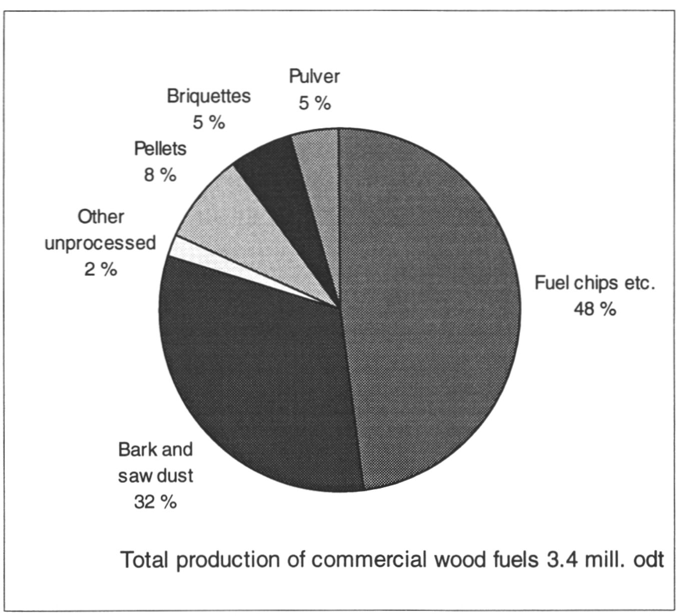

Figure 1. Commercial wood fuel production in Sweden in 1996 (source: Trädbränsle 1997, original source The Swedish Wood Fuel Association).

Good results have been obtained from both long-distance truck transportation of residues and truck/train transport of bales of residues. The baling concept seems to be favoured due to the long transport distances and successful drying trials. In general, central comminution of wood fuel seems to be more economical in comparison to forest/roadside operations. Some of the operations are also likely to utilise chain flail technology. The costs of forest residues are reported to be around 20—30 GBP per green tonne delivered at the plant.

Regarding the quality of wood fuel, the three most important aspects are moisture content, size distribution and cleanliness. The moisture content of stored fuel should be not more than 30—35 %.

6 Environmental considerations

6.1 Nutrient balance

The nutrient balance, especially on poor sites, is a common concern in all the countries studied. Although official guidelines do not exist in most countries, site and species specific recommendations concerning whole tree harvesting and collecting of residues are available. As an example of such ecological restrictions, the Swedish concept - already under modification - is presented in Figure 2. The seasoning of residues in order to reduce the moisture content is favoured in many countries. This has the advantage of increasing the amount of nutrient-rich needles and leaves which remain at the sites.

In **Denmark**, Forestry Commission has classified its own forests (27 % of the forest area) regarding wood fuel harvesting. Ash recycling and fertilisation have also been recognised as useful remedies in certain types of stands. In the **UK**, the Forestry Commission has published a guide regarding wood fuel harvesting, and so-called *Best Practice Guidelines* are being prepared in a joint effort between the industry, authorities and non-government organisations. These guidelines refer not only to nutrient balance but also to other aspects of wood fuel harvesting.

6.2 Silvicultural considerations

Removing logging residues can have an impact on the early survival and growth of regeneration stock due to changes in micro-climatic conditions and increased exposure to the sun. On the other hand, planting and seeding become easier and regular stocking is easier to achieve when the residues are removed.

6.3 Soil damage and compaction

Deep rutting is a concern in non-frost harvesting operations on soils with poor bearing capacity, e.g. clay soils and peatlands. Driving on a brush mat is often recommended in order to reduce soil damage, soil compaction and root damage, especially in thinning operations. On slopes, the residues also reduce water run-off

Area (see map)	Extraction form	Mesic soil / Peat soil: Poor – richer shrubs: coarse	medium	fine	Blueberry – herbs: coarse	medium	fine
1. Areas with pronounced risk of spring frost	Thinning excl. 1st thinnings Final felling			1		1	
	Stumpwood					1	
2. Areas of difficult natural regeneration in the northern zone. Counties: BD, AC& Z Others Altitude below: 400* 500* 600*	Thinning excl. 1st thinnings Final felling			1		1	
	Stumpwood					1	
3. Areas with significant acid-pollutant deposition	Thinning excl. 1st thinnings Final felling						
	Stumpwood					1	
4. Rest of country	Thinning excl. 1st thinnings Final felling		1	1	1	1	
	Stumpwood			1		1	

* In areas at higher altitudes, logging residue should not be extracted in conjunction with thinning or final felling except for sites of the tall-herb and thick-moss types, i.e. with subshrubs and a layer of inactive mor > 10 cm in depth (peat-like and only slightly decomposed).

