J. W. GOTTSTEIN MEMORIAL TRUST FUND

The National Educational Trust of the Australian Forest Products Industries

GOTTSTEIN TRUST

ENERGY FROM WOOD – POLICIES, LOGISTICS AND ECONOMICS OF BIOENERGY IN NORDIC COUNTRIES

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2008 GOTTSTEIN FELLOWSHIP REPORT

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Joseph William Gottstein Memorial Trust Fund

The Joseph William Gottstein Memorial Trust Fund was established in 1971 as a national educational Trust for the benefit of Australia's forest products industries. The purpose of the fund is *"to create opportunities for selected persons to acquire knowledge which will promote the interests of Australian industries which use forest products for the production of sawn timber, plywood, composite wood, pulp and paper and similar derived products."*

Bill Gottstein was an outstanding forest products research scientist working with the Division of Forest Products of the Commonwealth Scientific Industrial Research Organization (CSIRO) when tragically he was killed in 1971 photographing a tree-felling operation in New Guinea. He was held in such high esteem by the industry that he had assisted for many years that substantial financial support to establish an Educational Trust Fund to perpetuate his name was promptly forthcoming.

The Trust's major forms of activity are:

1. Fellowships and Awards - each year applications are invited from eligible candidates to submit a study programme in an area considered of benefit to the Australian forestry and forest industries. Study tours undertaken by Fellows have usually been to overseas countries but several have been within Australia. Fellows are obliged to submit reports on completion of their programme. These are then distributed to industry if appropriate. Skill Advancement Awards recognise the potential of persons working in the industry to improve their work skills and so advance their career prospects. It takes the form of a monetary grant.

2. Seminars - the information gained by Fellows is often best disseminated by seminars as well as through the written reports.

3. Wood Science Courses - at approximately two yearly intervals the Trust organises a week-long intensive course in wood science for executives and consultants in the Australian forest industries.

Further information may be obtained by writing to:
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J.W. Gottstein Memorial Trust Fund
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Clayton South VIC 3169
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Andrew Lang is inaugural chairman of SMARTimbers Cooperative, and is responsible for their log sourcing and milling management. He was a 2003 Churchill Fellow, was appointed to the Victorian Sustainable Timber Industry Council, and is a member of the Central Victorian Private Forestry Development Committee. He believes farm forestry has enormous potential for carbon sequestration, as a source of biomass for energy, and as a sawlog source for the timber industry.

Energy wood from a final harvest of spruce in Denmark

" Even if the future looks dark it doesn't have to have a given end. Change is constant. We have been through an Age of Steam and an Age of Oil. Now we have to do it smarter.
Since 1990 in Sweden we have managed to increase renewable energy to almost 40%, reduce greenhouse gas emissions by 9% and grow our GDP by 44%. Bioenergy for us is no longer an alternative energy but a major part of our energy supply system."

Ms Maud Olofsson
Minster for Enterprise and Energy, Deputy Prime Minister Sweden

(Opening address to World Bioenergy Conference, Jönköping Sweden, 27.05.2008)

Executive Summary

The three countries visited – Denmark, Sweden and Finland – have all developed bioenergy as their principal form of renewable energy. The aggregate of their populations is similar to that of Australia. Before the 1970s oil shocks their dependence on fossil fuels for energy overall was roughly comparable to ours. Their development of bioenergy since then means that we could draw on their expertise to provide possible solutions for how we here might proceed to develop bioenergy using the by-products of our agricultural and the forest industries.

This report is driven particularly by the need to develop the harvest and processing of first thinnings from integrated farm forestry, since this most presently most small-scale and dispersed part of the private forestry sector needs to solve how to make the first thinnings operation at least cost-neutral to encourage a many-fold expansion. And the obvious market for the thinnings from a dramatically expanded farm forestry sector is to local and regional bioenergy plants, as in these Nordic countries.

This study was driven by Australia's scope to create a greatly expanded farm forestry estate of up to 10% coverage of the 50 million ha of its more productive arable land. So an estate of up to a million ha of dispersed multi-purpose strip woodlots on farms across Victoria, and 5 million ha across Australia. This scale of planting over 30 years would produce a sustainable flow of industrial volumes of logs for milling, chip for paper making, smaller diameter roundwood for construction and veneer peeling, and biomass for energy.

This scale of planting would mainly be across farms with under 650mm rainfall. In replacing a small amount of the original forest cover it would significantly improve habitat and other environmental benefits, improve farm productivity, add to rural employment, and sequester significant amounts of atmospheric carbon, all with minimal impact on catchment flows and landscape aesthetics. And create very large volumes of biomass. All at relatively small cost to government.

Biomass produced from thinnings and harvest waste from this scale of plantings would provide significant amounts of baseload energy. For example, in Finland in 2004 about 20% of primary energy and 11% of the electricity supply in Finland were produced from wood-based fuels alone. (TEKES Technology Program Report 2004). This form of energy can be compatible with dispersed farm forestry. In each of the study countries most of the industrial roundwood, and hence the flow of forestry residue and thinnings to bioenergy, comes from mixed native forest owned by individuals and families and harvested in of only 1-2 hectares that may be many kilometres apart in any one area.

As with any new industry there are many issues that have to be clarified or resolved before investors see that there will be a good chance of adequate and sure returns. For such an expansion of farm forestry these issues include –

- Improving the logistics and economics of processing, handling and transporting large volumes of wood chip from many small sites. This includes use of tractor-mounted or powered forestry equipment.

- The way forest owners can achieve optimal returns for product and maintain satisfactory control of the process. Just how energy from woody biomass can fit into a state or national energy future.
- The sort of government policies and support, taxes and financial incentives that need to be in place to support and underpin development of such an industry sector, with its need for long-term investment confidence of at least 30 years.

I used Gottstein Fellowship funding, supplemented by funding contributed from five other organisations, to spend six weeks in Denmark, Sweden and Finland. There were three topics of my Fellowship study –

1. to learn about the logistics and economics particularly of harvesting first thinnings (energy wood), processing into chip and transporting to bioenergy plants.
2. to learn about the development of the policies and legislation that underpins the use of bioenergy, and how it is made cost-competitive.
3. to find out detail on the lower capital cost machinery and equipment mounted on or powered by farm tractors that could allow lower cost first thinnings in Australian farm forestry.

On this study trip my aim was to talk to people involved in practical aspects of the study topics – in government, R&D organisations or growers. I interviewed most for about two hours, though with some I spent up to a day in the field. My aim was to have most of my base information supplied by people who are either engaged in applied research, or who are managing at the farm level or are involved in industrial-scale application of forestry and bioenergy best practices. Accordingly this report is based on about 360 double-sided A4 pages of notes from these interviews. In addition I collected about 20kg of literature and publications relevant to the study topics.

I was funded by the Rural Industries Research and Development Coorporation (RIRDC) to go to the third World Bioenergy Conference at Jönköping, central Sweden, in May 2008. This was attended by about 1150 participants from about 58 countries and autonomous regions, Over three days I attended talks on my fields of interest by international leaders in applied research. Every day there were field trips and opportunity to talk with manufacturers of a wide range of machinery and equipment. In addition I went on pre- and post-conference full-day trips to a series of small and large bioenergy plants fuelled by a range of types and forms of biofuels, or which made pellets or biogas.

It is clear that there are two main ways to manage a state or national forestry industry. One is based on the largely corporate or state-owned and controlled forestry we see in Australia, Russia and Canada. The other is the predominantly individual and family-owned forest where management responsibility is devolved that we see in most of Europe and in Scandinavia. (Lang A. Churchill Fellowship Report, 2003).
In Australia an expanded farm forestry sector could be self-administered by grower cooperatives in the same way as vast family forestry sector in the Nordic countries. Over the four countries the 825,000 forest holdings are owned by families and individuals. These holdings average about 50 ha in Sweden, about 19 ha in Denmark and about 31 ha in Finland (24 ha in southern Finland). Harvest, managed by the grower or the grower associations, is from sites of 1-2 ha on average, and supplies most of the industrial round wood and much of the woody biomass used for energy.

Acknowledgements

This study trip was made possible by funding provided by the Gottstein Trust. This provided a crucial basis for gaining funding from other groups. These were -
Central Highlands Agribusiness Forum (CHAF)
Central Victorian Farm Plantations Committee (CVFP)
Mt Lofty Ranges Private Forestry Development Committee
Rural Industries Research and Development Corporation (RIRDC)
SE NSW Private Forestry Development Committee

In the course of the six weeks of this study trip over May/June 2008 I gained information from or was significantly helped by these organisations and individuals (those asterisked were interviewed). The list is approximately chronological.

Denmark: May 10-20

*Torsten Hanssen and *Karsten Raae, of Danish Forestry Extension, Copenhagen
*Bruce Talbot and Neils Heding, senior researchers, Skov og Landskab, Høsholm
*Kurt Boldrup, senior forester, Forest Management Association, Veile
*Henning Bilberg, trainee forester with HedeDanemark
*Jan Knudsen and *Klaus Holgersen of Lindana Chippers (TP)

Sweden: May 21-June 15

*Dr Stig Larsson, Director of Lantmännen Agroenergi, Svalöv
*Per-Magnus Ekö, Swedish Agricultural University, Alnarp Campus
*Tove Tomasson, *Karl-Johann Pålsson & *Svantje Oostra, extension officers at Skogsvårdstyrelssen (Swedish Forest and Environment Department), Höör
Hanna Savola, Sustainable Business Hub, Malmö
Niina Kautto, EU Institute for Energy (Ispra, Italy)
*Sofia Persson, Director, Södra Energi, Södra Skög (Southern forest owners), Växjö
*Henrik Johansson, GHG reduction office, Växjö Municipality
*Kent Nyström and *Karin Haara, Directors Svebio (Swedish Bioenergy Association)
*Kerstin Classon, Business Development Manager, Austrade, Stockholm
*Stafan Persson, Mellansskog (Central Sweden forest owners association), Uppsala
*Eve Holmgren, *Prof. Tomas Nordfjell, *Dan Bergström, *Prof. Iwan Wasterlund, Marina Hennigsson, Swedish Agricultural University, Umeå Campus

Finland: June 15-26

*Toni Lehtinen, sales manager, Kesla Forest Machinery, Joensuu
*Anti Asikainen, *Pertuu Antila, Markus Lier, *Lauri Sikanen, Juha Laitila, Finnish Forest Research Institute (Metla), Joensuu
*Eija Alakangas (senior research scientist Bioenergy), *Matti Virkunen (forest fuel procurement project), Technical Research Centre of Finland (VTT), Jyväskylä
*Kalle Kärhä, senior researcher, Metsäteho, Helsinki
*Lea Jylhä (international liason), *Ilpo Mattila (rural entrepreneurship), Central Union of Agricultural Producers and Forest Owners (MTK), Helsinki
*Kaisa Pirkola, Dept of Agriculture and Forestry, Helsinki
*Tuula Mäkinen (TEKES wood energy technology project manager), VTT, Espoo
*Tage Frederiksson, Director of Work Efficiency Institute (TTS), Rajamäki

I visited or talked with these forestry machinery or bioenergy plant manufacturers – FTG-Mowi, Keto, Tapio, Nokka, TP Lindana, Bracke Forest, Kirka boilers, AFM, Loma, Ponsse, Kesla, Biopress, Morums, Nisula, Bruks, Rottne, Narva, Logmax.

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Note: re exchange rates - At the time of this trip A$1 bought 0.61€ , about 4.5 Danish Kroner (DKK), and about 5.1 Swedish Kroner (SEK).

Glossary

Baseload – production of energy at a constant predictable output unaffected by external factors. For example the Averdøre-2 plant near Copenhagen has the rated baseload electricity output of 485 MW, equivalent to 242 2MW wind turbines at full output. But even in the windiest parts of Denmark wind turbines produce rated power only 40-50% of the time, and in summer for weeks they may produce no electricity.
Biofuels – In the Nordic countries 'biofuel' and 'biomass' are frequently used interchangeably. However in this report 'biofuel' refers to liquid or gas fuels produced from biomass by any one of a number of processes.
Biomass – organic material available as a feedstock for production of energy. It may be putresible 'wet' organic matter or ligno-cellulosic 'dry' material. In Sweden and Denmark it also includes municipal solid waste.
Black liquor – the lignin-rich by-product of the chemical process of converting wood to paper pulp. It has a fuel value about half that of wood. When it is burnt process chemicals are recovered for re-use. It is classed within 'biomass'.
Bolsters- the vertical members on a forwarder that confine the load
Carbon-neutral – use of biomass as fuel is regarded as a carbon-neutral process, as the CO_2 liberated came from previously living matter and is reincorporated rapidly into new living matter.
Co-firing – use of more than one fuel within the same furnace.
Co-generation – production of more than one form of energy– usually heat and electricity
District heat – an outward and return paired system of buried insulated pipes that distributes thermal energy around a community and/or industrial area, where the heat is drawn off through heat exchangers and the volume of water remains constant.
Energy wood – the term now used in the Nordic countries for the thinnings and harvest waste destined to be chipped for fuel.
Family forestry – The term given to the forests owned by families and individuals, to distinguish these from forests owned by state, church, municipality, corporations etc.
Feedstock – a general term used here for biomass in some stage of the supply chain before it becomes fuel
Forest chip – a distinction made in the Nordic countries statistics for woody biomass that distinguishes between chipped stem wood from forest operations, and bundled tops, woody biomass from manufacturing, etc.
Forest management associations (FMAs)– a term used in Finland for the local forest owner groups. Used here also for comparable groups in Denmark and Sweden
Forwarder – the specialist machines that carry out logs and harvest waste from within the forest operations site to the landing at the edge
Fuelwood - solid wood such as firewood billets used for cooking and househeating (or saunas).
Harwarder – a forwarder equipped with a harvesting head that harvests and forwards out in the one pass through a forest thinning site.
Heating entrepreneurs – Contractors who have an agreement to supply biomass to a heating plant.
Landing – the working area within or more usually on the edge of a forestry operations site, and usually serviced by an all-weather road.
Municipal solid waste (MSW) (also called Solid Recovered Fuel SRF) - municipal waste after all recyclables and toxic materials have been removed, leaving a flammable mass usually under 50% MC. Similar to Refuse Derived Fuel (RDF).

