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HARVESTING SMALL STEMS AND RESIDUES FOR BIOFUELS: AN INTERNATIONAL PERSPECTIVE

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SUMMARY:

The International Energy Agency, an autonomous body within the OECD, encourages R&D in the harvesting of forest biomass for energy through international collaboration in two harvesting Activities. In spite of the decrease in real price of crude oil many countries continue to recover forest biomass for fuel, although the justification for doing so varies.

KEYWORDS:

Biomass, Harvesting machinery, Fuel, Chips

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HARVESTING SMALL STEMS AND RESIDUES FOR BIOFUELS: AN INTERNATIONAL PERSPECTIVE

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Introduction

After the 'oil crises' of the 1970's considerable R&D effort was expended on the collection and utilization of forest biomass for biofuels. The peaking of oil prices following the weakening the OPEC cartel has lead to a reduction in this research effort. Many countries, however, still maintain a program of forest biomass collection, either through normal commercial practice, or government aided programs.

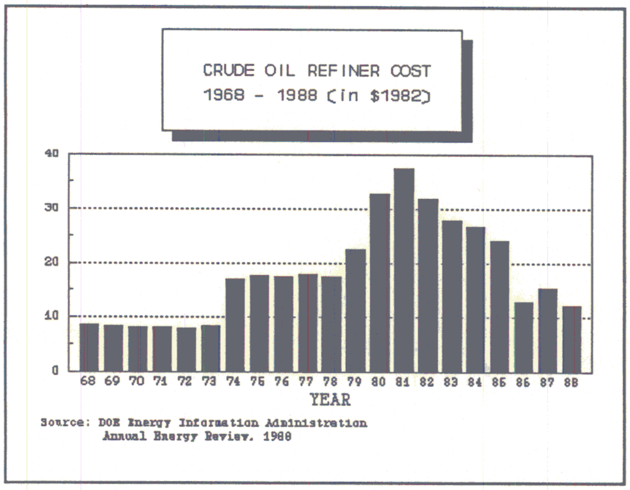
An international collaborative organization, the International Energy Agency, has a Bioenergy Agreement, which maintains a broad perspective on the development of fossil fuel substitutes from biomass. The rationale for most countries to contribute to this organization is based on an anticipation that oil prices will again rise, and the technology required to recover and process forest biomass may need to be quickly implemented.

This paper discusses the R&D role of the International Energy Agency (IEA) in the field of continuing the development of harvesting and processing of forest biomass for biofuels. It also highlights the developments in the area of small tree and residue collection for energy in those countries which participate in co-operative research and information exchange via the Bioenergy Agreement. Much of the information presented below was taken from presentations at various recent international seminars and workshops held under the Bioenergy Agreement.

BACKGROUND

In most industrialized nations the use of forest biomass for industrial energy purposes, primarily heating, has been reduced considerably over the last two to four decades. The increased use and dependency on oil and gas, and in some countries nuclear power, has lead to this decline. The main reason for the growth of fossil fuels usage has been their competitive price with other energy sources. Even following major price increases in the 1970's, which for a short period caused considerable impact, real crude oil price has subsequently declined.

The figure below giving the constant dollar price of crude oil refiner acquisition cost (composite of imported and domestic sources) is for the United States, but this trend was duplicated for most western nations. Prices rose sharply from 1973 to 1974, then took a further rise from 1978 to 1981. Since 1982 real price has fallen so that in 1988 the real price paid for crude oil at US refineries was similar to the 1974 price.



Much has been said regarding to the benefits of using renewable energy sources, such as biomass, wind and solar energy etc, as opposed to non-renewable energies, but at least in the short term most of these systems have not been able to stand alone in the cost-competitive market place. Where the use of biomass has expanded, this can often be traced to political decisions altering the cost structure rather than free market forces.

The forest industry is in the best position to increase the consumption of forest biomass. Considerable qualities are already utilized, but most, such as bark, are the by-products from materials already reaching the mill site. Few organizations actively seek additional material from the forest, although in most countries considerable quantities of forest biomass are available. With one metric green tonne of chipped forest biomass being approximately equal to one barrel of bunker 'C' oil in energy content, there exists a considerable storehouse of potential energy in forest biomass presently unutilized.