** As regards stumpwood, 20% of the stumps should be left and evenly distributed over the site.

Areas from which no logging residue should be extracted.

Areas from which about half of the logging residue may be extracted (see item 2)**.

Areas from which most of the logging residue may be extracted (see item 2).

1 Areas from which about half of the logging residue may be extracted, provided that special criteria are observed (see item 3.3)**.

1 Areas from which no logging residue should be extracted, unless special criteria are observed (see item 3.3).

Area divisions

1. Areas with pronounced risk of spring frost. (Counties AB, C, D & E east of road E55–Norrköping road E66, H and I. In addition, all islands off the Swedish coast.)
2. Areas of difficult natural regeneration in the northern zone.
3. Areas with significant acid-pollutant deposition (Counties: K, L, M, N & O).
4. Rest of country.

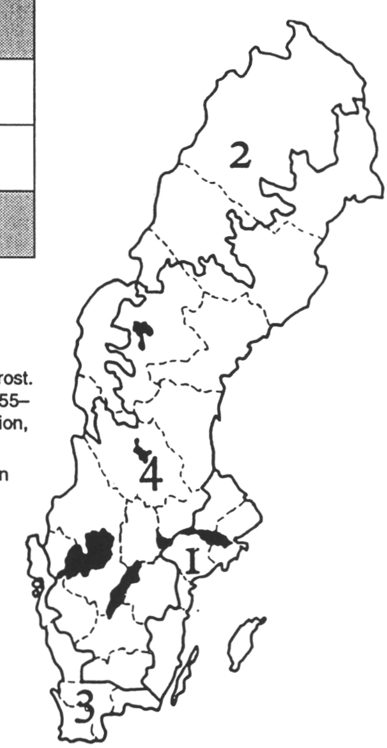

Figure 2. Ecological restrictions regarding harvesting logging residues in Sweden as recommended by the National Board of Forestry.

related erosion. The removal of logging residues can therefore have a negative impact on the soil and cause root rot in thinnings. Soil compaction reduces tree growth and increases the risk of soil erosion through reduced infiltration capacity of the soil. In Denmark, soils are mainly sandy and so soil compaction is not a serious problem. Nevertheless, the Danish Forestry Commission currently demands wide tyres on all forestry equipment operating on their lands. There are implications that central tyre inflation systems will also become increasingly popular.

6.4 Emissions

Emission-related problems in wood burning installations are only related to open fireplaces and small-scale burners. In **Denmark**, there is a subsidy programme for approved biofuel burners. The Danes are also studying possibilities of equipping harvesting machinery with catalysts to reduce emissions during the harvesting phase.

6.5 CO_2 fixation

The same amount of CO_2 is released from wood combustion than would be released by the natural decaying process. Provided that the forestry cover, growth rate and mortality remain constant, burning wood fuel does not essentially affect the CO_2 level. On the other hand, new forests and short rotation plantations act as carbon fluxes reducing the negative effects of CO_2 emissions from fossil fuels. This has been recognised in all countries studied. In Denmark, the forest area is being increased by 10 to 25 percent in order to increase CO_2 fixation. The programme will be grant aided for 20 years. Subsidies for planting and weeding are also available.

Table 12. Estimate on new work opportunities in case wood fuel use increases 10 million m^3/a (Hakkila & Fredriksson 1996)

Component	Work years per mill. m^3	Use mill. m^3/a	Work years total
Wood fuel component from first thinnings	50	1	50
Whole tree chipping of small-sized trees	675	4	2700
Logging residues from regeneration cuttings	240	5	1200
Total procurement	395	10	3950
Heating/power plants	90	10	900
Total direct jobs	485	10	4850
Indirect jobs	630	10	6300
Grand total	1115	10	11150

7 Employment

In Finland, Hakkila and Fredriksson (1996) have estimated that the increase of wood fuel by 10 million m^3 (4.2 million odt) would create altogether 4850 new direct jobs (Table 12). The number of indirect jobs created is estimated to be 1.3—fold giving a total of 11 150 new jobs. This is equivalent to 265 jobs per 100 000 odt. Other estimates have also been in the range of 200 to 250 new jobs per 100 000 odt - excluding indirect jobs. For example, Danielsson (1996) estimates that the employment effect of wood fuel harvesting in Sweden is 200 direct jobs per TWH (95 jobs per 100 000 odt) and about 400—450 jobs/TWh including indirect jobs.