Nominal boiler output – the rated energy output of a boiler operating at its designed optimal capacity or efficiency, usually expressed as megawatts (MW).
Primary energy - The gross energy use or production in a country or region, including electricity, heat and transport energy.
Private forest – the term used in Nordic countries to mean 'owned by private individuals or families'.
Regional forest owner association – term used in Denmark for organisations generally comparable to Forest Management Associations (FMAs)
Short rotation coppice – perennial woody crops that regrow from the base after cutting, allowing a series of harvests from the one planting operation
Stump lifters – a levering attachment fitted to a tracked excavator, used for prising softwood stumps from the ground so they can be converted to chip
Woody biomass – Biomass from trees, bushes and shrubs. It includes forest wood, wood processing industry residues (including black liquor), fibre board residues, particle board residues, and used wood (urban recovered wood).

Forest chip, produced from harvest waste in a family-owned forest site, and sold as biomass feedstock for a CHP bioenergy plant, to produce carbon-neutral baseload electricity and district heat.

Energy: definitions, explanations, units and conversions

For people new to the subject of energy from woody biomass the units used and the conversions between them can be initially quite confusing. However these units are frequently quoted in the Nordic forestry/bioenergy sector and are used in all papers and research reports on this general topic. To understand the potential and scale of energy from woody biomass and the relationship between thermal energy (heat) and electricity the reader must acquire familiarity with the terminology and with conversions between units. Hence this separate section for energy units, their conversions, and other bioenergy terminology.

To avoid confusion between these units that will regularly recur in this report it needs to be understood that any energy units used will usually relate to one of these different situations or contexts. The context for the usage of a unit may be important.

1. **the energy value of a unit volume of the fuel –** so a loose cubic metre (m3 loose) of forest chips will be paid for according to its energy value expressed as megawatt hours (MWh) or as gigajoules (GJ). For a m3 loose of 40% moisture content (MC) spruce this will be 0.7-0.8 MWh. This means a bioenergy plant is only paying for the realisable energy in the forest chip.
2. **the aggregate or total energy of a type of fuel**. For instance the total energy produced from straw in Denmark in a certain year will be expressed in terawatt hours (TWh). The energy value of biogas produced in Sweden from sewage plants, or energy value of biogas upgraded for use as vehicle fuel, will similarly be in the units of terawatt hours. In some cases where the aggregate is expressed in joules the total figure will be petajoules (PJ. 1 TWH = 3.6 PJ).
3. **the output of a bioenergy plant**. This is usually first given as an energy capacity figure, being the rated boiler output in MW. Where it is a combined heat and power (CHP) plant the electricity production will be given as the rated or measured turbine output in electricity as MW-e, and the heat supplied into the district heating system will be either expressed as as megajoules per second (MJ/s. where I MJ/s = I MW), or as megawatts of thermal energy (MW-th). These values are usually the output when the plant is operating at its designed optimal efficiency, such as at peak demand in wintertime. Annual peak load times for CHP plants are about 6000 hours/year in Finland, and peak load times for district heating plants about 4500 hrs. (TEKES 2004). Other figures will occasionally be used for CHP plants, including steam pressure and temperature, steam flow per unit of time, and efficiency of conversion of feed fuel compared to energy output of the boiler.

2MW main boiler of the Lagan district heating plant in Sweden. This plant is fueled by briquetted sawdust from a local sawmill. The heat from the furnace/boiler is piped around the small community of about 2000 people in buried insulated pipes, with heat exchangers at each house drawing off heat energy, but not water.

Bioenergy plant efficiency. Energy plants divide into three main types -

- District heating (DH) plants, producing only heat. 85-88% of energy contained in the fuel is converted to energy. These plants are usually less than 10MW.
- Condensing power plants designed for production of electricity only. Up to 40-45% of energy is recovered as electricity with the rest of the energy lost in cooling water and flue gases (these plants are too inefficient for using biofuels, and are not discussed here)
- Combined heat and power (CHP) plants (or co-generation plants). These plants have an efficiency of 85-90%, with 20-30% produced as electricity and 55-70% as heat. These plants can now be scaled down so that heat output is only 5-10MW or less. (TEKES 2004)

Prefixes for energy units (*Energy in Sweden* 2007)
Kilo 10^3, Mega 10^6, Giga 10^9, Tera 10^{12}, Peta 10^{15}
So a megawatt (MW) is 1,000,000 watts, and a gigajoule (GJ) is 1,000,000,000 joules.

Conversions
1 megawatt-hour (MWh) = 3.6 gigajoules (GJ). 1 gigajoule = 0.28 MWh.
1 megawatt (MW) = 1 megajoule per second (MJ/s) thermal energy
A megawatt output = 24x365 MWh = 8800 MWh/yr
A terawatt-hour (TWH) = 3.6 petajoules (PJ), and a PJ = 0.28 TWh

Units of wood chip biomass – cubic content/weight:
For Norway Spruce with a specific gravity of 400kg/m3 solid wood, and at 40% MC .

- A solid m3 weighs about 400kg and produces about 2.8 m3 of loose chip.
- A m3 of loose chip weighs 140kg and contains about 0.35 m3 of solid content
- A tonne of woodchip fills approx. 4.0 m3
- A tonne of chipped spruce contains approx. 1.4 m3 of solid wood

The forest chip bunker at the Llungby CHP plant in Sweden. This chip is taken by a grab to a hopper that feeds a secondary furnace. This runs over May to October for extra wintertime energy demand of about 30,000 MWh. This boiler has a 16 MW rated output.

The main furnace in this plant producing 105,000 MWh runs 11 months of the year and is fuelled by 55,000 tonne/yr of municipal solid waste. This boiler has a 18MW rated output.

The Llungby CHP plant produces 140 GWh of heat and 20 GWh of electricity.

Units of calorific value (using the same 40% MC chipped Norway Spruce)

- A loose cubic metre of chip contains approx. 2.6 GJ or 0.72 MWh energy
- Fuel consumption (for boiler efficiency of 80-90%) is about 1.48 loose m3/MWh of this chip. (*Biomass fuel supply chains* 2007)
- A m3 of solid wood yields about 7.3 GJ
- A tonne of woodchip yields about 10.4 GJ
- MSW yields about 2.6 MWh/tonne (figure from Llungby Energi)
- A tonne of sawdust pellets or briquettes (10%mc) yields 4.50-5.00 MWh
- One litre of fuel oil = 36 MJ = 10kW
- Calorific value of 1000 l of fuel oil = approx. 14m3 woodchips
- 1000 litres fuel oil = 36 GJ
- Calorific value of 1000 Nm3 of natural gas = 15m3 woodchips
- 1000 Nm3 natural gas = 11 MWh = 39.7 GJ
- Energy of 1 Nm3 of natural gas and 1.1 litres of 95 octane petrol are approximately equal.
- 1 tonne fuel oil = 42.7 GJ.
- I tonne crude oil equivalent (toe) = 11.63 MWh = 40.868 GJ
- A million tonnes crude oil equivalent (mtoe) = 40.868 petajoules (PJ)
- A terawatt hour (TWh) = 3.6 PJ

(1 Nm3 natural gas is a cubic metre of gas at standard temperature and pressure)
(figures and conversions from *Wood for energy production* Denmark 2002 and *Energy in Sweden* 2007)

Australian fuels - energy information

I tonne NSW black coal	= 23 GJ
1 tonne Victorian brown coal	= 10 GJ
1 tonne green wood	= 10 GJ
1 tonne oven dry wood	= 20 GJ
1 tonne Carbon	= 3.67 t CO2

(figures from *Greenhouse solutions*. M Diesendorf 2007)

General rules of thumb for energy

- A DH plant requires approximately 10,000 tonnes of 40% MC chip per MW capacity (More efficient CHP plants with dry fuel including pellets can use down to about 1500 tonnes/MW).
- For a DH plant, cost of installing the distribution network is about half the overall capital cost.
- A MW of electricity will supply 500-750 Australian electricity-dependent homes for a year.
- An average Australian family uses about 13,000 KWh/yr of energy (a Danish household uses about 7000 KWh/yr). In winter up to half of power consumption in an electricity-dependent house can be used for space and water heating.
- Australian industry and households consume up to 45,000 MW of electricity/yr (with over 70,000 MW of thermal energy annually being also generated, but not used).

(figures from media sources, and pers comm.)

Recent history of bioenergy in Denmark, Sweden and Finland

The conversion to use of renewables and particularly bioenergy in these countries studied has been driven by three main factors – the need for national energy security, climate change policies, and generation of rural employment. It has been accompanied by work on improving energy efficiency, on public transport infrastructure and in stimulus of biofuel use. Underpinning the process have been strategies that have taxed fossil fuels (see following table), taxed CO_2-equivalent emissions, put a value on 'green' electricity produced, and have stimulated significant expenditure on R&D. Laws have been passed that oblige households, businesses and municipalities to maximise recycling and that ban putting flammable municipal waste or putrescible municipal waste into landfill.

Commercial energy taxes and prices in Sweden 1970-2006: öre/KWh

	1970	1980	1990	2000	2006
Heavy Fuel oil					
Price	1.5	12.3	21.7	26.4	39.9
Tax/%	0.3/16.4	1.3/9.4	11/33.6	18.2/40.9	33.7/45.8
total	1.8	13.5	32.7	44.6	73.7
Premium petrol					
price	3.7	17	25.6	39.4	49.6
Tax/%	6.8/65.1	16.7/49.5	37/59.1	51.2/56.5	55.3/52.7
total	10.5	33.7	62.8	90.6	104.9
Diesel fuel					
Price	2.6	13.7	29.1	38.6	52.2
tax/%	4.1/61.2	1.3/8.5	11/27.4	29.5/43.3	36.1/40.9
total	6.8	15	40.1	68.1	88.3
Coal		**1983**			
Price		5.3	4.7	4.7	7.3
Tax/%		0.2/2.9	5.3/53	18.3/79.6	36.3/83.2
Total		5.5	10	23	43.7
Forest fuels			**1993**		
price			11.9	11.2	21.35
Tax/%			0/0	0/0	0/0
total			11.9	11.2	21.35

(*Energy in Sweden* 2007)

In practice the outcomes have been that existing energy plants have been converted from coal or oil first to natural gas and then to be fuelled by biomass. New energy plants using natural gas and biomass have been built. Much of what had been municipal or industrial residues that had a significant cost of disposal have now become fuels with a value that at least offsets their handling costs.
In Sweden the choice of fuels for district heating from 1970-2006 shows this –
Oil - 14.3 TWh up to a peak of 30.9 in 1980, a steep fall till 1987, and to 3.2 TWh,
Coal - 0.4 up to a peak of 12.9 in 1886, steep fall till 1990, and down to 3.2 TWh.
Biofuels (including waste and peat) - from 0.3 TWh steadily up to 36.2 TWh. Over the period the DH energy total has climbed from 14.6 TWh to 55.4 TWh.

(*Energy in Sweden* 2007)

At the local and farm level handling of forest residues and thinnings has now changed dramatically since the 1970s. The first thinning that previously had been delayed for many years until average stem volumes were about 0.5m3 is now able to be done cost neutral at stem volumes down to an average of 0.15-0.2m3, due to the demand and hence price for forest chip. This obviously results in better yields and growth rates. The first thinning at 25-40 years may yield up to 60m3/ha. The price being paid/m3 solid for energy must be competitive with the price for pulp wood, as both markets are competing actively for the same product. Usually the energy plant will be closer so the lower cost of transport to this will be always a part of the calculation.

Even so the rising demand for biomass due to the political pressures of climate change and from consequent national targets for greenhouse gas reductions has made the industry realise that while there are great volumes of unused resource, there are also real technical issues and costs in accessing that resource. Sweden for instance is estimated to use residues from final harvest on only 37% of sites in 2006, up from half that in 2003. However this volume currently being accessed is more than equalled by the volume of wood – about 5 million tonnes of dry matter (DM) - that is, in stands of dense young forest that is presently uneconomic to do a first thinning using conventional forestry harvesters and forwarders, but which would benefit from a first thinning.

At present it is simple economics that are involved: per cubic metre of chip loaded at the landing energy wood from a stand harvested only for first thinnings costs about 50% more than the residues from a final harvest. Other issue of volume of biomass available per hectare in the stand, distance from markets and soft ground all play a significant role. 56% of the 4.13 million ha (or 18.4% of Sweden's forest area) of these unthinned sites are in the northern half of Sweden and about 27% are on soft ground that should only be harvested in winter. The parameters of a stand requiring a first thinning are that the trees are below 15m tall and the site will yield over 30 tonne DM/ha. (*Unutilised biomass resources in Swedish young dense forests* 2008)

A Finnish 10 tonne Sampo-Rosenlew energy wood harvester with feller-buncher head, able to perform thinning at lower cost/m3 than heavy conventional harvesters.

Biomass for energy in Denmark, Sweden and Finland

Bioenergy is now a significant source of energy in Denmark, Sweden and Finland (also in many other countries not in this study). There are some differences between countries in the choice of raw feedstocks, largely due to the respective scale of their forest industries. But basic similarities lie in the way renewable energy sources, and particularly for this study, bioenergy, have been fostered and encouraged by carbon tax, incentives, and legislation since about 1980. The efficient use of biomass for fuel has been made easier by the fact that in most communities there were already small district heating (DH) plants or combined heat and power (CHP) plants, and so the necessary infrastructure existed for distribution of biomass-generated heat energy to households, businesses and institutions.
So in essence the use of woody biomass in these countries is now increasingly
<u>economic</u> – due to taxes on alternatives, and incentives for its use
<u>efficient</u> – due to the design of the plants and the use of both heat and electricity
<u>environmentally sound</u> – with carbon-neutral by-products of the timber industries and agriculture steadily replacing fossil fuels (and, in Sweden, also nuclear power). The introduction or expansion of district heating has meant the steady replacement of large numbers of fossil fuel-fired boilers with significant emissions. For instance in Jönköping, Sweden, a new plant replaced 19 small oil-fired local boilers.