INTERNATIONAL ENERGY AGENCY

In 1974 the International Energy Agency was formed as an autonomous body within the framework of the Organization for Economic Co-operation and Development (OECD) to implement an international co-operative energy program. Twenty-one of the OECD's twenty-four members joined the IEA.

A broad based energy program was developed to address the basic aims of IEA. These are:

i) co-operation among IEA participating Countries to reduce excessive independence on oil through energy conservation, development of alternative energy sources and energy research and development;

ii) an information system on the international oil market as well as consultation with oil companies;

iii) co-operation with oil producing and other oil consuming countries with a view to developing a stable international energy trade as well as the rational management and the use of world energy resources in the interest of all countries;

iv) a plan to prepare Participating Countries against the risk of a major disruption of oil supplies and to share oil in the event of an emergency. (Anon, 1982)

The Paris based IEA is therefore a self interest group consisting of mainly Western nations who wish to protect themselves from future disruptions in oil supply by co-operation in the oil market, and in the development of conservation means, and in alternatives to oil. The IEA sponsors a number of research areas covering a wide range of energy technologies including nuclear fusion, geothermal energy and wind energy. With the historic importance of forest biomass as an energy source, it is not surprising that in late 1977 a forestry agreement became part of the research programme of IEA.

Recently this agreement has been converted from specifically forestry to bioenergy by including other sources of biomass. After this change it is now called the Bioenergy Agreement, but it still retains a strong forestry content. Fourteen countries co-operate under the Bioenergy Agreement: Austria, Belgium, Canada, Denmark, Finland, Ireland, Italy, Japan, New Zealand, Norway, Sweden, Switzerland, United Kingdom and United States.

CO-OPERATIVE RESEARCH UNDER IEA BIOENERGY AGREEMENT

Under the umbrella of the Forest Biomass and subsequently Bioenergy Agreement, co-operative development work on harvesting systems for collection and processing of forest biomass has been undertaken since 1978.

Some of the early projects were large scale aiming toward the development of hardware. With the lessening in urgency for recovery of additional biomass, emphasis within the various IEA projects has also altered, from development to scientific exchange. Objectives now emphasize the exchange of information and concepts to keep those specializing in bioenergy work aware of developments in participating countries, rather than investing large amounts of resources on limited life span developments.

Under the present structure of the Bioenergy Agreement the collection of forest biomass for biofuels is handled under two Activities. One is entitled "Integrated Harvesting Systems" and has the objective,

> ***"To develop systems for harvesting wood for energy from conventional forestry in conjunction with traditional logging assortments in one-pass operations including consideration of transport, system evaluation, economics and environmental implications"***

The second harvesting oriented Activity is "Harvesting Small Trees and Forest Residues". The objective for this project is,

> ***"To develop systems for the harvesting small trees and forest residues in conventional forestry including consideration of transport, system evaluation, economic and environmental implications".***

Countries participating in these two Activities are Canada, Denmark, Italy, Finland, New Zealand, Norway, Sweden, Switzerland, United Kingdom, and the United States. These two projects provide channels for communication amongst both researcher and field practitioners. They have a limited life, commencing in January 1989 and concluding December, 1991, and must regularly satisfy a controlling body that they are making progress towards their goals. Both projects have already held meetings to bring together the international representatives and present developments in areas pertaining to each topic.

To illustrate the on-going work on forest biomass recovery in each of the nine countries which participate in the harvesting project of the Bioenergy Agreement, a summary of the activities in small stem and residue harvesting for forest biomass is presented. Because Italy and Switzerland are recent entries into the harvesting projects, and their representatives have not yet had the opportunity to present developments within their countries, discussion of activity within these two countries has been excluded.