8 Policy

The **Canadians** have begun to recognise the forest biomass as a sustainable, CO_2 neutral energy source, but so far few economic, policy or taxation incentives exist.

All fuels are subject to the federal goods and services tax (GST, 7%). No extra taxes are placed on wood fuel, but other energy sources are taxed up to 30 % of total unit cost. There are incentive schemes for remote native communities for establishing district heating systems. Financial support includes infrastructure and start-up costs. The national sustainable forestry standards (CSA) may lead to an increased use of wood fuel within the forest industry.

A new 20 million CAD programme for the renewal of heating and cooling systems, as well as for increased energy efficiency, has been launched in the commercial and industrial sectors. The mechanisms, however, are not clear for the time being. There is also a possibility for accelerated write-off (30 % depreciation) for plants using wood for generating electricity or producing steam for industrial use (for comparison, the depreciation for heating investments is only 4 %). In British Columbia, plants obtain a bonus for generating electricity from wood waste.

In **Denmark**, 50 % of the households are on district heating. So far, natural gas has been favoured in district heating, while municipalities lying far from the gas line - often on the coast - rely more often on biofuels. Coal is prohibited in district heating stations and light fuel oil may only be used as additional fuel during peak periods. Households receive subsidies to convert from electric heating to district heating, gas, biofuels etc. All fuels are subject to value-added tax and, with exception of wood fuel, also to CO_2 tax and fuel specific other taxes. Through taxation, renewable fuels are made competitive in comparison to fossil fuels.

With respect to electricity generation, the electricity companies in Denmark are required to increase the use of straw and wood fuel for generating electricity. At the same time they are allowed to charge a higher price for the electricity produced with these fuels.

The aim of the Danish energy policy is that by the year 2020 some 30 percent of the total energy consumption in the country should come from renewable sources (wind, solar, biomass, municipal waste etc.). Subsidies for innovative power and heating plant projects are available nationally and through also EU. There is also a clear shift towards co-generation plants.

In **Finland**, the CO_2 tax in heat production is FIM 70 per each ton of CO_2 (Table 13). Natural gas gets a 50 percent tax discount until the end of the year 1997. Only 17 % of the CO_2-tax has to be paid in the case of peat. Wood is exempted from all fuel taxes and fees. In 1998, the taxes are likely to increase by 15 to 20 percent. Nevertheless, environmental fuel taxes in Finland are only a fraction of those in effect in Sweden and Denmark.

No fuel taxes apply in electricity generation in Finland, rather the consumers pay an electricity tax. Class I electricity in Table 13 refers to household consumption etc. and Class II to industrial and horticultural consumption. For the following 5 years, all power plants less than 40 MW in size and using domestic fuels will be supported by means of a 16 FIM/MWh tax refund. In 1998, this support is likely to be available to all electricity produced with wood fuel regardless of plant size. Both electricity tax and the tax refund will increase in 1998.

Table 13. Fuel taxes in heat production and electricity tax in Finland.

	Basic	CO_2	Service security fee	Total	FIM/MWh
Fuel peat, FIM/MWh		4.2		4.2	4.2
Natural gas, FIM/1000 m^3		142	5	147	14.7
Coal, FIM/t		169	7	176	24.8
Light fuel oil, FIM/m^3	104	186	21	311	31.3
Heavy fuel oil, FIM/t		221	17	238	21.1
Electricity, Class I, FIM/MWh		33	0.75	33.75	33.8
Electricity, Class II, FIM/MWh		14.5	0.75	15.25	15.2

1 FIM = 0.26 CAD = 0.19 USD (Oct 8, 1997)

Table 14. Fuel taxes in heat production in Sweden as of Jan 1 1997, rounded figures (Prisblad 2/1997).

Fuel	Industry					Others				
	Energy	CO_2	S	Total	SEK/ MWh	Energy	CO_2	S	Total	SEK/ MWh
Fuel oil 1 (<0,1 % S), SEK/m^3	-	263	-	263	27	654	1050	-	1704	172
Fuel oil 5 (0,4 % S), SEK/m^3	-	263	108	371	34	654	1050	108	1812	168
Coal (0,05 % S), SEK/t	-	228	150	378	50	278	913	150	1341	177
Gas oil, SEK/t	-	275	-	275	21	127	1101	-	1228	96
Natural gas, SEK/1000 m^3	-	196	-	196	18	212	785	-	997	92
Peat (0,2 % S, 45 % MC), SEK/t	-	-	40	40	15	-	-	40	40	15
Other biofuels	-	-	-	-	-	-	-	-	-	-

SEK 1 = USD 0.13 = CAD 0.18 (October 8, 1997)

Based on silvicultural criteria, regional Forestry Centres may approve a 5.70 USD/m^3 subsidy for harvesting energy wood in certain young stands.