In Australia the energy contribution from woody biomass to the national electricity total demand is under 0.5%, and is mostly as sugar cane waste (bagasse). The contribution here of woody biomass to total energy use is up to 5%, mostly as firewood for domestic heating. (*Bioenergy: a future for the Australian forest industry* 2001)
By comparison, in Denmark the contribution from biomass to energy (including thermal energy) is about 6%, and this is mainly from straw and woody biomass. In Sweden it is closer to 20% (and climbing toward a target for 2020 of 40%) and far exceeds any other form of renewable energy. In Finland overall it is about 24% and in central Finland is closer to 50%.
It must be kept in mind that the national energy requirement for these three countries splits roughly to 50% as heat, 25% as electricity and 25% as transport fuels. Finland is remarkable in that almost 20% of the nation's electricity is presently generated from woody biomass and timber industry by-product in CHP plants of up to 500MW (electric and thermal combined output). (*pers comm. Kent Nyström, Svebio*)

In these three countries the district heat is generated mainly by bioenergy and waste-to-energy plants. These may be small DH plants at 5MW or less, or may be produced by CHP plants with boiler ratings of many hundreds of megawatts, as in the following examples. These industrial-scale energy plants fuelled by biomass show that in Australia, as carbon pricing and the energy and capital cost of implementing carbon capture and storage impact on energy costs, it is quite feasible that such bioenergy plants could play an increasingly significant role, fuelled by what are now the largely discarded waste products and residues of the agriculture and forestry industries.

Bioenergy in Denmark
In Denmark the extensive conversion of fossil fuel-fired power plants to use biomass or waste for energy is almost complete. There is much more use of straw as fuel there than in Sweden or Finland (though Finland does bale significant volumes of a native

phalaris species for biofuel). About 25% of available straw (about 18 petajoules in 2005) in Denmark is being used either as whole big bales in a 'cigar feed' process, or with straw shredded and then fed to boiler via a screw auger, or with the straw pelleted for transport and handling, and then powdered before firing. (*Bioenergy for electricity and heat* 2007)

This latter is the process for the refitted Amagervärket plant on the harbourside in central Copenhagen. In 2003 Unit 2 of the three unit coal-fired plant dating from the early 1970s was converted to be fired by straw pellets with the output reduced to about 70% of the coal-fired output and using about 130,000 tonnes of straw pellets a year, equal to about 2100 hours at full load.
In 2005 Unit 1 began a refit to allow firing by a combined fuel system of one or more of coal, wood pellets or straw pellets. Unit 1's new boiler will be able to be fired 100% with coal or wood or with 90% straw. It is part of the Copenhagen Plan setting up an adequate heat supply for the city for the next 20 years. It will receive a new turbine, new flue gas treatment system and a new stack. The plan also involves a 4 km long tunnel to take steam to the inner city heating grid. The renovated Unit 1 will produce 80 MW electricity and 250MJ/s of heating. The three power plants in total will supply 13% of the island of Zealand's power consumption, equal to the winter heating requirement for 115,000 houses. (*Bioenergy for electricity and heat* 2007)

What has driven this move to using biomass (and waste) for energy is clear government policy and legislation, reinforced by, but usually developed ahead of, European Union (EU) policy. The process is driven by subsidies for plant conversion or construction, increased carbon pricing, and transfer of the taxes on fossil fuels toward lifting the payment for biomass to a supported price in Danish Kroner (DKK) per gigjoule of energy content

Of the current use of biomass in Denmark about 48 petajoule is from wood, of which about 14 petajoule is as imported pellets. Overall of the energy from wood, 40% is from fuelwood, 30% from pellets and the remainder as wood chips and wood waste. Fuel wood is almost entirely used in home fires, chips and wood waste fire larger boilers in power plants and district heating plants, and pellets are used in both areas. There are 490,000 ha of forest in Denmark with most wood removed ending up as energy wood, either directly or as by-product from sawmills and processing plants. Danish production of wood chips has quadrupled between 1992 and 2007, and the available resource is used almost in full. The plantings that will double Denmark's forest area over the next 100 years will see the amount of available energy wood continuing to rise.

In Denmark the price of wood pellets has been much more volatile than prices of wood chip and straw. These until 2007/08 were quite stable for many years at about 35 kroner/gigajoule for chips and about 30 kroner/gigajoule for baled straw. (*Bioenergy for electricity and heat* 2007) However as they are more readily transportable, pellets from the Baltic countries, and more recently also from North America, have been imported by plant operators. Pellets are able to be ground and blown into a boiler in the same way as coal, making it simpler for conversion of coal fired plants or co-firing. Straw is also increasingly being pelleted for this reason, though in many smaller DH and CHP plants the feed is as whole square bales.

Example 1 - Averdøre Multi-fuel power plant, Denmark.
The 570MW Averdøre-2 plant, which began operating in 2002, is designed to be fueled by either straw, wood pellets or natural gas. When first planned it was assumed that natural gas would supply 85% of the fuel needs, but a leap in gas price meant that in early 2001 biofuels were decided upon as the main fuel source.
Denmark had legislated to cease the use of coal as the primary fuel for energy and Averdøre-2 was designed to replace three coal fired plants and thereby reduce net emissions of CO2 by 10%, nitrous oxide by 20% and sulphur dioxide by 30%. It uses a unique combination of gas turbines, fossil fuel boiler and biomass boiler. In co-generation mode the new plant is a world leader for efficiency, in converting up to 95% of the fuel into useable energy.
Electricity output from the plant is about 485 MW, and supplies about 20% of the demand for eastern Denmark, or enough electricity for about 800,000 households. It generates 570MW thermal energy supply for the district heating needs for about 180,000 homes in Greater Copenhagen. This energy is mainly from about 150,000 tonnes of straw and 300,000 tonnes of wood pellets annually.
The straw boiler is equipped with a vibrating grate which is divided into three air zones for each of the four feed lines. The capacity of straw storage is nearly 3000 big bales, and up to 12 trucks an hour can be unloaded. The straw is fed though straw shredders. The shredded straw is then feed into the boiler via screw stokers
The plant combines steam from both biomass and fossil fuel boilers. The ultra supercritical steam turbine operates at temperature of about 580C and 300 bar pressure, and at the times was the most advanced steam turbine anywhere in the world. The efficiency of the biomass plant is 45% and of the fossil fuel steam cycle is 48.2%. Boiler feedwater is partly heated by the exhaust flue gas from the gas turbines and is fed into the boilers at 310C. (*Bioenergy for electricity and heat* 2007, and information from plant operators - Dong Energy).
Note: It is this recovery and use of heat energy (particularly through district heating) at every part of the cycle that help make the Scandinavian and Finnish CHP plants so efficient. Another source of efficiency is the relatively short transmission distances possible when the countryside has CHP and DH plants in or near almost every urban centre.

Example 2 - Herning CHP plant, Jutland, Denmark
Herningverkärt was built in 1984 as a coal and oil-fired CHP plant, supplying the city of Herning (pop about 50,000, and district population about 150,000) in northern Jutland with heat, and the national grid with electricity. In 2000 the plant was converted to natural gas, and in 2002 it was converted to be co-fired with natural gas and woodchip. This required the bottom part of the boiler to be refitted with a 90m2 vibrating grate, and facilities for handling and storage of chip to be installed. The decision to replace coal with natural gas and then woodchip was largely due to the tightening environmental requirements for power plants. At Herning the availability of woodchip was determined to be adequate, and the economics were judged to be workable, compared to the costs of installing a desulphurisation plant and when the financial incentives for producing ‘green’ energy were included.

Now with its use of 250,000 tonnes of woodchip a year the Herning plant is the largest consumer of woodchip as sole-fuel in the country. Fired output is 288MW (combined energy). Steam temperature is 525C and steam pressure 115 bar and

volume of 118kg/second. An electricity efficiency of 30% means production of 89MW-e. District heating output is 174 MJ/sec.
The undercover chip storage is about 13,000m3 (loose volume) and is equivalent to about 75 hours of full load operation. The plant has also instilled a full log chipper and has outside storage. It is supplied by several larger contractors and a number of smaller ones. Each has a supply contract running for some years in advance, with price negotiated annually. (*Bioenergy for electricity and heat*. 2007)

The Herning 288 MW CHP plant

Example 3. Remote-monitored bioenergy CHP plants, Zealand, Denmark. Two of the straw-fired CHP plants in south-east Denmark are among a number of smaller bioenergy plants that have been designed for up to 24 hours of unmanned operation, with remote monitoring from another plant at Kyndyvärket over a hundred kilometers to the north. One is the Maribo-Sakskøbing plant on the island of Lolland, which provides 90% of the district heating needs of the towns of Maribo and Sakskøbing. Fired output is 37MW, with an electrical efficiency of 29%, electrical output of 10.6 MW and district heating output of 22.5MJ/s. This plant uses 45,000 tonne of straw per year.
A little to the north, near Vordingborg on the southern tip of Zealand, the straw- and woodchip-fired Masnedo plant is monitored from the same control room at the Kyndbyvärket plant near Frederikssund, and is also able to run up to 24 hours unmanned (during the day this plant has 9 staff). This CHP plant has a nominal boiler output of 36.4 MW and produces 9MW of electricity (at an efficiency of 25%) as well as district heating for Vordingborg. It consumes 40,000 tonnes of straw a year and 5-10,000 tonnes of woodchips.
Straw is now bought and sold by a process of public tenders in order that the pricing is transparent. The pricing of biomass has to allow the process to be relatively profitable for all parties, within this new commercial post-fossil-carbon scenario.
(*Bioenergy for electricity and heat*. 2007)

By another measure, in Sweden for a number of years woodchip price was about 110-120 Swedish Kroner (SEK) per MWh of fuel value (where a tonne of air-dry chip will produce well over a MWh of energy), but the price has this year gone to about 160 SEK/MWh, and could hit 190 SEK/MWh in 2009. At the May 2008 prices it was approximately as good a net return to a farmer in southern Sweden to use some parts of the farm to grow short rotation coppice willow for supply of chip for the local CHP plant, as to grow grain under the now 'freed-up' EU agricultural policy and at prevailing grain prices. (pers. comm. Dr Stig Larssen)

Denmark, Sweden and Finland – similarities and differences

In Sweden and Finland the overall situation is similar to Denmark, with most district heating provided by plants in and near urban centres. Three main differences exist. One is that Denmark and Sweden use municipal solid waste (MSW) as a fuel on a large scale – Sweden even charging to take it from Norway and Holland - while Finland still puts much of its MSW in landfill. The second is that Finland is advanced in using chipped softwood stumps for fuel while in Sweden and Denmark this is still not a commercially accepted practice. (pers comm.Swedish Agricultural University staff, Umeå)

The third is that while Denmark's government officially abhors the use of nuclear energy both Finland and Sweden use it to produce a large part of their electricity supply. They do differ in that Sweden has had a referendum that voted to shut down the remaining ageing nuclear plants as alternative energy becomes available. Sweden sees expansion of use of bioenergy, including second generation biofuels from ligno-cellulosic material and biogas from organic material, as the main pathway toward this goal. Finland by comparison is the only EU member country that has built new nuclear capacity in the recent years.

However Finland is also the EU member country that has the highest proportion of electricity generated from biomass and forestry industry by-product. Finland makes up to 20% of its electricity in large biomass (including black liquor-fuelled) CHP plants, far more than either Sweden or Denmark. The world's largest CHP plant fired with biomass is at Pietarsaari on Finland's west coast. As with many other large bioenergy plants in this part of the world it is part of a large pulp and paper plant – in this case UPM Kymmene.

While the timber processing industry in Sweden and Finland is a major user of electricity and heat energy it also generates much of what it consumes from its own waste product. The Kraft process pulp plants particularly are usually often net exporters of energy. Thus, while the statistics show that by-product of the timber industry is the source of this high fraction of national energy in both countries, in reality a significant percentage of it is not woodchip fueling municipal CHP plants but black liquor – the lignin-rich by-product of the chemical pulping process - being used in the pulp making factories' own CHP plants.

Peat, while not classed as biomass by the EU, still makes up a significant fraction of the fuel supply in both Sweden and Finland, and they are strongly pushing for it to be included as a slow-renewal biofuel, with its carbon cycle of perhaps 100 years. The Finns and Swedes both have massive resources of peat (Finland has as much energy in its slowly renewing peat bogs as Norway has in its North Sea oil and gas reserves), and in briquette form it is a significantly denser fuel than the softwood woodchips CHP plants otherwise have to use to qualify for green energy certificates. (*Local fuels* VAPO 2007)

Development of harvesting and handling woody biomass for fuel

In the three study countries the supply of forestry residue biomass for energy production collectively is around 10 million m3 solid, and each country aims is to significantly increase this over the coming decade. In 2006 Finland used about 3 million m3-solid (6.1 TWh) and has a target of 5 million m3 solid by 2010 and 7.5 million m3 by 2015. In 2006 Denmark consumed about 0.7 million m3, and Sweden 5-6 million m3 of forest chip (pers. comm. and *Kemara supports* Petty and Kärhä). In addition more than this amount in the form of billets of firewood (fuelwood) is consumed domestically, with Finland alone estimating use of 6 million m3 solid in 2007. (*From root to soot* 2007)

It takes the combination of many factors to develop an energy sector based on vast volumes of woodchip - a relatively low density fuel that requires high cost specialist machinery to be able to be produced and transported cost-effectively. The furnaces for this high moisture content fuel are of different design to those fuelled by powered coal or gas or oil. The development of the bioenergy sector has required the support of the other parts of the industry, of manufacturers and of energy producers. It has also required tax and subsidy support to make this fuel more competitive. This has required appropriate legislation to be passed by governments based on clear long term policies. In practice these have been directed by environmental and employment concerns and a desire for improving national energy security.

Development of forest chip supply and use - Finland

The production of forest chips began in Finland in the 1950s on a small scale, using small trees from first thinnings. These were delimbed and topped to produce the high quality chip that the early furnace feed systems required. Silvicultural management needs and creation of rural employment were the main drivers for this development. However increasing labour costs made the expansion of chip supply uneconomic until the stimulus to improving national resource security came with the first oil shocks in 1973. The machinery by this time was becoming more efficient, and expansion of supply was more readily achieved.

a household chip-fueled heater in rural Denmark showing the homogenous quality of chip required. A year's chip supply is produced in a few hours from the owner's thinnings and tops.

From the early 1980s government policy and incentives in each country (see later chapters for detail) began to drive conversion of heating plants toward using forest chip for fuel. This process of developing better specialist machinery was led by Finland, which had the forest resource and had no other domestic source of energy, apart from its development of nuclear power. In Finland supply peaked around 0.7 million m3 solid around 1981.However in the early 1980s the price of oil collapsed and the development of chipping systems again stalled. Only after 1995 did they begin to rise in Finland to the previous heights. This time the drivers were improved silviculture and the issue of rural employment at a time of economic recession, overlaid with the climate change issues being driven in part by Finland's membership of the EU.