CANADA

Background

Canada with its large forest base of 195 million hectares, and producing over 175 million m^3 annually, has a significant potential for the production of biomass fuels. An estimate of the amount of forest biomass available for energy from forests harvested for conventional products is 65 to 70 million m^3. In some areas the amount of material left unharvested on the site can exceed the amount harvested for conventional products. (Pottie, 1987)

Regionally the western part of Canada, especially British Columbia, has the largest surplus of supply, both in absolute and proportional terms. Ontario and Alberta are the only provinces with practically no surplus residues available for utilization, while the Atlantic provinces have only limited supplies at mills. (Owens, 1988)

In western Canada the considerable supplies of forest residues available for utilization come from both sort yard debris and logging residues. Several publications, mostly emanating from the Forest Engineering Research Institute of Canada (FERIC) in the early 1980's, covered the opportunities to recover and utilize this material. Total annual biomass availability in British Columbia alone has been estimated at approximately 23 million odt (oven dry tonnes), not including a potential 17 million odt from the biomass harvesting of non-commercial forest. However in spite of this availability, and that the forest industry in British Columbia accounts for about 80% of the total industrial energy consumption, the utilization does not tap this potential. Among the many reasons for this are the availability of subsidized oil and natural gas, and the lack of an institutional arrangement to compensate the electric utilities for the associated benefits of co-generation. (Manning, 1987)

Eastern Canada also has a large opportunity to recover small stems and residues for fuel however actual recovery is relatively low, the majority of forest biomass being utilized is from mill sources; bark, sawdust, slabs, etc. Forest biomass utilization does however still occur. On Prince Edward Island for example, recent construction of a number of institutional heating system using fuel chips has allowed the maintenance of an integrated collection and processing system for forest biomass. (McKnight, 1988)

Harvesting Systems

In Western Canada logging systems are primarily processing tree or log length in the stand, and extraction to roadside by either cable or ground systems. Often this material is then transported to a central site for further sorting and processing before being sent to its final processing site. Significant quantities of residues are created at the central sort yard locations. However as they are often distant from a potential utilization source, this material often creates a disposal concern rather than being an asset. Recovery of material from thinning and stand residues is at a very low level because of its low value.

Because of a smaller tree size and generally flatter terrain, logging systems in the East differ from those in the West. Mechanized felling with skidder extraction to roadside, and stroke delimbers processing from stockpiles, is the most common harvest system (Gingras, 1989). The most common method to produce fuel chips in the forest is to take advantage of this system and process the material left at the road side by the main harvesting operation. Chippers used in this role range from the larger scale Morbark 22[1], to the smaller Trelan D6.

In addition a number of chipper-forwarder units are also being used to chip residue material, slash and small stems, left on the cut-over. These off-road units are the Bruks 800CT and 1001CT.

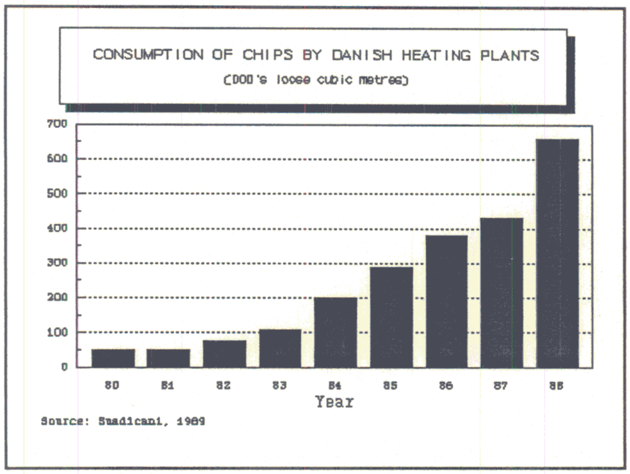
An estimate by Guimier, 1989 puts the roadside recovery and transportation (100 km) of residue material results at a delivered cost of about $Can 23/green tonne (gt). This is still above the equivalent crude oil price, indicating why the use of this system has not expanded in spite of a ready availability of raw material.

SUMMARY: ***Residue recovery concentrated in the East, significant potential to collect additional material put currently uneconomical.***

DENMARK

Background

Denmark has a relatively small forest base with approximately 500,000 hectares of predominately Norway Spruce and Beech. Interest in the harvesting of small stems in Denmark is high because of the strong market for pulp logs in Sweden, and increasingly, a demand for energy chips for the district heating plants in Denmark. The energy chip market has moved from 50,000 m^3 in 1982 to 700,000 m^3 (Loose volume) in 1987, boosted by government incentives for oil-alternative fuels via a heavy taxation (VAT) on fossil fuels.