Investment support is available for power and heating plants in the **Netherlands**. An energy tax is levied on fossil fuels, excluding industry. **New Zealand** reports no policy tools favouring wood fuel. In **Norway**, CO_2 taxes are levied, and there has also been an investment subsidy since 1997.

In **Sweden**, the use of wood and other biofuels is mainly promoted through fuel taxes (Table 14), which make biofuels competitive in the heating sector. Further increases have taken effect as of July 1, 1997, when energy tax was increased by 2 %. For plants with a production of over 25 GWh there is also a fee for nitrogen oxides amounting as 40 SEK/kg of NO_2 equivalent. Furthermore, the Swedish government has decided that the industry should pay 50 % of the CO_2 tax instead of the current 25 %. However, Parliament has not so far ratified that measure.

As explained earlier, the new **UK** Government has set a target of generating 10 % of electricity from renewable energy sources by the year 2010. The plants currently planned will have a guaranteed price of 0.057 GBP/kWh for the first 15 years of production: the current price for existing power plants is 0.024 GBP/kWh. Since new technology such as pyrolysis is likely to be utilised in all plants the projects may be subject to EU funding.

9 National wood fuel related research funding

Canadian Forest Service uses some 1 million CAD/yr for wood fuel related research in biomass production, including short-rotation forestry. CANMET's research funding is some 3 million CAD including bioenergy conversion.

The **Danish** funding is estimated to be equal to 5 to 6 man-years.

In **Finland**, the six-year, USD 40 million Bioenergy Research Programme will continue until the end of the year 1998. It is funded by the Technology Development Centre Finland (TEKES) Ministry of Commerce and Industry (29 percent in 1996), Ministry of Agriculture and Forestry (8 %) as well as companies and other sources (57 %). In 1996, some 55 percent of the funding was directed towards production of wood fuels. In 1996, there were 36 wood fuel production projects in existence , 16 research, 10 industrial and 10 demonstration projects. The respective share of financing was 60, 7 and 32 percent.

In both the **Netherlands** and **Norway** research funding is some 1 million USD annually. Main funding body in the **Swedish** wood energy research is NUTEK with some 46 million SEK per year. Some 300 researches and 100 companies are involved. In the **UK,** the Department of Science, Energy and Industry funding for wood fuel related research through Energy Technology Support Unit is GBP 150 000.

There is a trend for governments to intervene less directly with more reliance on market forces to achieve energy policy goals. However, governments' roles in setting market rules are becoming more important. A key finding is of this survey that there is a greater emphasis on government's roles as regulators and arbitrators to ensure the proper functioning of the market consistent with overall, including long-term, policy goals (The Role of IEA... 1996).

10 Barriers to the increased use of wood fuel

The barriers were rated on a scale from 1 (low barrier) to 5 (high barrier) by the country representatives. A summary of the results is presented in Table 15 and 16. The biggest technical barriers seemed to be the lack of plants using wood fuel. In addition, the non-existence or unreliability of logistics and distribution systems were considered problematic areas on technical side. The improvement of logistics and the management of wood fuel supply chains was seen as one possible way to improve the efficiency and economics of operations. The fuel is also too heterogeneous for some users. The establishment of quality standards would help to maintain a minimum quality level in plants with technical problems but also international trade and exchange of information would be a benefit. Quality standards could include size distribution, moisture content, particle shape, calorific value, inorganic contamination, fungal contamination, ash content, ash quality and contents of pollutants.

Table 15. Technical barriers.

Technical barriers	AVG	STDEV	Min	Max
Lack of heating/power plants using wood fuel	3.9	1.3	1	5
Lack of large-scale, year-round users of wood fuel	3.8	1.6	1	5
Lack of information on environmental impact of wood fuel harvesting	2.5	1.0	1	4
Lack of suitable equipment and methods for harvesting wood fuel	2.3	1.3	1	5
Lack of information on environmental impact of burning wood fuel	2.2	0.9	1	4
Lack of suitable equipment and methods for transporting wood fuel	1.9	1.0	1	4
Lack of suitable equipment and methods for burning wood fuel	1.6	0.7	1	3

Table 16. Non-technical barriers.