Since 2000 in Finland the increase in consumption of forest chips has been about 320,000 m3 solid /annum, probably the highest in Europe. This has been made possible by the combination of the structure of the industry, and the high priorities given to renewable energy by government, including the introduction of a carbon-based fuel tax and through investment in R&D. This has given confidence and funding support to investment and development activity by Finland's energetic and innovative engineering and machinery companies. Similar activity has taken place in Sweden and Denmark at about the same time or slightly earlier.

Most of the manufacturers of forest harvesting and processing machinery and the leading makers of the Fluid Bed Combustion (FBC) furnaces used in larger bioenergy CHP plants are based in Finland. FBC technology allows the combustion of non-homogenous biofuels with uneven particle size and high moisture content (45-55% MC). It provides the ability to burn low grade fuels and on-line fuel switching, and reduces output of harmful emissions including nitrous oxides and sulphur dioxide.
By 1998 in Finland the consumption of forest chip was back up to 500,000 m3 solid.

R&D processes for development of Bioenergy

At this point Finland's National Technology Agency (TEKES) Wood Energy Program began, with involvement of 27 research organisations and 53 enterprises. The following five years saw an unprecedented growth in the use of forest energy. By 2002 in Finland forest chips were being used by 365 plants larger than 0.4 MW. Growth has been fastest in the area of co-generation – CHP plants producing both heat and power. At this time most forest chips were coming from the cheaper source of forest residue, and whole tree chipping of early thinnings had stagnated. However from 2003, with the introduction of feller-buncher heads and harwarders (harvesters that also forward), production of whole tree chips has lifted. The use of stump and root wood to provide energy is also increasing. (TEKES *Developing technology* 2004)

The logistics of the harvest, forwarding, chipping and transport of first thinnings has been closely studied by researchers in all three countries. Much effort and development has gone into reducing costs of chips from first thinnings relative to forest chip made from residue. At the scale of these countries' forest chip sectors, development of logistics has focussed on improving the operational availability of the machinery involved.

‘The majority of procurement cost of forest chips is caused by terrain and transport. Therefore the core of forest chip logistics is in control of transportation. Converting the biomass into transportable form is also an essential part of the logistics system, as chips have to be loaded direct from the chipper into truck or container. The link between the chipper and the transport is the Achilles heel of the traditional technology’.

For a number of reasons the large scale production of forest chips is a demanding task from the viewpoint of logistics

- Biomass has to be collected from a large number of timber sites.
- Small size of sales. The yield per site is low. This means frequent moving of machines from site to site, guiding of contractors to new sites, and underutilisation of truck capacity.
- Scattered location of work sites. Varying distances to the bioenergy plants continuously changes the productivity ratios between the subsequent operations in the system.
- Variation of biomass properties. The raw material is composed of small trees, forest residues, roots and stumps. Each biomass source may require use of specific machines and each source produces a different type of fuel. The variation of chip properties must be levelled.
- Change in quality. Comminuted wood fuels deteriorate rapidly during storage. The form and duration of storage have to be designed to ensure the quality of chips.
- Small inventory. Due to the risk of quality loss, buffer storage of forest chips tend to be small. For the peak season in winter (in these countries) biomass is stored at the road side or at terminals in an uncomminuted state.
- Blending of fuels. The supply of forest chips is seldom sufficient to meet the fuel needs of a large plant. Therefore forest chips are co-fired with bark or sawdust (or coal, natural gas).

(*Developing technology for the large scale production of forest chips*, The Wood Energy Technology Programme 1999-2003, 2004 TEKES).

A Danish Silvatec self-feeding self-propelled chipper with a rear hydraulic high-lift bin. It can unload direct into a winch-on trucking container, into a trailer shuttle bin or onto the ground.

In-field chipping of forestry residue. A harwarder on the right, and a forwarder with compacting bolsters on the left feed a Bruks chipper and bin mounted on a Ponsse Forwarder. This drives to unload into trucking bins on the landing 50 metres away (just out of frame to the right). [Note: in normal practice the harwarder loads would be stacked to dry over summer]

The Finnish project found that economies of scale tended to improve when there was integration of chip production with other forestry activity. Moving the chipping to the plant site was found to help smooth out procurement fluctuations. Over shorter distances (under10km) loose residue is transported to bioenergy plants in 150m3 truck and trailer combinations. However normally forest chips are produced at the landing. There they are blown direct into 100 -130 m3 truck/trailer combinations, a process that can take 1.5 hours. These truck-trailer combinations can only be used at landings large enough to allow turning. This close linkage of truck and chipping makes the linkage 'hot' and vulnerable to delays and breakdown. It can involve waiting, stoppages and operational inefficiency. It can be improved in a number of ways. Either the truck and chipper are an integrated unit and this is used when cartage distances are short. Or the chipper blows direct into containers, which can be waiting full when the transport truck arrives, thus reducing truck waiting time.

'Small Heat' Entrepreneurs
In addition to the larger forest chip producers, in 2002 there were 172 small heat enetrepreneurs operating in Finland. This number has since expanded to be over 400 in 2008. These are either single farmers, cooperatives or syndicates, or limited liability companies that are responsible for fuel supply and heating of rural buildings like schools, and they are paid for the heat produced rather than the fuel volume. The average size of boilers in 2002 was 0.48 MW, and the total capacity was 83MW. The annual consumption of fuel was 80,000m3 solid and the turnover was 5 million euros.

By 2006 total capacity of plants supplied by entrepreneurs was over 170 MW. Of the heating plants managed by heating entrepreneurs 28% were district heating plants and the balance were single building or single institution plants. The average size was 0.5 MW. About 157 heating plants were managed by cooperatives of forest owners or limited companies Single enetrepreneurs or groups of entrepreneurs were responsible for managing another 178 plants. In 2006 heating entrepreneurs overall used about 580,000 m3 (solid) of forest chip, which was 7.6% of total volume used for heat and electricity production in 2006. Municipalities are the single most important customer for heating entrepreneurs, though the number of private customers is growing. Historically the heat energy business often started with the customer making the reduces the likelihood of losses. With new heating plants, investment in plant was by the entrepreneurs in 50% of cases. (TTS *Heating entrepreneur activity in 2006*).

In Australia the market for chip for energy is at its very beginnings and while we can obviously benefit from the new generations of chippers and lower cost equipment, including lightweight harvesting heads, the volumes of chip available will be more suited to the heating entrepreneur model, and supplying single building or institutional plants of up to 1MW. In the 'heating entrepreneur' model, the volumes of supply are small enough that some of the more problematic issues of logistics are reduced and undercover storage may be economic.

Chipping SW Vic. farm forestry thinnings, using a self-feeding chipper to do four rows per pass

Short rotation coppice (SRC) for biomass production

In addition to the biomass sourced from forestry and the forest industries significant volumes of biomass in these countries come from a range of other sources. Biomass from annual crops is quite important in Denmark where straw is used, and in Finland volumes of the native perennial Phalaris arundinaceae, or reed canary grass, are baled to be used as biofuel. Increasingly biomass is also being produced from short rotation coppice (SRC). This can be from selected forms of the basket willow (Salix) and also from selected species of the Poplar family. Other crops grown for production of biomass include Miscanthus. Other significant sources of biomass for energy production are the waste products from food processing, and agricultural residues. These include sugar beet residue, olive pits and exhausted olive cake, and rapeseed cake.

In southern Europe, at equivalent latitudes to southern Australia, various perennial species suited to longer day length, higher temperatures and lower rainfall are being trialed. These include cultivars of Salix. While in Australia there is little likelihood of salix being a mjor SRC species, it may be suited to some sites with available high fertility waste water, including leachate from landfill.

Some aspects of the economics, management and harvesting of SRC willow may be relevant to other species more likely to be used in Australia including ti-tree and blue mallee.

Background to development of short rotation coppice willow.

There are about 300 species of willow in Europe and Russia, and some have a growing pattern suitable for growing for production of large volumes of biomass per hectare from a short rotation coppice management system. Work began in Sweden on hybridising and selecting suitable strains in the 1970s and 1980s. By 2006 there were over 15,000 ha of SRC willow under cultivation in Sweden (mostly planted since the early 1990s) and about 500 ha is being added every year. Every year in Sweden about 2500 ha is harvested with the chipped biomass supplying about 25 DH and CHP plants in central and southern Sweden. Ongoing hybridising work is being carried on by Lantmännen Energi, a commercial business set up by Lantmännen, the Swedish farmer’s cooperative.

Dr Stig Larssen, Director of Lantmännen Energi- solid wood fuels, with stems of a one year old Salix hybrid at the Svalöv research station in southern Sweden. At harvest at three years growth the stems at ground level are up to 8 cm diameter.

Much of the area planted is in central Sweden on the approximate latitude of Stockholm, but more recently subsidiary businesses have been set up in the UK, Germany and Poland to manage production and supply of biomass to the energy industry in those countries. For example a new bioenergy plant near Lockerbie in Scotland intends drawing some of its biomass from 4500 ha of SRC willow. In the 2008/09 year Sweden Lantmännen Energi will contract to deliver to the 25-30 energy CHP and DH plants a total of about 200 GWh of salix chip harvested from about 3000 ha.
Salix chip is relatively low density with 1.43 m3 weighing 0.46 tonne green and 0.23 tonne dry (so a m3 of loose chip weighs about 0.16 tonne). Chip is delivered to the mill either directly from winter harvest or from short term storage. Chip is normally supplied at about 50% MC. Seven contractors with one harvesting machine each, leased from Lantmännen, do the harvesting and supply. As the availability of woody biomass for energy plants has tightened up many plants have worked out how to combine salix chip with other feedstock material. So Enköping power plant in central Sweden now uses 10-15% of locally grown salix, and other plants are using up to 30% when they cannot get alternative supply.

In Poland coal-fired plants supply about 92% of Poland's electricity, and some are beginning to co-fire chipped salix with black coal to reduce emissions to conform with EU emissions targets. Poland has a target of 25% renewable energy by 2020. Their regulations require initially in 2008 sourcing any biomass used for energy 5% from agriculture and 95% from forestry. This ratio rapidly reverses with succeeding years so that by 2014 biomass for co-firing must come 100% from agriculture. For boilers fueled only by biomass 60% must be sourced from agriculture by 2014. This all translates into a strong demand for hybrid willow plantings.

(pers. comm. Dr Stig Larssen)

Technical details

- A SRC willow planting has a lifespan of at least 25 years. It is normally topped in the first year to stimulate coppice shoots and then is harvested every three to five years, to yield about 25 oven dry tonne/ha.
- Salix can be used as a biofilter. It is usually grown on wetter sites and can be grown in wastewater from sewage treatment or in leakage from landfill. Some heavy metals are taken up by the plant. It can process nutrients from sludge from town sewage treatment plants, and ash from heating plants.
- Soil pH should be 5.5 to 7.5. Salix grows well in light to heavy clays, organic soils or in sandy soils where there is easy access to water. Weed control at establishment is essential. Pest control is also critical. Yield of about 8-10 bone dry tonne/ha/yr of chip can be expected on good well managed sites in Sweden. Regular fertilising is necessary to maintain high yield.
- The energy ratio is high for SRC willow compared to other agricultural crop biomass, with less than 5% of energy harvested being required for harvest and processing.
- The density of willow is less than most other hardwoods. It is used to co-fire with coal, or for biomass-fueled DH or CHP plants

Management

Planting is done in spring and early summer with 1-year-old willow rods pushed vertically into the prepared soil. A tractor-drawn planting machine is used that cuts and inserts lengths of willow into 2 or 3 pairs of rows at each pass. The 1.8-

2.4m long willow rods are prepared the previous winter and stored in boxes at -4C until just before planting. Planting is in twin rows 75cm apart, and with 150cm to the next rows either side. The plants are spaced at about 59-65cm. This layout allows for the mechanical harvester and for the following tractor and bin.
The cuttings are about 18cm and are pressed into the well-worked ground so only about 1-2cm protrudes. Planting density is about 13,000/ha.
Fertilising in Sweden is commonly done with sewage treatment sludge just before planting, the year after, and the year after every harvest. The sludge is analysed and any shortfall in nutrient supply is made up by some other means.
Harvest is done when the diameter at the shoot's base exceeds 6 cm, or when the overall yield is about 25 oven-dry tonnes per ha. SRC willow is harvested in winter after leaf fall. The fallen leaf is an important source of nitrogen for the next coppice cycle. Shoots can reach a height of 7-8 metres and are harvested and chipped in the one machine. Until recently Claas Jaguar forage harvester with a beefed-up cutting front have been mainly used. Over the years a number of other machines have been trialed and the machine currently being adopted is a Krone forage harvester with a German-developed harvesting front.

A 4-row salix willow planter, showing the bundles of hybrid willow cuttings. Contractor's planters may be twice this width.

In the background is a small (green) coppice harvester designed to mount on a tractor's front linkage. Contractor harvesting is normally with a heavy modified foreage harvester.

Scale of biomass supply for energy production

To have a major flow of chip to energy plants requires some favourable factors.

- There must be the contractors with the suitable machinery, able to make an adequate margin for felling, chipping and transporting chip.
- The wood resource must be already growing there in adequate volume and price, either from thinnings or as harvest waste.
- The growers must be prepared and able to manage the forests to produce a supply of energy wood to contractors.
- The policy and legislation must be in such a form and lending to such an investment time scale that investment is attracted into construction of bioenergy plants and away from supply of fossil fuel sourced energy.

In Finland, Sweden and Denmark all these factors now exist. It has not happened overnight but as a result of planning directed by government policies for at least 30-40 years. There have generally been policies and legislation that have encouraged establishment or conversion of energy plants using biofuels. The development and growth of forestry management associations (FMAs) has been supported in each of the countries to provide skilled oversight, and management for absentee landowners. The returns for chipped thinnings and harvest waste has been made more reliable and competitive by clear policies encouraging the conversion for CHP and DH plants from fossil fuels to biofuels. These policies may have either subsidised chipping, or subsidised energy supply from bioenergy plants, or more usually both. Usually the finance for paying the subsidies has come from money raised from taxing fossil fuels.