Harvesting Systems

R&D in Danish harvesting systems has concentrated on utilizing the higher level scandinavian harvesting systems for thinning. Combinations of motor manual felling and bunching, in-woods chipping, and forwarding to roadside of whole trees and tree sections for roadside chipping. Medium sized feller bunchers, such as the Kockum 81-11 are commonly used, and for in-woods chipping, small tractor mounted chippers such as the front-fed Hafo.

[1]The use of trade names is for the reader's convenience, and is not an endorsement by Mississippi State University, or the USDA Forest Service.

Mechanized felling and bunching in skid rows, followed by in-woods chipping has shown most promise during recent whole-tree chipping trials. In more difficult terrain motor-manual felling and bunching at roadside, or in larger skid rows with a mini-skidder has shown potential (Suadianci, 1989).

SUMMARY: ***High demand for fuel chips collected mainly from thinnings. Demand boosted by Government energy taxation structure.***

FINLAND

Background

Finland has a forest base of 20 million hectares producing 54 million m^3 per annum, of which less than 30% comes from thinnings. Finnish silvicultural practice incorporates usually three thinnings, before final clearfell at age 70 to 90 years. Finland has considerable potential to increase harvesting volumes, especially from first thinnings, where tree size is only around 0.025 to 0.05 m^3.

Like most other developed nations the share of wood-based fuel in Finland's energy production has decreased, from 45% in 1960 to 10% in 1986, but this still represents a higher proportion than in many other countries. Most use is from farm owners who harvest from their own resources, and the forest industry which utilizes wood wastes from its own facilities.

Based on a national Energy Policy Program developed in 1983, wood based fuels were to be increased to the equivalent of 6 million m^3 by the year 1995. The drop in crude oil price since this date has brought to a stop this trend of increasing utilization of small wood for fuel (Petäjistö, 1988). Forest chips as a fuel source are now meeting strong competition from peat, oil and electricity, although revenues of small sized timber allow for significant potential in the increase of harvesting for wood fuels most of Finland.

The potential to increase the use of industrial wood wastes is seen as limited as this source is already well utilized. Farm use is already high so the expansion of the fuel wood chip market from small trees is through the fuel market in district heating plants (Hankala, 1988).

Harvesting Systems

Harvesting in Finland is almost exclusively by a shortwood system, using both motor-manual and highly mechanized techniques.

Because of the ownership structure of the forests, about 30% of the annual volume harvested in Finland is by farm tractor based systems, both by farmers and small scale contractors. The remainder is harvested by larger contractor-based operations, increasingly dominated by the use of grapple harvesters. These are used mainly in final thinnings, but a growing number are also working in third or second thinnings. Farm tractor mounted processors and harvesters are still too expensive for use by other than contractors harvesting over 5000 m^3 per year.

Several companies in Finland, as in Sweden, have invested in new drum debarking technology which will allow both debarking and delimbing within the drum. This is usually utilized on small trees which expensive to delimb, thus delimbing function can be eliminated from the harvesting operation. This allows for a more cost effective first thinning operation and more raw material, both pulp and residues can be taken to the mill. As crude oil prices have fallen, this option is not as cost competitive, but it does allow those installation to have a more flexible energy policy, especially if oil prices fluctuate in the future (Mikkonen, 1989).

SUMMARY: ***Fuelwood forms significant part of national energy budget, but there is potential to collect more from thinnings. The forest industry have adopted use of central processing techniques via adjusted drum delimbing-debarking to integrate biofuels collection.***

NEW ZEALAND

Background

The commercial harvest volume in New Zealand is currently 10 million m^3 per annum, of which about 10% is obtained from thinnings, produced from one million hectares of pine plantations. An additional 500,000 m^3 per annum is collected for the use as household fuelwood.

Like many other developed countries New Zealand is heavily dependant on imported oil as an energy source, most of which is consumed by the transportation industry. In the 1970's the discovery of a large natural gas reserve has lead to the use of gas for both industrial and domestic use. Wood provides approximately 4% of the energy consumption in New Zealand (15 PJ) while imported oil provides about 39% (153 PJ). The major forest mills consume most of their residues; no forest sources are specifically exploited. Measurements have indicated that potential 60-70 odt per hectare are available for recovery from clearfelled sites after the removal of conventional products (Twaddle, 1987).