Non-technical barriers	AVG	STDEV	Min	Max
Spokesmen and lobbyists representing other sources of energy are more effective	3.6	1.3	1	5
Lack of incentive mechanisms to promote the use of wood fuel	3.5	1.5	1	5
Lack of awareness of the positive impact on national and regional economy among potential investors, users and legislators	3.3	1.3	1	5
There are no spokesmen nor lobbyists for wood-based energy	3.2	1.3	1	5
Lack of confidence in the technology among potential investors and financiers	2.9	1.1	1	4
Lack of awareness of the technology among potential investors, users and legislators	2.2	1.0	1	3
The legislative framework discriminates wood fuel as energy source	2.0	1.3	1	5
Public opinion is against the use of wood for energy	1.8	0.8	1	3

According to the interviewees there is sufficient information on the environmental impact of burning wood fuel in large plants, but more research would be needed on small scale burning of wood.

Even though much suitable equipment and many methods already exist, some interviewees considered that the systems were not sufficiently economical. Economics are, of course, the overall limiting factor for the increased use of wood fuel. The economy of harvesting wood fuel naturally depends on individual conditions, not least on the policy tools applied.

11 Developments during past ten years

In **Canada**, there has been an initial increase and then a subsequent decline in wood fuel harvesting. In Eastern Canada, logging residues were processed for the U.S. electric power industry but that has declined. On Prince Edward Island, municipal waste has replaced wood fuel as a source of energy.

The trend from full-tree extraction systems to cut-to-length systems makes the collection of forest residues more expensive. Household use of wood fuel has been relatively steady. There has been an increase in the firewood industry with some 30 % currently exported to the U.S. Pulp mills are utilising bark, residues and cooking liquor in their burners. District heating in remote native communities is a new federal initiative. There have been difficulties in developing cooperation with the large number of communities. Anyhow, the annual wood consumption in there plants would be less than 1000 m^3 per plant.

Research under Forestry Canada's forestry bioenergy program ENFOR and CANMET's bioenergy development program has been active. Removal of federal excise tax from ethanol produced from biomass (initially corn) for use as gasoline additive has been seen as the first step towards the removal of non-technical barriers to the use of biofuels in Canada. Other steps will also be needed concerning other forms of bioenergy use, such as heat and power generation.

In **Denmark**, harvesting equipment has matured and productivity has tripled. Logistics of the operations still remain a problem. The consumption of wood fuel has doubled during the past 10 years, and is expected to double again within five years. All power plants have been equipped with condensing units giving an efficiency of 110 to 125 percent based on the lower heating value. Research has been redirected from productivity and development to fuel quality and environmental issues.

In **Finland**, the use of chips declined since mid 1980's, but has begun to increase again in the mid 1990's. An interest in utilising logging residues after regeneration fellings has expanded with the increased number of heating plants capable of using wood fuel. Since 1992, some 50 heating contractors responsible for wood fuel production, delivery and the work at the heating plants have started to run plants in the scale of 0.1 to 1 MW. As indicated earlier, forest industries are becoming more involved in the wood fuel sector. **Norway** reports little interest in wood fuel, except traditional firewood.

In the **Netherlands**, there has been a growing interest in wood energy since 1994. The first wood fuel harvesting trials were carried out in 1996, and the first plans for building plants were made in 1995. Commercial scale operations are expected to start in 1998 or 1999. The main types of operations are district heating (in competition with natural gas) and power production at the 10 to 20 MW scale, as well as cofiring in power plants using coal.

Wood fuel harvesting has a very low profile in **New Zealand** since there are lower cost alternatives for energy production. Nonetheless, waste around landings appears to be a possible source of wood fuel that might be harvested at a competitive price.

In **Sweden**, introduction of baling is one of the most promising new technology especially as comminution is moving towards terminals and users. A number of new wood fuel companies have been established, and the pellets industry is expanding. The users of pellets are typically small industrial users. The operating climate is favourable in Sweden, and there are less regulatory obstacles to building plants than earlier. Machine manufacturers are also showing an increasing interest in the wood fuel sector.

In the **UK**, the industry is getting highly involved in bioenergy. Licences to build wood fueled power plants are finally in sight. There is also a consensus in sight for best practices in wood fuel harvesting. A number of new concepts have been introduced through IEA Bioenergy cooperation.