The three study countries have clear policies for the future of their forests and have set ambitious targets (see chapter on policies and legislation). A significant element in each country's policy is that thinnings, harvest residues and timber industry residues and by-product be used as a source of CO_2-neutral energy.

Denmark aims to increase its forest area from 12 to over 20% over the coming 100 years. While much of this is as environmental mixed species plantings (not unlike our landcare approach) principally to maintain quality of groundwater supplies it will still be harvested in a sustainable way for sawlog and energy wood.

Sweden has a target that it will cease importing fossil fuels by 2020, and provide all energy (including vehicle fuels) from renewable resources, backed up by peat and nuclear energy. The aim is to increase the share of gross energy produced from biomass and timber industry by-products to about 40% by that time, including the supply of liquid and gas transport fuels. Sweden leads in production of biogas from organic waste, and in the development of short rotation coppice systems for biomass production.

Finland has firm targets for increased production of bioenergy principally from woody biomass. It is estimated that Finland will require an additional 7500 MW of new electricity capacity by 2020. 1600MW will be supplied by a new nuclear reactor commencing in 2009. The balance will mainly come from CHP plants co-fired with wood chip and peat. The added capacity of these plants will be requiring annual supply each of up to 2 million tonnes per year of biofuels. The wood component of this will be sourced from more intensive thinning management of forest, and the increased volumes of harvest residues from the shorter-rotation forestry that this more timely thinning stimulates. (*Developing technology…* TEKES)

Logistics of chip supply to a CHP plant in Denmark. One supplier to the Herning CHP plant mentioned in a previous chapter is the 970-member regional forest owners association based 100km away at Veile. This cooperative supplies about 25,000 m3 annually to the Herning plant. Delivery price is negotiated for the season starting on July 1st based on a group of 10 factors, only one of which is inflation. One key factor is international oil price. For the coming year the association has gained a 15% increase on the previous price of 91 Danish kroner per m3-loose delivered. The association has to pay all costs of chipping and transport, usually pay a royalty, and still make a margin. They are paid by the gigajoule (where 1MWh = 3.6GJ) of energy content, and each truck load is weighed and a moisture check made. Up to 6 samples are taken per delivered load of about 130m3. These samples are oven-dried to give the energy value of the chip, which is the basis for payment.

The wood from denser hardwoods works out at about 100-125 DKK/m3 -loose, but almost all the chip delivered is from softwood thinnings and harvest waste. Generally the timber to go into chip is felled in winter or spring and left to dry over summer. The delivered cost of the chip to the association over 2007/08 was about 82Dk/m3-loose, compared with the payment of 91Dk/m3-loose. The cost of fuel, and hence the chipping and transport cost, has to be very carefully judged in order to make the necessary margin.

A Danish-made Silvatec self-propelled chipper (replacement cost 3.5 million DKK) processing dry spruce tops from field edges for the Herning CHP plant. Logs will go to pulp or milling.

Usually the timber is chipped by contractors with a larger capacity self-propelled or truck-mounted chipper. It is then carted by a mobile forwarder bin to truck containers by the roadside and collected for transport two at a time. About 80% of the contract volume is processed on site in the forest, and the balance is stacked on an all-weather access site to be drawn on in case of prolonged wet spells. Often thinnings are stacked on site under a waterproof cover that has vents to let out moisture and heat. After needle fall (containing about 80% of nutrient removed in harvest) the stack is chipped and carted. (pers.com Kurt Boldrup).


Chipper bin is emptied into trailer bin. It travels to fill up winch-on truck bins

Another supplier to the Herning plant is HedeDanemark, a large private company that has many subsidiary businesses including forests management, heavy forest machinery contracting, and management of municipal trees and gardens. Chip for the Herning contract comes from all these sections within economic transport range of the plant. Separate agreements are made with forest owners, municipalities and landowners, always with the tight margins in view. HedeDanemark has to balance its contract obligation with the Herning CHP with the fact that chip-for-papermaking delivered in Sweden may net more than chip-for-energy delivered to nearby Herning. (pers com. Hedding Bilberg)

Logistics of chip supply in Sweden

In Sweden the production of woodchip for fuel began as early as the 1970s, particularly in the regions where there were few alternate uses for energy wood and there was a need for employment options. The values of woodchip as fuel were identified and further developed though the 1980s. The further development of the industry was reinforced by the introduction of a carbon tax in 1991. (pers com. Kent Nysröm)

Now the supply of chip to town or municipal plants is generally coming from from some of the many private businesses that operate locally or from one of the six regional forest owner associations. The largest one of these is Södra Skog and is based in southern Sweden.

Södra Energi is the trading company for handling all the biofuels generated within the Södra organisation – a grower-owned and controlled group which operates in southern Sweden and has a membership of about 35,000 members. The energy section of Södra in the last few trading years has turned over an annual volume of about 3.2 million m3-loose of biofuels, with an energy value of about 2.5 TWh.

With its 18 employees Södra Energi had a turnover of about 367 million Swedish Kroner in 2007. This material includes chipped forest residue, bark, sawdust, peat and sawdust pellets. It means that even the waste from operations in members' forests has a market value. Sales are mainly to customers in Sweden, with the largest customers sited between Ystad on the south coast and Stockholm. 33 of these larger customers are CHP plants up to the scale of Herning, supplying larger cities. 20 are larger pellet plants whose product go to industrial users and domestic supply needs.

(pers.com Sofia Persson, Södra. Published Södra information)

Mellanskog**,** with 26,000 members and another of the larger Swedish forest management associations, is based in Uppsala, and covers much of central Sweden from Stockholm north. The history of forest owner associations in Mellanskog's region date back to 1930 in the east and 1907 in the mid-west. In addition to the 5 million m3 of roundwood product it handles every year it deals in biomass from thinnings and harvest waste. From these sources it supplies woody biomass to 7 CHP plants producing over 500GWh and consuming over 250,000m3, 15 CHP or DH plants consuming over 50,000m3 and producing from 100-500GWh, and 38 DH plants consuming 10,000 m3 and producing 20-100GWh of energy.
(pers com Stafan Persson, Mellanskog)

In Sweden the processing and handling of thinnings and harvest waste is generally similar to that in Denmark. Road transport distances are kept to below 80km, chipping is by large plant and payment is by the energy value of the chip. Bundling of green harvest waste has been replaced by use of compacting forwarders supplying in-field chippers. Harvest waste and heads are left to dry for at least a summer to allow needle drop and improve energy value of the chip.

Logistics of chip supply in Finland. A Metsäteho study estimated that in 2007 in Finland there were about 1000 machine and truck units employed across the country in the production of forest chips for energy plants, and 770 of these were working for the major forest chip suppliers. Finland has a current consumption of about 3.4 million m3 (solid volume) of woodchip. This is estimated to be about 10% of the potential energy wood available. To harvest and handle this volume requires 100 energy wood harvesters and harwarders, 100 stump lifters, 300 forwarders, 75 mobile chippers, 100 chip trucks and 50 energy wood trucks.

The Finnish target for woodchip by 2010 is 5 million m3 (solid volume), and for 2015 is for 7.5 million m3. To allow this increase in production volume the truck and machine numbers will have to reach an estimated 1700 units by 2015. This would consist of energy wood 300 harvesters and harwarders, 560 forwarders, 175 stump lifters, 220 mobile chippers, and 120 energy wood trucks.
The major barrier to increasing the use of forest biomass is its poor energy competitiveness, even when compared with peat. The Finns see development of more innovative methods of forest fuel production as essential for offsetting this.

(*Machinery for forest chip production* 2007)

Early thinning systems: mechanical options and economics

In Sweden and Finland particularly the development of more cost-effective systems of early thinning are being given extremely high priority. At present there is a clear lag in both countries between the theoretical volumes of first thinnings that should be flowing from forestry and the actual volumes. In 2006 in Finland this amounted to 180,000 ha receiving first thinning as against 250,000 ha due for first thinning. (Developing technology TEKES). In Sweden it is estimated that up to 5 million m3 of thinnings could be being harvested annually if more cost effective processes can be developed. Since these countries are relying on increasing volumes of woody biomass to substitute for fossil fuels this significant shortfall is of great concern.
In Finland an additional reason to make improvements in thinnings efficiency is to to replace present imports of up to 20 million m3 annually of Russian roundwood by means of improved forestry growth rates and productivity.
Since Finland is the country that despite its small population dominates the European development of forestry machinery, the activity there rewards closer study. It warrants a close look also because it is the country that has the most highly developed use of energy wood for production of heat and electricity.
Finland, as with Sweden, sees woody biomass as the main renewable source for both energy and second generation biofuels. In Finland for instance much of the expanded requirement of energy wood from the present 2.5 million m3 to 7.5 million solid m3 (and 15 TWh of energy annually) by 2015 is projected to come from a more cost-effective, timely and comprehensive program of early thinning. However for contractors to date early thinning has been the least profitable part of the entire forestry cycle. This is due not only to the small stem diameter, but also to the high density of stands (up to 10,000sph), the mixed species stands, and the amount of undergrowth that often may impede the work.

The work in Finland to this end revolves around the following aspects –

1. the development of automated machinery, with either harvester or forwarder being operated remotely
2. better training of machinery operators to result in higher production
3. use of lower capital-cost machinery for small stem diameter thinning
4. development of more efficient systems to remove and process first thinnings

So treating these main areas of development in this same order –
1. Development of automated or remotely controlled machinery is applicable to the forest systems in these countries but is not so applicable for our situation in the dispersed small woodlots of farm forestry. The equipment cost is still very high, the level of training required is extremely high, and the Australian farm sawlog woodlots sites would appear more likely to reward other approaches.

2. Improved training of machinery operators has been shown to have a significant impact on the production and economics at any one site, and it is likely that here also more skilled operators would be measurably more productive. A paper presented at the World Bioenergy Conference 2008 by Kalle Kärhä of Metsäteho examined the topic of improving cost effectiveness of harvesting first thinnings and concluded that the best immediate area to concentrate effort on was operator training.
(*Approaches to increase cost efficiency*… 2008)

However, their sites are mixed species, with random spacing, and with a greater variance in diameter, and more end products from the harvest material than we normally would have here (though we could move this way with farm forestry). We are dealing in monocultures, and there are presently no more than three possible products for first thinnings – poles, chip and fuel wood.

3. Use of lower capital-cost machinery. Applied research in Finland has shown that the lower capital cost and hence operating cost machinery that may also be less specialist in nature, such as agricultural/forestry tractors, can be as productive in harvesting small diameter stems as the much more costly specialised harvesters.
This aspect for cost reduction would appear to be the more relevant for farm forestry in Australia. Thinnings here do not have the market options that exist in Sweden and Finland. We do not have the aggregate volumes, the demand from bioenergy plants or pulp plants, the transport possibilities or the potential to spread costs of harvesting first thinnings against other more profitable operations in adjacent sites. But we do have the tractors.

4. Development of more efficient harvest, bunching and transfer systems.
This includes the introduction of special energy wood forwarders with hydraulic bolsters that compress the load, thus allowing more to be carried and thus approaching the load capacity of the forwarders, and hence the economics of handling this low density material. Work on this has been done by several companies including John Deere (Timberjack) and Ponsse in Finland. The technical Research Centre of Finland (VTT) has developed a prototype compacting forwarder that can add up to 50% more load when carrying whole stem first thinnings.
Other research includes the trialing of different patterns of working though a forest area. This is not so relevant in Australia where the trees are grown in straight lines with even row and plantings spacing.
Applied research includes the trialing of machinery that combines the functions of harvester and forwarder (the Harwarder), of a machine that bundles aggregated whole small stem diameter trees for later pickup (Juha Laitila et al, Metla, published in Silva Fennica), and the trialing of different systems of chipping and transport of chipped thinnings. Manufacturers Brucks and Silvaro, as well as John Deere and Valmet, have all worked on this aspect, though with machines priced at the top of the range.
(*Approaches to increase cost efficiency*… 2008)

Costs
It is instructive to look at the cost ranges in Scandinavia for the various stages of dealing with first thinnings. The Work Efficiency Institute (TTS), Metla and Mesäteho in Finland have all done work on this, as have the Swedish Agricultural University (SLU), The Swedish Forestry Research Organisation (Skogforsk) and several of the large forest owner associations in Sweden (Södraskog and Mellanskog).
Generally the cost of fuel, machinery and labour are almost identical in the two countries, as is the value of the product.
An early study by Finland's Work Efficiency Institute (TTS) on four harvesters of different sizes and capital costs performing early thinning found that they produced 6.9-7.8m3 solid/hour, and the differences in the productivity between machines was significantly less than the difference between operators. The differences in productivity between various operators in the same machine were as much as 35-40%. The smallest of these machines was a Valtra 120 forestry tractor with a small harvesting head on a rear-mounted crane, and the largest was a Timberjack 770. At

stem volumes of 0.05-0.1m3, cutting costs for the smaller machines were up to 40% less/m3 solid in these early thinnings. The point of clear crossover of cost per solid m3, and divergence in productivity rates, happened at about stem volumes of 0.5m3. (*Productivity and logging trace of thinning harvesters.* 2000)

A more recent Metsateho paper gives an average cost of industrial harvesting of first thinnings in Finland in 2005 as almost 16 euros/m3 solid. This is with the use of medium-weight rubber-tyred articulated specialist harvesters. (*Approaches to increase cost-efficiency of wood harvesting in Early thinnings*, Kärhä et al. 2008)
SödraSkog, as a commercial grower owned and controlled association in southern Sweden, has a good handle on average costs of thinning. Södra will normally pay a grower about 20SEK/m3 solid standing. This is the grower's net return. Södra assumes the contractor cost to thin will be about 50SEK/m3-solid, and cost to transport chip at about 40-50 SEK/MWh (with 1 m3-loose of chip of 50% MC being about 0.7MWh). (pers com Sofia Persson, Södra)

In Finland a government subsidy system (Kemera) encourages timely thinning of young non-industrial small private stands where the thinnings are to be used for energy production. The site has to have a management plan (usually as part of a larger family forest holding), the dbh of trees removed must average less than 10cm, and the stand area must be over 1ha. In 2008 Petty and Kärhä in a Metsateho study estimated the returns for energy wood harvesting with and without the Kemera supports. Their base   figures for the production chain were –

Stumpage	4€ /m3s	
Cutting costs	4.8€/m3s (0.05m3s)	5.2€ /m3s (0.08m3s)
Forwarding costs 250m	6€ /m3s	5.6€ /m3s
Chipping costs	7.5€ /m3s	
Transport costs	4€/m3s (20km)	7.7€/m3s (120km)
Overheads	2.5€/m3s	
Whole chain production	**28.8/m3s€**	**33€/m3s**

Average price delivered at the energy plant gate for forest chips from all sources was 28.8 €/m3s (14.4 €/MWh), or less than the normal thinnings whole chain production cost of 35-43 €/m3s (17.5-21.5 €/MWh).
With the addition of the Kemera support the returns for chip are bolstered to just a little more than the whole chain production costs, meaning it should be possible to have a net return to the grower of between 5-10 €/m3s. (*Kemera supports*… 2008)

Equipping farm tractors for harvesting, handling and processing first thinnings

In Australia we have the situation for farm forestry that there are many areas that have no good access to timber harvesting equipment for their first or even second thinnings. This is a disincentive for the expansion of planting of farm sawlog woodlots. In the Nordic countries there are parallels to this situation with early thinning currently being not done due to the high cost of harvesting and extracting small diamter stems. Governments particularly of Finland and Sweden are investing in research in how to increase the proportion of forest that receives a timely first thinning. One solution that is being explored is the use of multi-purpose farm tractors equipped with add-on forestry equipment. These ‘forestry tractors’ have been shown to be able to be more than competitive with standard forestry machines in these small diameter thinnings. They can really come into their own in the situation in the Nordic countries where there are significant distances between sites, where there are not many sites in total, or where the removal volumes are quite low. The situation in Australia is similar to these criteria – small dispersed forestry sites, with small diameter thinnings that need to be removed at a break-even cost even though total harvest volumes may be low at only 30-50 m3/ha. Once the sites are thinned we have the problem of how to process this material in a cost-effective way to turn it into a useful commodity. In the case of Finland or Sweden this is primarily into forest chip for bioenergy. Here it may be initially into firewood to sell into the urban demand. This section of the report deals with the systems and equipment that are available there that may suit our needs, or that could be imported.