With its dependance of foreign sources of energy, New Zealand, like Italy and Norway, maintains an active interest in the IEA Bioenergy Agreement for the potential longer term gains if oil prices again rise sharply.

Harvesting Systems

New Zealand uses predominately motor-manual systems for harvesting, the most common system being chainsaw felling coupled with tree length extraction to a landing by wheeled skidder. Tree size at clear-felling (average 2 - 3 tonnes per stem) precludes the use of many more highly mechanised systems. Some mechanised operation occur in thinning (Raymond, 1989), but at least in the short term, motor-manual operations will continue to dominate.

1988 saw the introduction to New Zealand of a harvesting system designed to recover in forest residues from pre-commercial thinnings for fuelwood. This was based on a forwarded-mounted Bruks 1001CT chipper recovering manual chainsawed stems from the forest floor. The system failed after several months operation due to a number of reasons, including the competitive price of alternative fuel sources.

SUMMARY: ***Low level of forest recovery of material for fuelwood, apart from domestic firewood. Interest in Project because of national dependance on imported energy.***

NORWAY

Background

Norway, with its access to the North Sea oil fields is less involved in the utilization of biofuels than its Scandinavian neighbors. Fuel oil is relatively cheap, and biofuels have not become established as an energy source in the larger industrial plants, apart from the metallurgical industry in Norway which has an annual consumption of 1 million m^3 (Gjølsjø, 1988). The majority of other fuelwood collected is used primarily for domestic heating.

Norway has a forest resource base of 66 million hectares. This provides an annual roundwood harvest of about 10 million m^3, plus an additional 2 million fuelwood. Thinning produces 0.7-1.0 million m^3 per year, and little forest residues are collected specifically for fuel use. Norway maintains a participation in the harvesting Activities as an insurance against future need.

Harvesting Systems

Because of the comparatively small tree size harvested in Finland, and with the pattern of small scale land ownership, about 45% of the annual harvest volume is recovered by farm tractors equipped with various forestry attachments. The remaining volume is recovered by the more specialized scandinavian style forest machines such as harvesters and forwarders.

SUMMARY: *Ready availability of North Sea energy, interest in biofuels for longer term gains.*

SWEDEN

Background

Sweden has strong emphasis on the collection of small thinning and residues, driven by their lack of domestic fossils fuels and compounded by recent political decisions to phase out their existing nuclear power stations by the turn of this century. The nuclear decision is expected to at least double the price of electricity to the industrial consumers over the next 10 to 15 years (Hultkrantz, 1988)

With the Swedish forest industry being the largest single electricity consumer, the ready markets in both the pulp and paper mills and in local district heating plants make the use of forest biomass more attractive than in many other developed countries. Sweden has presently 50 district heating plants using wood as a significant proportion of their fuel. These consume about 1.5 million m^3 of fuelwood per year.

In addition to the political forces causing a need to examine fuel alternatives, a large survey undertaken of the forest resource in Sweden in 1960's - 70's found that to improve forest health thinning had to increase from the then level of 10% of the total harvest to a maintenance rate around 20 to 30%. About 15 million m^3 of fuel wood is currently consumed annually with estimates that the Swedish forest base of 25 million hectares could potentially produce an additional 10 to 15 million m^3 per annum, principally from thinnings.

Harvesting Systems

Since the beginning of the 1980's the collection of logging residue after clear-cutting by mobile chipping units, such as the Bruks, has be practiced. A problem with handling such material is the high expense, and while in-woods chipping is still undertaken, to overcome the high cost the concept of bulk handling or bundle handling of small trees from first thinnings has been developed.

To cope with the standard of maintaining a 30 meter strip between strip roads within the stands, a combination of manual and mechanised felling is used. A feller-buncher clears the strip and about 9 meters either side of the strip while the motor-manual system fells the internal portion.