12 Evaluation of cooperation under IEA Bioenergy

12.1 Advantages and disadvantages

The research cooperation in forest harvesting under IEA Bioenergy was evaluated by the country representatives by rating a number of statements with a scale from 1 (low national interest/concern) to 5 (high national interest/concern). The summary of the results are presented in Table 17 (Advantages) and Table 18 (Disadvantages).

Promotion of networking scored highest. In fact a good network is a prerequisite for most of the other advantages of cooperation. The network has also led to other forms of cooperation, like consultancies and joint research projects, especially within the EU.

Staff development in international matters was also ranked very highly among the participants. The number of people involved was relatively low, however.

The examples of successful *technology transfers to the home country* through IEA Bioenergy cooperation include the importation of the flail techniques from the USA to Finland. Finland has also benefited from the logging residue techniques developed in Sweden. The Swedish baler concept is likely to be adapted in the UK, and the information has even been passed over to Ireland - so-far a non-participating country.

Cooperation within IEA gives the participating institutions more credibility and international flavour which may have *positive impacts on national research.* To some extent, cooperation also helps to clarify the country profiles of the participating nations.

IEA cooperation is also a *promotion and marketing channel for national technology and know-how*. Equipment manufacturers get the opportunity to show their equipment during excursions arranged in connection to meetings and workshops. For example, Silvatec chippers and harvesters from Denmark have been successful in the UK, Holland and Germany partly through the links established within IEA. Consultancies have also become more common.

Increasing the interest of industry towards research has so far not been very successful. More industrial involvement in meetings and workshops would be needed. At least in Denmark, IEA Harvesting Newsletters are circulated within the industry. Such practices, and direct invitations to meetings and workshops, might remedy the situation.

Savings through cost sharing did not rank very high. Savings may appear through successful joint research projects and through the exchange of information regarding new technologies. The testing of baling in Sweden and the UK is one example of this.

In general, the disadvantages of IEA cooperation were minimal. Even views concerning the additional costs involved varied a lot. The interviewees, who had not received any funding through the Activities, were somewhat unhappy - especially in cases were the national funding to participate in the meetings was difficult to obtain. In general, it was seen that the participating countries should provide means for active participation.

Table 17. Advantages of cooperation.

Advantages	AVG	STDEV	Min	Max
Promoting networking	4.3	0.8	3	5
Staff development in international matters	4.0	0.9	3	5
Technology transfer to home country	3.9	1.3	1	5
Positive impact on national research	3.6	1.1	2	5
Improving national image internationally	3.3	0.9	2	5
Promotion and marketing channel for national technology and know-how	3.0	1.2	1	5
Increasing the interest of industry towards research	2.9	1.2	1	5
Savings through cost sharing	2.8	1.6	1	5

Table 18. Disadvantages of cooperation.

Disadvantages	AVG	STDEV	Min	Max
Additional costs	2.6	1.3	1	4
Scarce national resources are distributed into a variety of small projects	1.8	0.8	1	3
Increased external guidance	1.4	0.7	1	3
Know-how and technology leaking abroad	1.1	0.3	1	2

12.2 Alternatives/Complements for IEA Bioenergy cooperation

The interviewees could not see any real alternatives for the IEA Bioenergy cooperation. Instead, national programmes and projects, direct contacts to international partners and cooperation through EU were all seen as valuable complements for the current cooperation.

12.3 Future form of IEA Bioenergy cooperation

The current form of cooperation seemed to be satisfactory to the interviewees. The importance of national programmes and the integration of IEA cooperation and the national programmes were emphasised in some comments. Certain synergy benefits exist in cases were the same organisations are acting as contracting agencies both with the national programme and the IEA. Separate small joint projects did not obtain much support. According to some interviewees, the funds available for joint research under the Tasks and Activities should be spread more evenly among the participating countries.

13 Discussion

In all countries, the potential for the use of wood fuels is very high compared to the current situation. In some countries, like Canada, unutilised mill residues would be probably the cheapest source. In many other countries, in which mill residues are practically fully utilised as raw material or for energy production, the cheapest source of additional wood energy would be logging residues. However, this is a question of economy. Particularly in Canada, New Zealand and Norway there are cheap alternative energy sources, since policy tools to promote the use of wood are limited or non-existent.

It has been argued, that environmental taxes are better policy instruments than subsidies - at least less bureaucracy and control would be required. New issues such as carbon balance, sustainable forestry principles, certification in forests, environmental management systems and need for even greener image within the forest industry, are likely to increase the decision makers' interest in promoting the use of wood fuel in the future, particularly in countries where other domestic sources of energy are scarce.

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