Equipment used in Nordic countries for family forestry and local contracting - Forestry tractors.

Forestry tractors are specially equipped to be able to work on rougher trackless terrain often littered with harvest waste, rocks and stumps. Often they will be working in the snow, in low light or the dark. Equipment includes underbody shielding, extra hydraulic pump, reinforced forestry tyres, chains, cabs with full impact protection bars, full-perimeter working lights and extra shatterproof upper windows. A forestry crane is usually mounted on the tractor, centrally just behind the rear window. With their reach of over 5.5 m and equipped with a grapple of light felling head they are more than capable of felling and loading first thinnings or handling storm-thrown trees.

The largest manufacturer of forestry tractors is Valtra. Valtra is working with Kesla, one of the largest Finnish makers of forwarder trailers, chippers, truck cranes and other equipment, to produce more well matched and efficient tractor-trailer outfits. The range of forestry equipped Valtra tractors is from the shorter wheelbase 4-cylinder models of 60-88 kW, to their longer 6-cylinder tractors of 80-120kW. These forestry tractors all have a rotating seat with crane controls built-in to the armrests. This allows the operator to switch quickly from a transport mode facing forward to the loading or working position facing backward.

These tractor and forwarder trailer combinations can have a similar production rate with small diameter (under 15cm dbh) trees as a thinning harvester or harwarder, but are far less costly and more versatile. Such tractors in Finland in 2006 cost from 28,000 € for a 1996 95HP 6400 in good condition, to a new 125 HP 6850 costing about 73,000 € (in either case the cost of extra agricultural tyres and rims to allow it to be more versatile adds 4-5,000 €).

The utilisation of farm tractors in energy wood harvesting in young stands has increased steadily in Finland. Energy wood harvesting can be a profitable business for farmers with other seasonal use for their tractor, and for contractors operating year-round in energy wood harvesting. The forestry tractors can be particularly effective in the harvesting part of the process. In forwarding, with their highway speed of 30-40km/hr, they can in some situations have an advantage over a conventional forwarder with its travel speed of 5-8km/hr.(*Energy wood from early thinnings*. 2007)

Forwarder trailers. This, plus a chainsaw and a tractor, makes up the basic equipment of the serious Nordic family forester. These trailers are made by over a dozen manufacturers in Sweden and Finland and are of a range in specifications from two pairs of bolsters and a 6 tonne capacity, to the 12 tonne capacity heavyweight with four driven wheels and four pairs of bolsters. Makers include Nokka, Junkari, Farmi and Kesla in Finland and FTG Mohedra in Sweden. They can all be fitted with a pivoting crane with a reach from 5-8.5m, and grapple. Prices range from 6,000 € for a smaller capacity model with no crane, up through 12,000 € for a larger model with no crane and with four driven wheels and heavier capacity.

A contractor's Valtra forestry tractor with Kesla 9 tonne trailer-forwarder

Cranes (loaders). Many forwarder-trailer makers make their own cranes and other accessories. The Finnish trailer company Nokka for instance makes a large range of cranes and also produces grapples and clamshell (pelican) buckets. Other crane makers such as Cranab may be specialists. While cranes are normally fitted to forwarder trailers, they may also be fitted to trucks, larger chippers, or can be fitted direct onto the tractor on a reinforced frame mounting, or on the front or rear three point linkage. Cranes come in a wide range of lifting capacity and reach. Controls are either direct hydraulic or electric over hydraulic. Normally cranes for forestry work are fitted with a rotating grapple, but if oil supply is adequate they can also be equipped with a small harvesting head.

Cost of cranes is approximately 7,000 – 15,000 € or more, depending on capacity and reach. For instance the 2008 yard price for a Finnish-made Kesla 203 T crane, rotator, grapple, stabiliser legs and bank of control valves is about 11,500 € in the factory yard. This crane has a reach of 6.7m and a load rating at 4 metres extension of 700kg. This crane is normally fitted to a Kesla 9T trailer (factory yard price of from 6,000 € for base model), or 9HD forwarder-tailer (Finland yard price from about 13,000 € - with base specs of hydraulically assisted all-wheel drive and 2-wheel brakes).

Essentially the same crane could be fitted to either the tractor, a forwarder-trailer or to a chipper. All it requires is the proper base plate, and enough volume and pressure of hydraulic fluid. For the Kesla 203T crane this is a working pressure of 175 bar and 30-50 l/min. (2008 Kesla factory price advice and brochures)

A Valtra forestry tractor with frame-mounted crane, showing red Nisula accumulating shear heads (feller-buncher heads) and an Arbro stroke delimber head (left)

Harvesting heads. There are many makers of small to medium harvesting or aggregating heads in Sweden and Finland. Many of these use either a hydraulic shearing blade or fixed pair of cutting blades that are adequate for small diameter softwoods. Fewer are fitting with the sawchain cutting bar necessary for denser hardwoods.

Weights of heads range from about 125kg for a grapple with a built-in chainsaw blade costing up to $10,000 landed here, up to about 500kg for essentially a scaled-down single grip harvester head. These may cost from $70,000 to $100,000 landed here. In between is an array of heads that can be carried by a tractor mounted crane, that can fell and either aggregate or process and cut to length first thinnings stems. Several of these makes are already available in Australia, and all could be imported.

A major consideration in choosing among heads is the amount of oil flow and pressure they will need to work effectively. The appeal of the heads, such as those made by Pentin Parja or Nisula of Finland, that use a shearing cutter to sever a trunk is that they may only need about 70l/minute of dedicated hydraulic flow. This may be available in larger modern farm tractors. On the other hand the processing heads with hydraulically driven chainsaw bars such as those made by Keto usually need over 100 l/min or more of dedicated flow. To obtain this flow may require an extra oil pump on the other hand driven off the PTO plus a separate oil tank. Some trailer forwarders have this option. Density of the wood and diameter of the truck are important factors in choosing types of cutting systems.

Stroke delimbers. One option that could be applicable to some timber growers is the stroke delimber head, such as are made by Tapio or Arbro. This performs the function of the processing head in removing light branches and bark, but requires far less oil flow. They are also cheaper for the same trunk diameter capacity. While they are slower this is less of an issue if the trees are larger diameter, such as second thinnings softwoods.

Chippers and shredders. Chippers have a large range of cost and capacity. Again there are dozens of makers and most make at least five models. At one end are the hand-fed PTO disc-chippers which take stems up to 150mm and could be used for turning thinnings into chip for farm household chip-fired heating systems. These may cost from A$6000 - 8000.

In the middle range are disc chippers that can be crane and grapple-fed, may have a longer feed table with auto-feed, can take stems of 250mm and produce from 10-12m3/hour of chip. At the top end for tractor-driven units are those producing up to 50m3/hour of chip. These may have a crane fitted on the frame, may be 3PL or trailed and cost around $75,000 and up, and require 135-200hp to drive. Most of these will also come as a self-powered wheeled version.

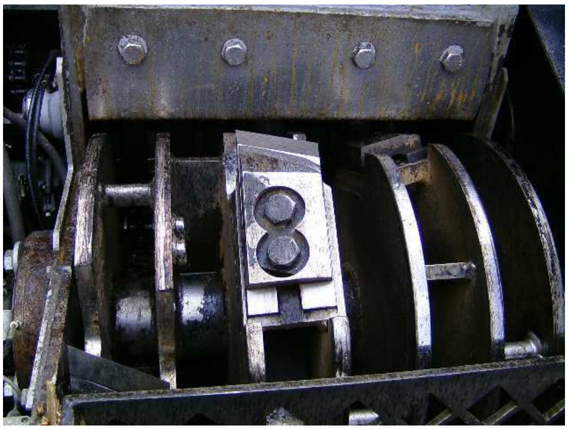
Often in these study countries when a tractor is powering a larger chipper it may also be equipped with a wheeled or front linkage tipping bin. The tractor will then have a chipper at one end and a bin at the other, making it far less easy to manoeuvre.

Lindana (TP) in Denmark make a version of their largest pro-powered chipper to fit directly onto Fendt 9000 series tractors to reduce overall length significantly.

In any decision on chippers there are likely to be two deciding factors. First is the cost of the labour needed to feed the machine weighed against machine cost and the value of the chip produced per unit of time. The other is the size and uniformity of chip. Disc chippers will produce chip from most material of better size and uniformity than drum chippers. This may be critical in deciding the market that the chip can be sold into. For smaller auto-feeding furnaces smaller more regular chip is required. Larger DH or CHP plants can use a coarser less uniform chip.

Shredders produce a far coarser product than chippers, more applicable for composting or mulching. They use a hammer mill principle and require more power to process a given volume. Their advantage is when the feed material is dirty or has other contamination. In this case they save significantly on sharpening an replacement of blades.

Tub grinders and crushers are comparable to shredders in being able to deal with feed that may be contaminated with dirt and stone, but have higher capacity. Some CHP plants will use these to convert stumps into suitable fuel.



larger tractor pto drum chipper

Danish-made Loma shredder

chip from industrial drum chipper

shredded wood

Firewood processors. In the study countries some of the first thinnings are converted to firewood, for which there is a ready sale. The wood usually used for firewood is from the hardwood species. These are quite low density by the standards of most Australian hardwoods and might compare with young bluegum or poplar. There are a number of firewood processor manufacturers in each country. Some of these machines are already imported, but generally are not of adequate capacity to be a commercial proposition for a grower network wanting to develop a firewood business in Victoria, unless the species was of low density and other positive factors were in place – such as an existing demand for bagged firewood of this species.

Availability of equipment for Australian farm forestry. A limited range of forestry equipment suitable for some farm tractors is already being imported. It is likely that over the next few years this will greatly expand. Already examples of Farmi forwarder trailers and chippers, Lindana, Patu and Junkari chippers, Keto, Rotne and Narva heads, and Rotne thinning harvesters have been brought in by Australian

importers. Individuals have imported other products, from manufacturers Mohedra and Kesla among others.
Equipping a farm tractor to allow it to harvest, handle or process first thinnings is only sensible if it allows this work to be done significantly more cheaply than the contractors' charge, and in safety and comfort for a full working day. Assuming the contract cost using a forestry harvester and forwarder is at least $30/m3 to harvest first thinnings and forward out of the woodlot to the landing, this means that investing in equipment to equip a farm tractor needs to improve on this significantly.

Nordic experience indicates that to work most efficiently in the woodlot the felling needs to be done so groups of trees are aggregated in bunches of three or more in an easy-to-collect layout, for instance in one row out of four. The cheapest mechanised way this can be done is by a simple harvesting head on a forestry crane, possibly mounted on the front or rear 3-point linkage, but more normally mounted at the rear on the reinforced tractor frame. The frame reinforcing system for forestry crane mounting is common in Finland, and several companies, for example JAKE, make fittings to suit a wide range of tractors.
A crane with reach to 6.5m allows 4 rows in conventionally-spaced farm forestry to be processed in one pass, with the harvested trees being placed beside each other – as efficiency of collection improves when grapples are picking up full loads. The harvested trees can then be left till leaf fall and loss of about half the moisture content before being gathered by a forwarder trailer drawn by a tractor with a rear 3pl mounted crane and grapple. For far less outlay than a purchase of a specialist forestry machine a suitable farm tractor could be given a versatile forestry capability, with a potential operating cost of under $100/hour including driver and fuel. In Finland the operating cost was assessed for a forestry tractor harvesting energy wood in randomly spaced mixed species trees and operating at over about 600 hours a year. The operating cost of about 40 €/hour included fuel, maintenance, drivers wages, depreciation and all other fixed and variable costs. (*Energy wood from early…* 2007)

It needs to be said that not all farm tractors will be suitable for use in such forestry work. Ideally the base machine will be heavy enough to be stable when equipped with a crane, but not too wide. It requires adequate oil flow and preferably should have a second oil pump and tank dedicated to the harvesting crane and head. It should be able to have the crane mounted in front of the driver. This will be either at the front of the tractor, or better still, where the driver can rotate the seat and controls, at the back. Clearly a contractor could afford to spend more to set all this up when the amount of work and improvements in productivity justified it.