A forwarder extracts the pulpwood/energywood material on its first pass through the stand, and returns on its second pass to extract the sawlogs. The forwarder is equipped with a chainsaw grapple to assist in loading. While the sawlogs have been removed from the stem, the remaining long length can exceed the capacity of the forwarder so the grapple saw is used to reduce the tops to convenient lengths.

At the road edge the tree sections are stacked in high piles and left to settle for about one week. This stockpiling period causes the stack to self compact making it easier for a truck to obtain a full payload. The legal maximum gross payload in Sweden is 51.5 tonnes, allowing a maximum payload of about 33 tonnes for the truck carrying tree sections. High sided aluminum panelling is used by the tree section trucks to contain the load impose a weight penalty of about 3 tonnes. A separate mobile hydraulic loader is normally used to load the tree sections. A larger unit then might be expected for the tree size is used (about 25 tonne/meter) to assist in the packing of the sections in the containers.

These tree sections are then processed through a drum delimbing/debarking units at the mill site. The advantages of this system are the recovery of more pulp wood, recovery of additional wood fuel at a lower cost, and improved site conditions in the forest (Kvist, 1988).

SUMMARY: ***Strong incentive to increase biofuels production with reduction in generation in nuclear power. Trend to use integrated pulpwood/fuelwood production from thinnings by utilization of drum delimbing-debarking.***

UNITED KINGDOM

Background

The United Kingdom has a limited forest resource, about 1.5 million ha of productive conifer woodland. Much of the commercial forests is grouped towards southern Scotland, distant from much of the industrial area. North Sea oil and gas and coal resources impact upon the demand for biofuels to such an extent that little commercial use of forest biomass occurs. (The largest wood fired boiler in the UK - 5MW, is used to provide heat for a Scottish distillery). About 900,000 tonnes of wood are used as fuel per annum, of which about one half of this being recovered from the forest, ie forest residues and scrub woodland, while the remainder is generated from residues within the wood processing industry (Mitchell et al, 1988).

Some residue collection is by mobile in-woods chippers. The raw material is used for high value end products such as garden mulch. Much of the justification for these operations is in site preparation before replanting. About 1.6 million m^3 per annum is produced from thinnings, but a strong small roundwood market also means that biofuels market cannot compete for this material.

An active research program in harvesting systems funded by the UK Department of Energy allowing the undertaking of testing various options to harvest small trees and residues over both England and Scotland.

Harvesting Systems

The majority of harvesting systems in the UK are based on short wood methods, with motor-manual felling, delimbing and bucking, and extraction by forwarder. There is an increasing trend toward mechanization with mechanical processing coupled with motor-manual felling. Whole-tree harvesting, with landing processing, has taken place on a limited scale, but problems of residue accumulation has hampered development, as the market for this resource is currently low. (Mitchell et al, 1988)

Various trials have been undertaken on systems for the recovery of residues and conventional products from thinnings and premature clearfelled stands since 1987. Thinnings were motor-manually felled utilizing a strip method, then chipped with differing types of mobile chipping units, including a Hafo (Danish), trailer-mounted Sasmo and Erjo chippers and a prototype chunker. Whole tree options used mechanised felling with a Makeri 33T, and landing processing with a tractor mounted Nokka head separating roundwood and residues, were tried. (Mitchell et al, 1989)

The production of fuelwood chips from these types of systems range from about 6 to 17 £/gt (at roadside), with the whole tree in-woods chipping being the cheapest option.

SUMMARY: ***Active research programme in harvesting and processing options, but forest biomass usage limited. Involvement for future benefits.***

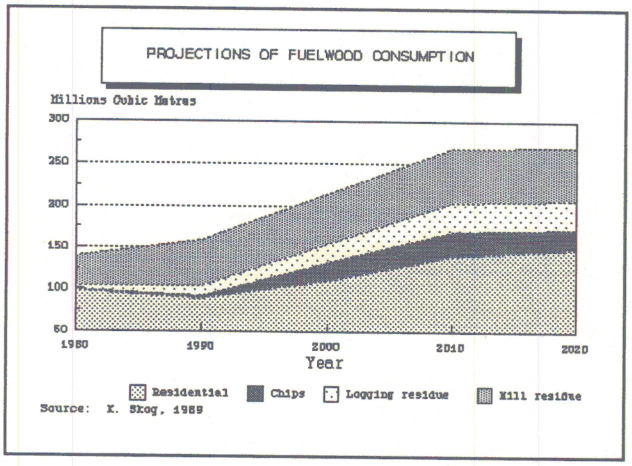
UNITED STATES

Background

The United States has a productive forest base of 195 million hectares, producing about 390 million m^3 annually. Total consumption of wood for fuel is about 150 million m^3 per year, (Skog, 1989).

The Pacific Northwestern region of the United States has a substantial supply of under-utilized woody biomass occurring in a number of forms. The larger trees of the coastal region are harvested incompletely as they break on falling and can not be fully recovered as the larger equipment required for these stems can not cost efficiently recover the small pieces. This mix results in residues often exceeding 220 tonnes per hectare. Other forest lands have become overstocked with mature but very small diameter trees. Conventional harvesting of these stands have not been profitable in spite of the large standing volumes of biomass.

The forest industry in the Northwest has installed wood fired boilers to meet their own energy needs and to utilize mill wastes. The abundant availability of hydro-electric power in the region has stymied the expansion of the use of co-generation. In addition, the power transmission lines to the lucrative markets in California now operate at full capacity so there is little incentive to increase biomass utilization,



(Lambert, 1989).

The present Californian market for forest biomass is very strong because of artificially high prices for electricity as a result of a political decision to require utilities to purchase power from alternative energy source producers. A long term fixed price was included in this decision which has led to a surge in the number of new biomass fueled power plants. Demand for wood fuels is therefore on the rise as the generating plants seek raw material.

Approximately 3 x 10^6 bdt of forest residues were used by the California electric facilities in 1988, much of which is obtained from national Forests in the Northeastern parts of the State. Little cut-over residue is collected for fuel, the difficult terrain rendered this option uneconomical (Hartsough, 1989).

The Intermountain region of the USA also is predominately steep terrain making the recovery of forest biofuels difficult. The operational recovery of material is also hindered by the lack of good markets for the material. An oversupply of mill residues and lack of strong markets for hog fuel mean limited application of most residue recovery systems (Johnson, 1989).

Small tree harvesting and residue recovery in the Lake States is usually performed in response to a land management prescription. Without these management incentives harvesting of this smaller sized material is rarely justified. Trees typically removed in these circumstances are used for pulpwod, residential firewood and fuel chips for industrial applications. Mechanized systems are becoming increasing popular for thinning with harvesters such as the Lokomo-Makeri and Silver Streak units being utilized. Chipping for fuel chips in red pine thinnings and in Jack pine stand conversions have produced delivered fuel costs of around $US11 and $US18 per green tonne, respectively, (Sturos and Thompson, 1989).

The large energy consuming pulp and paper base in the South, along with favorable terrain, affords the opportunity to utilize considerable forest biomass for energy. Most pulp and paper facilities aim towards a high level of energy self-sufficiency and therefore attempt to consume of their internally generated wastes and also buy in residues, particularly from the sawmilling industry. In the southeastern region over 1800 MW of electric power is currently produced from forest biomass, mostly from co-generation facilities at pulp and paper mills. Few stand-alone wood fueled power plants are in operation, the largest being a 16 MW plant in Florida, however a number of new plants, including one of 76 MW plant, in the Virginia and North Carolina area have recently been scheduled for construction (Badger, 1989).

A number of in-wood fuelwood recovery operations are operating in the South. A total of 119 whole tree chippers have been identified as being used to produce either solely fuel chips or a combination of fuel and pulp chips (Young et al., 1989). Part of the maintenance of whole tree chipping activity lies in the site preparation benefits that accrue to the removal of non-merchantable biomass for the harvesting site (Stokes et al., 1989).

Harvesting Systems

A diversity of harvesting systems operate in the USA because of the wide range of conditions, however in general most conventional product systems are based on long length extraction to a landing.

There is some spread of the more mechanized systems utilizing a shortwood approach, mainly in the more northern states.