Costs of felling have been extensively studied over recent years in Finland. The manual felling system for small trees (energy wood) of 0.13-0.18 m3 (or a diameter of up to 15cm) using a chainsaw on an extension frame allows felling and aggregating into bunches of 3.6-5.1 m3 per effective work hour. Use of a tractor with a light forestry crane and a feller buncher head can be compared against this base figure. Size of the removed trees has a high impact on productivity and costs of mechanised felling. With a machine cost of 50 €/hour and an average tree size of 0.17 m3 the cost of felling is 20€/m3 solid. If the average size is 0,10 the cost goes up to 30€/m3, and if the average size is is 0.5m3 the cost falls to 9-10€/m3 solid. The important factor with mechanised felling is that larger piles can be accumulated on the site thus reducing the costs of forwarding out. (*Biomass fuel supply chains* 2007)

Legislation and policies driving bioenergy development.

Each of the three countries visited has evolved a situation where bioenergy makes up a significant and growing fraction of renewable energy, which makes up a growing fraction of national primary energy needs. Each has reached this situation along slightly different pathways, but the common features are

- Historically a well developed forestry industry and timber manufacturing sector.
- A stable recent political structure which engaged in long-term planning.
- Strong private ownership of the forest resource, and a well developed system of forest management associations (FMAs) or their equivalent.
- A government preference for FMAs to oversee forest management, harvest and marketing, and to supply training and services.
- An awareness that reliance on imported fossil fuels is not in national interests, and a population that is educated about and supportive of change.
- A system that strongly favours investment in social equality and is accustomed to high taxation rates.
- A historical very heavy local use of wood for fuel, and development since World War Two of district heating systems for towns and cities.
- Coherent national policies with long time lines, implemented by legislation, with short term impacts softened by assistance and subsidy to local government, householders and affected business and industry.

Denmark's Energy policy development
In Denmark conversion of district heating plants to use of waste and biomass began in 1976 with the introduction of the first energy plan, **Danish Energy Policy 1976**. Before the energy crisis of 1973 90% of Danish energy consumption was covered by imported oil. Today Denmark is self-sufficient in energy, in large part due to its share of North Sea oil and gas. In 2005 natural gas extraction equalled 393 Petajoules of energy, oil contributed 796 PJ and renewable energy sources contributed 126 PJ. Actual Danish energy consumption was 830 PJ, so that renewables by then were about 15%. 40% of this, or 50 PJ, is produced from biomass.

While the first energy plan was focussed on security of supply, environmental considerations became more important over the next decades, and in the last few years climate commitments have had the highest priority. However the issue of security of supply has remained of crucial importance in the planning. In 1979 the Danish Government commenced a swing toward more use of natural gas and the first Department of Energy was set up. In **Energy Plan 1981**, with a focus still on limiting imports of fossil fuels, a higher priority was given to socio-economic and environmental considerations. The first subsidy schemes for utilisation of straw and wood chips were implemented. Taxes levied on fossil fuels made biomass competitive for fuel for district heating and electricity generation. Also the domestic consumption of firewood increased.

By 1985 the Danes were aware that emissions of greenhouse gases were likely to become the overriding problem for the energy sector. In 1986 parliament voted for an expansion of electricity capacity by 1000MW, to be produced by some large new plants and a larger number of smaller plants fired with wood chip, straw, waste,

natural gas and biogas. Some of these were to be local CHP plants of a capacity of 80-100 MW. The 1990Brundtland Report led to **Energy 2000 – an Action Plan for Sustainable Development.** This included that energy should be reduced by 15%, that consumption of oil and coal should be reduced by 40 and 45% respectively, with natural gas and renewables taking over.
To drive the change in use of fuels by DH and CHP plants Danish parliament in 1990 passed the **Heat Supply Act**, which gave the Energy Minister powers to regulate choice of fuel. As a result of this a large number of oil and natural gas fired DH plants have been converted to natural gas fired CHP plants. Many smaller DH plants outside main urban areas have been converted to using biomass fuels.
The fourth of Denmark's six energy plans was **Energi 21**, introduced in 1996. It contained the long term objective that CO2 emission by 2030 must be 50% below the emissions of 1998. This was to be reached by energy savings, more efficient use of energy resources, and 35% of gross energy by 2030 to be from renewables. Coal was to be phased out and consumption of oil and gas to be effectively unchanged. In 2001 with a change of government to a Liberal-Conservative coalition, energy policy was radically changed, with choice of fuels able to be decided by the market. This was repeated in the Energy 25 strategy introduced in 2005.

However a new strategy in 2007, **A Visionary Danish Energy Policy**, went back to close to the Energi 21 approach. It added the intent to double the investments in Danish energy research to one billion Danish kroner a year (A$220 million), attain energy savings of 1.25% annually, and have the transport sector using 10% biofuels by 2020. This plan has the targets of reducing fossil fuel consumption by 15% by 2025, and for Denmark's total energy consumption not to have increased since the mid 1970's, in spite of continuing economic growth. This last has been the case to date, with the energy consumption flat between 1980 and 2005 despite about an 80% increase in GNP over that time (much of this presumably from sale of excess fossil fuel).

In 1993, as a result of the Energi 2000 plan, Danish parliament entered an agreement on the increased use of biomass in the energy supply. One part of this specified that the central power plants were to use 1.4 million tonnes of biomass a year, including a million tonnes of straw. This target for straw will be reached when a new plant opens that will be using 170,000 tonnes a year. In the present free market for sale of electricity the power companies are compensated for the additional costs of firing with straw, as they cannot pass on the extra costs and lose market share.
At present energy companies can use biomass fuels to stay under their CO2-e emissions quota. Emissions are now increasingly expensive with penalty for discharging over quota raised in 2008 from 40 euros per tonne to 100 euros per tonne. Between 2005 and 2007 the Danish government set a quota of 33.5 million tonnes annually, a 15% reduction on the previous emissions level. From 2008 to 2012 the number of quotas will be reduced by 25%, thus driving the cost of emissions higher and making it more attractive to invest in energy savings and renewable energy.
(*Bioenergy for electricity and heat* 2007)

Sweden's forestry and energy policy development
Of Sweden's total land are of 44 million ha about 23 million ha is forest, most of which is managed for production. The history of forest management and ownership in Sweden is similar to the other neighbouring Nordic countries, with great exploitation

from the introduction of steam driven sawmills in the 1850s and of tar production both before and after that date. The expansion of population into the forest of the north of the country was stimulated by establishment by the Crown of forest commons between **1861** and **1918**. These were private forest areas owned in common by landowners and managed jointly, in addition to their areas of individually-owned forest. Over the years the management of forest commons became more independent of government control and this was clarified by the **Forest Commons Law (1952)**.
(*Forest commons in boreal Sweden* 2006)

The majority of Sweden's forest is owned by families or individuals. Nearly half of these owners are members of one of the six main forest owner associations. These associations now produce about 30% of industrial roundwood, nearly 20% of sawmill capacity and over 40% of pulp production. The formation of associations was stimulated by the increasing acquisition of private forest land by industry in the 1930s and the need for individual owners to group together to increase their bargaining power with the industrial forest processors, and to retain more control over forest management.
Present management of forestry in Sweden is guided by the **Swedish Forestry Act**. The current act is based on the initial Act that was passed in 1903. In 1949 a revised act tightened laws and extended it to include the social aspects of forestry and also the sustainability of production. After the oil price shocks of the 1970s it was clear that Sweden with 75% of its overall energy needs coming from imported fossil fuels was in a very vulnerable position. Prices for oil had increased approximately tenfold from 100 Swedish Kroner/m3 to about 1000 SEK/m3. Government realised it needed to develop a more stable supply of energy. Already there had been some work done on woodchip as an energy source. The thinking was that if biomass supply industries were encouraged it would develop industry in the rural areas and keep money in the regional economies. All the added values had been identified by the early 1980s.
(pers. comm. Kent Nyström)

The **Oil Replacement Committee** that was appointed recommended use of taxes and subsidies to cause a market change away from fossil fuels and a development of alternative technologies and energy sources. As a result a significant and increasing amount of biofuels is used in district heating plants. Investment grants since before 1991 stimulated the building of these plants to produce a more clean and efficient provision of energy for heating. Further investment grants in 2003 for conversion of plants to use biofuels has resulted in an increase from 6 Terrawatt hours of biofuels to a present 17 TWh.
In 1991 a CO_2 tax was introduced, with industry bearing most of the brunt of the increase in costs. After 2 years the tax was halved to reduce movement of industry out of the country. Since then it has been further reduced in line with other EU countries.

In 1993 the **Swedish Forestry Act** included further revisions that made environmental goals equal to the production goals and brought more pressure to bear to ensure renovation of over-harvested forest. The **Swedish Forest Agency**, Skogsvårdstyrellsen, is responsible for overseeing sustainable forest practices all through Sweden and for implementing the broad provisions of the Act. The Act is quite specific about the general goals for forest management, but leaves much of the detail to Skogsstyrellsen officers to develop for local circumstances. All forestry felling plans come through the Skogsstyrellsen offices to be vetted, and inspection is made of harvest sites to ensure compliance with the Act.

Political measures over this time resulted in a doubling of the use of bioenergy over the 1990s. In 2003 Sweden introduced **Green Energy Certificates**. These were developed to stimulate production of electricity from biomass, small hydro schemes, wind and photovoltaic cells. The market for the certificates is created by end users having to purchase a quota proportional to their emissions. In 2003 7.4% of their emissions had to be covered by green certificates. In 2004 - 8%, 2005 -10%, 2007 - 15%, 2010 -18%. The Green Certificates are active until 2016. then guarantees apply til 2030. The penalty businesses or energy supply companies must pay for not having the right amount is 150% of the going quota price. In 2005 an **Emission Trading System** was introduced. (pers. comm. Kent Nyström, Svebio)
As well as policy that targets business and energy production Sweden has introduced a number of measures to reduce energy use in the home. The **Energy Efficiency Program** is directed at improving insulation and raising consciousness of transport use. Both public awareness programmes and energy costs have affected domestic heating. Over the ten years from 1997 wood pellet consumption has tripled from 500,000 tonne/year to 1,650,000 tonne in 2008 (400,000 tonnes of this is imported). This splits roughly 30% to each of domestic, institutions and small energy plants. In urban areas where district heating is newly available the cost of connecting a household to this is now more than competitive with alternatives, including reverse cycle airconditioning or heat pumps. (pers.comm. Kent Nyström, Svebio)
Sweden's **National Energy Agency** does an annual detailed national energy audit that is published on their website. Presently renewable energy supplies about 40% of Swedens primary energy. Of this 27% is from bioenergy (including municipal solid waste), 1.7% is from wind and 0.1% is from solar energy. The balance is hydroelectricity. (pers. comm. Kent Nyström, Svebio)

Sweden's experience over the last thirty years, beginning when it was one of the few countries to apply a carbon tax, has shown that reducing greenhouse gas emissions does not necessarily make GDP growth stall. In fact in Sweden GDP growth is more positively correlated with bioenergy development. From 1990 to 2007 bioenergy development increased by 70%, GDP by 40% and GHG emissions decreased by 9%. One of the reasons for these figures is that the research and development by industry has been increasingly exported. Now the export of renewable energies technology is the eighth largest and the fastest growing export sector. (pers.comm. Kent Nyström, Svebio)

Increasingly, Swedish municipalities are producing biogas from organic waste and upgrading it to the standard of vehicle fuel or selling it into the European natural gas reticulation system. Increasingly, people are buying vehicles that run on either 85% ethanol, biomethane or biodiesel. Many city buses, including most of Stockholm's buses, are already fuelled by either raw ethanol or propane-boosted biomethane. Sweden has a target of ceasing imports of fossil fuels by 2020. By this time they also aim to have renewable energy contribution to primary energy increased from the present 40% to 49%. The electricity produced from forest waste and wood processing by-product is already nearly 25 TWh. (pers.comm. Kent Nyström, Svebio)

At the local level Swedish municipalities, town and villages have moved to producing significant bioenergy locally. A leading example, Växjö Kommune, was by 2007 producing over 95% of district heat and 35-40% of electricity requirements using biomass. The fuel for the 104 MW Sandvik 2 plant comprises chipped logging residues plus sawdust, bark and milled peat.
With all the heating for the Kommune now produced in one place this means that the thousands of boilers and chimneys have been replaced by one modern efficient plant with excellent flue gas purification where up to 99.5% of ash is caught. Any remaining ash is scrubbed from the flue gas before it goes through the condenser. Most of the ash after treatment is returned to the forests as fertiliser. This reduction in particulate emissions and noxious gases was a major reason driving the municipal investment in the Sandvik plant. The Sandvik 2 boiler produces about 47MW-e and about 90MW-th. Växjö Kommune has about 348km of district heating pipelines progressively installed since the Kommune moved toward district heating in 1970. One outcome of the way the Kommune has moved to cut its use of fossil fuels is that it now can claim to have the lowest greenhouse gas emissions per head in the EU at about 3.5 tonne. (*The Sandvik plant* 2007)

Södra Skog, Sweden's largest forest owner association, with 35,000 members owning 2.3 million ha of forest, is a major user and supplier of energy. The association is a good example of how Swedish policies and legislation have driven the efficient use of forestry waste and processing waste for energy generation. Södra generates all the energy for its sawmills and pulp and paper plants from biomass, and as well is a net supplier of about 300GWh of green electricity – enough for 40,000 households. (pers.com Sofia.Persson. Svebio publication 2008)

Roundwood from windthrown trees and dangerous branches within a Jönköping city park, sold to Södra Skog as energy wood and destined to become heat and electricity.

Findings and recommendations

It is evident in the three countries in this study that they are steadily increasing use of biomass for energy and that improving the flow of biomass from early thinnings is seen as critical in expanding supply.
Forestry tractors are playing a role in early thinning, particularly with small contractors (including small heat entrepreneurs), and forest owners.
The logistics of aggregating large volumes of forest chip from dispersed sites are being perfected.
The underpinning strategies to drive development of bioenergy and reduce reliance on fossil fuels are critical to the economics of the whole process.