Residue collection for biomass is rare with most activity being in the active Californian market. A number of larger mobile harvester units were designed to recover residues from conventional harvesting, with perhaps the most noted of these being the Nicholson-Koch unit, however none persisted for long past the development stage. Baling technology surfaces regularly as a method of overcoming some of the consolidating the raw material, but these have not been developed to a stage where they represent an readily accessible technology. Chunkwood, as a comminution techniques for residues and small stems received greater attention, particularly by the US Forest Service at the Houghton Michigan Laboratory, but this technology has also seen little expansion past the development stage.

The increased use of chain flails to delimb and debark in the woods allowed the recovery of pulp quality chips, along with the fuel component. The stems are processed through the flail unit prior to chipping where the limbs and bark are removed by chains attached to a rotating drum. The chips produced are acceptable quality for most grades of pulp. The bark and limbs can be feed to a hog to produce fuel acceptable for wood fired boilers. While there are about 50 flail units in use throughout the USA, only 5 are currently teamed with a hog.

Where fuelwood operations exist they tend to be larger scale operations using feller-bunchers (usually rubber-tired), grapple skidders, the bigger in-woods chipping units such as Morbark, and produce large volumes of in-field chips per day (200+ tonnes). These operation can produce biofuel chips at the approximate oil-equivalent cost of $US24 per barrel, (Brinker and Tufts). Many operations exist because of the downstream benefits of decreased site preparation costs for the establishment of the next crop.

At least one firm has been successful in moving whole trees to the pulp mill so that additional biomass for fuel can be recovered. The harvesting system furnishing wood for this mill is essentially the same as conventional operations, except that specially designed trailers transport the stems to the mill yard. There limbs and tops are removed at the mill's extended length debarking-delimbing drum

SUMMARY: *Biofuel supply and demand vary regionally. There is some slow expansion in the West and Southeast, but most other areas the situation is more static. A number of harvesting systems are used, with the most prevalent being conventional in-woods chipping of non-merchantable small stems.*

SUMMARY

The predominate use of forest biomass in the IEA Bioenergy Agreement participating countries is by the forestry industry, utilizing residue material taken into the mill site with conventional products. Only in a few cases is material actively gathered from the forest, and in these cases demand is driven either by government incentives (eg Denmark) or coupled with efficiencies in improving the harvesting operation by integrating activities (eg Sweden and Finland).

Residue collection from the cut-over is usually the most unfavored option to collect addition material, as it is spread across a large area and is non-uniform in size. Residue processing from previous operations offers a cost benefit as the material has been extracted 'free-of-charge', while fully integrating the biomass processing with the collection of conventional products appears to offer the most promise.

The current price of crude oil means that many potential forest biomass uses are in hiatus. The flurry of R&D activity which occurred in the late 1970's and early 1980's has slowed considerably, as the need for seemly instant solutions diminished with time. Taking a longer term perspective it is probably unfortunate that the oil prices has fluctuated so widely in recently years. The use of bioenergy received a welcome boost but many promising areas have been curtailed as the short term economic competitiveness importance has declined. The International Energy Agency, through the Bioenergy Agreement plays a role in keeping assuring that the past lessons in forest biomass recovery are not lost, and that the R&D effort is maintained, abet on a smaller scale.

For forest biomass to attract renewed interest from industrial markets a number of developments or changes in the market structure must occur. These include,

1. Competitive with oil prices on the open market. This will come when oil prices again rise to about $US25-30 per barrel.

2. Users must be able to have security in supply. In many countries highest use is in winter, when supply problems exist. Harvesting and processing system must be efficient to match the high level of service expectations of present industrial concerns.

3. New users who will be unfamiliar with the product will not be attracted if the price of the raw material fluctautes wildly, therefore they need some security of purchase price. Logging contractors producing the raw material will also need to be confident that there will remain a sufficent sized market paying an adequate return, for them to invest in the necessary specialized harvesting and processing equipment.

For as long as they are readily available oil products will be essential and integral components of our society and industry. Without any major unforeseen developments, such as armed conflict in oil producing regions, or some new dire warning of the greenhouse effect backed with firm evidence, the demand for information on biomass harvesting and processing will continue to be at a steady but undramatic rate. The Bioenergy Agreement under the International Energy Agency creates a forum under which the past lessons will not be lost and ensures that a steady level of advancement will be maintained.

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