For the Australian situation it shows that –

1. **industrial volumes of roundwood, and large volumes of energy wood can be sourced from dispersed small woodlots**. Woodlot thinnings and final harvest can yield a full mix of pulpwood, ply logs, sawlogs, energy wood and fuel wood. Products separated at harvest can be aggregated into commercial volumes at the local level for local processing or on-sale. Early thinnings can be done cost effectively by local contractors if an ongoing market exists**.**
2. **woody biomass and timber processing by-product can provide a substantial part of national primary energy needs**, provided the cost of carbon is above $25/tonne, and necessary market signals are in place including for efficient thermal energy utilisation.
3. **the intensive management of dispersed small forest lots need not be at the expense of environmental values**, including water quality, biodiversity, recreation and habitat retention.
4. **family forest owners effectively and willingly manage their forest holdings** to a high standard through the generations, and their ownership to them usually represents more than simple financial value.
5. **aggregated product from dispersed small-scale family forests can be the basis for development and expansion of a broad range of other industries**, and can replace imports, expand exports, increase employment and produce carbon-neutral energy.
6. **To establish family forestry on a viable scale** at the local, regional and national level there needs to be support by applied research, responsive training and advisory services, profitable markets for all products, and available cost-effective systems for harvest and transport.
7. **there must be clear market certainty in the industry directions, driven by clear long-term policies and underpinned by legislation,** for the necessary scale of continuing long-term industry investment to take place, including into the establishment and managing of long-rotation sawlog plantations.
8. **effective, frequent and regular consultation** by government bodies and departments with the forest-owner representative groups, particularly about research priorities and policy directions, is vital for development of a viable and expanding family forestry sector.
9. **investment into forest technology, forest industry products and forest cluster products** can be both profitable for the industry and produce spin-off exports of product, expertise and equipment.

And finally, because the reality is that the success of the Nordic family forestry sector relies on the full involvement of the forest growers themselves in every aspect -

10. **it is more effective if government does not control or provide all services of extension, training, inspection and marketing**. They can be successfully relinquished to grower-controlled management associations, with the role of government being confined to setting guidelines and providing necessary funding and support, including to stimulate the less profitable forest management operations that are still critical to overall profitability.

The significance to Australia of the Nordic models of family forestry and of biomass to energy

If landowners gain enough confidence to invest in integrated multi-purpose plantings, or make significant land available for joint ventures, the economic benefits of a greatly expanded farm forestry sector across Australia would be significant, in the order of many billions of dollars annually. As in the Nordic countries studied, the benefits range from increased rural employment, an extra farm enterprise and retention of habitat on farms to an active research sector, and export of products and expertise. Development of carbon-neutral energy and fuels from forestry industry by-product provides a significant additional benefit.

The expenditure by government to support and stimulate the Australian farm forestry sector is minor relative to the potential value of the longer-term outcomes. In the Nordic countries the landowners provide most of the invested funds, business invests in its own research and production facilities, and the income tax paid by the people employed in the industry more than offsets expenditure by government on industry support programs. In practice most of their funding for development of the energy or other industry support is coming from taxes on fossil fuels, and so is being paid by their industries and the whole population.

While it is beyond the strict range of this study, there clearly must be a review of many of the often-conflicting and short-sighted policies relating to the forestry industry. It is time that new Australian government policies are developed to produce the desirable situation where multi-purpose farm forestry in Australia grows steadily to become – as in the Nordic countries – a significant producer of sawlog, biomass for renewable energy including biofuels, broad environmental benefits and significant carbon sequestration. The whole sector with its great unrealised potential must be subjected to a new appraisal. The example of management and outputs of family forestry in the Nordic countries should be looked at for the necessary fresh insights.

In essence this report is advocating a change in culture. For much of the time since settlement farmers have focussed on cutting and clearing forest. Vast areas are now clear farmland. It is time to replant a fraction of this, and the present landowners can be the ones to make most of the investment and gain most of the benefits. The process of replanting has already started. It needs conscious long-term government support.

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Appendices

The following three sections in the appendix are included to add some detail for those interested. The summary of the development of bioenergy in Finland effectively brings the three study topics (and many other related topics) together. The reader can attempt to relate them to our Australian context, and learn of the scale of potential economic benefits to the individual forest growers, and to the wider economy.

1. National energy data, and relative production of bioenergy.

Finland (5.3 million pop)
In 2006 Finland was generating about 21% of its primary energy from biomass from forestry and the forest industries sector. 7% was being generated from forest chip. This totalled alone totalled 3.4 million m3 solid or 24 petajoules (6.7 TWh). This is less than 10% of the estimated potential amount.
The target for 2010 is 33 PJ and for 2015 – 45.4 PJ, and 2020 it is 50.8 PJ (14 TWh). By this time the target for overall energy from biomass including peat, agricultural biomass and black liquor will be 204.1 PJ (56.6 TWh). The aim is to hold total energy consumption to near the 2006 level of about 1130 PJ or 314 TWh.
This 2006 figure breaks down approximately as 50% industry, 16% Transport, 20% space heating, 13% other uses. Sweden has a target of producing 49% of its total energy needs from renewables by 2025. (*Local Fuels*… 2007).

Denmark (5.3 million pop)
Renewable energy in Denmark in 2006 produced about 16% of primary energy or approximately 128 PJ (35.5 TWh). Of this total about 40% is from biomass, 30% from MSW and 20% from wind. Of district heating total energy of 129 PJ, 8 PJ was from straw, 12 PJ (3.3 TWh) from woody biomass, and 19 from MSW.
Denmark's gross energy consumption per person from 1980 to 2006 has been steady at 159 GJ (less than a third that of USA at 509 GJ)
(*Energy in Denmark* 2006)

Sweden (9.1 million pop)
By 2006 renewables supplied about 28.8% of 624 TWh total energy. Bioenergy supplied about 27%, or about 116 TWh (418 PJ). This figure is up from a base of about 40 TWh in 1970 when bioenergy was mainly use of black liquor in the paper industry and small-scale domestic heating. Electricity generated from biomass fuels by 2007 was about 25 TWh. Between 1970 and 2006, while energy use in transport has almost doubled from 56-101 TWh, the use in industry has stayed about level at about 157 TWh , and use by residential and services has fallen from 165 to 145.
(*Energy in Sweden* 2007)

2. Finland - private forestry ownership and intensive management

For countries in northern Europe and the Nordic countries the history of policies and legislation concerning sustainable management of forestry go back further in time than this report has space or scope to cover. In these study countries the most relevant developments and legislation have been in the last 100 years for privately-owned forest. Several other things need to be kept in mind -

1. Almost all forest is as managed mixed native forest stands. After harvest there is rapid regeneration both from natural seedfall with infill planting of improved provenances of one or both of the two indigenous conifer species.
2. Almost all forest holdings are mapped and covered by detailed forest management plants (for Finland's family forests alone plans cover about 10 million ha). Growth rates are regularly assessed. Management plans run for ten years. Detailed harvest and thinning planning runs five years ahead.
3. While the average family's holding may be around 40 ha for southern Finland this will consist of up to 40 mapped smaller lots of different age, species mix, growth rate, geology or position on the landform. Trees in the area of springs, watercourses and other significant habitat will all be exempt from harvesting.
4. About half the forest owners in Sweden are members of commercially-active cooperatives which act for grower-members, compete to buy and process their forest product and timber of other producers, and generally are efficient and highly profitable entities.
5. All the forest owners in Finland and most in Denmark will be members of a local FMA. The FMAs have many roles including training, supervision of harvesting and replanting standards, management of certification and marketing. Many of these are roles that in Australia are done, usually less well, by government.
6. Forestry is intensively managed but on a sustainable basis. In these countries these two things are not mutually exclusive. 'Sustainable' means that the growth increment is greater than the harvest removal, that the species mix is retained, that habitat and water quality are protected. In addition through the 'Everyman's Right', access to forest for recreation and collection of fungi and berries is open to all.

Each country in this study has distinctive differences in development of family forestry. This chapter focuses on Finland partly as it has a similar population and land area to Victoria, but has such great differences in its forest industry development.

It should be kept in mind when reading the following account of Finnish family forestry that the country is one third within the Arctic Circle. The growing season ranges from 150days in the south down to 110 days in the north. The population is 5.3 million and the area of land is about 30.9 million ha. Of this 10% is lakes and about 6 million ha is arctic mires and peat land. The excellent rail and road system reduces impacts of climate and terrain, allowing industry and population to be highly decentralised. Finland has the highest percentage of forest cover in the EU (77% - about 23 million ha) and also the highest amount of forest area set aside in reserves (over 7%).

This country has the highest education standard in the world by most measures. It is a world leader in exports of fine paper, in production of forest industry and timber processing machinery, and of electronic communications equipment. Its three largest

timber processing companies are among the world's top twelve. It is a world-leader in design and construction of multi-storey wooden buildings, including laminated softwood load-bearing structures and stressed plywood beams. It is a leader in applied research and industrial design. It has a successful international airline, and a significant ship building industry. Its 2007 GDP was 179 billion euros.
Finland's economic and social success has as its basis the sustainable management of the mixed species native forests, its high level of ownership by families and individuals, and the pivotal role in forest management and marketing played by forest management associations.

Finland was an autonomous Grand Duchy within the Russian Empire from 1809 until 1917, when it proclaimed independence. This resulted in a brief but bloody civil war which the right wing faction won. Civil war factories producing arms and other war material around Jyväskylä then began to produce papermaking machinery, and this continues to the present.
The forest has always been Finland's main natural resource and source of export income. Finland even under Swedish rule in the 1700s had had a significant timber industry producing resins and sawn timber, with tar as the main export. The industrial exploitation of forest continued, as part of a slash-and-burn agriculture, right up to the early 1900s in the east of the country. By 1875 this had resulted in reduction of the forest cover over the country from over 80% of the land area down to almost 25%. The rise of the milling industry dates back to the 1850s. In this period there was also development of a boat building industry. The first paper making plant was established in 1880. By 1920 sawn lumber and pulp made up over 70% of timber industry exports, with lumber alone being 54%. By 1996 these were together making up only about 21% with sawn product fallen to only 14%, while paper and paperboard and other product had risen to 69%.

Private forest ownership was always part of life in Finland. The records from the time of earliest settlement over the 1300s and 1400s show that permanent rights for forest use were granted to private estates. This was both to raise taxes and to increase expansion of settlement under Swedish rule. By 1459 regulations stated that when a tenant died his 'taxable house'- the estate including forest - should not be subdivided or left abandoned.
More widespread smallholder ownership of forest began under Swedish rule in 1775 when each farm was allocated its own forest area as part of land reform. It increased again following independence from Russia in 1917, and then again following the resettlement of the inhabitants of the area of east Karelia, which was ceded to Russia after the Second World War. Private ownership had by then become a key part of Finnish forestry. By 1901 there were about 120,000 forest owners, and the majority owned over 100ha. By 2006 there were about 444,000 separate forest holdings of over 2ha, with the majority owned jointly between 920,000 family members. So presently about one in five Finns is a forest owner. Half of these holdings are under 20ha, one third are of 20-50ha, and about a fifth are over 50ha.
(*Decades of private forestry in Finland* 2008)

Policy development and legislation.
The government of Finland was uneasy about unsustainable forestry practices in the early 1880s following obvious overexploitation of large areas after restrictions on the sawmilling industry had been repealed in 1861. Several committees were set up and

the outcome of their recommendations was the first Finnish forestry law, enacted in 1886. The law forbade devastation felling by stating that ‘forest must not be laid to waste’, and specified the leaving of seed trees standing on clear felled sites.
At the end of the 1890s a boom in timber product demand prompted more disquiet and in 1900 a **Private Forestry Committee** was set up. Its brief was to investigate the sustainability of the Finnish forestry practices at that time, including the ‘true extent of ever-continuing complaints about limitless fellings’, and to recommend necessary changes. Its report described the state and use of private forests in those days. It found there was ‘undeniable proof of the dangerous loss of forest resources’. The key reasons were the earlier forms of forest use: tar burning, slash and burn, and the industrial use of raw wood, including the sale of ‘extensive young immature forests that that are part of the forest capital that should be saved for future production as a condition of efficient forestry’.
The suggestions of the Private Forestry Committee began to be implemented in the early 1900s and have become the central part of the legislation and promotion of private forestry. They included that wood production should be secured by legislation, and by providing support and advisory services for private forestry.
In 1907 the Finnish Forest Management Tapio was established and at about that time the very first of what have become Forest Management Associations (FMAs) were established as forest grower cooperatives. A decree was issued in 1917 to prevent forest devastation, and to safeguard natural regeneration of forests. Responsibility for supervising this regulation was given to the district forestry boards acting under the State Forestry Board. However the legislation was not very effective and forestry advisory work was only just beginning.
To rectify the situation another act, **The Law Concerning Private Forests**, was passed in 1928. The principles of this remained valid through to the mid-1990s, though it was revised in 1967. This Law defined forest management principles more specifically than before, particularly regarding the full regeneration of harvested areas. It gave the state the ability to put areas of mismanaged forest under its own protection. The area under protection annually in the 1960s was around 30,000ha but by the later 1990s was in the order of tens of hectares.
The task of monitoring practices in contravention of the Law was given to 19 district forestry boards, also established in 1928 and operating under the principle of self regulation among forest owners. Also in 1928 the first **Forest Improvement Act** was introduced. This defined the financial support available from the state towards long-term silviculture and improvement activities in private forests. The works this financial assistance applied to included drainage, restocking of unproductive forest, seedling stand improvement, and, post 1948, construction of forest roads.
In the late 1990s Finnish forestry law was completely revised and brought into line with the forestry objectives agreed to at the Rio Conference of 1992, and with the general principles agreed to at the Helsinki conference of the European forestry ministers. The drivers for this were the strengthening of international forest and environment policies, and environmental politics and conflicts in the country involving forestry. Thus the Law Concerning Private Forests of 1928 was superseded by **The Forestry Act** which became law in 1997.

This Act concerns forestry owned by all groups and contains much of the directives from the previous Act on regeneration of harvested forest, but is much broader. Its purpose is to promote the socially, ecologically and economically sustainable use and management of forests. The Forest act also safeguards biodiversity. Forests must be managed and used so that the biological diversity of seven specific habitats are protected. In addition to springs, streams and rivulets these habitats include small forest ponds, nutrient rich hardwood swamps and heathland islets in undrained bogs. The forest owner has to advise of intention to harvest in the region of any of these habitats 14 days prior. Consequences of unlawful operations can lead to criminal prosecutions. In 2004 there were 110 Forestry act violations and one conviction. Convictions carry penalties of steep fines or up to two years prison.

In 1997 the Forest Improvement Act of 1928 was replaced by the **Sustainable Forestry Funding Law**. Funding can be made to an individual landowner or a joint venture formed by landowners. Funding is made according to the provisions of the Act and including for forest regeneration, controlled burning, energy wood harvesting (first thinning), forest fertilising, drain maintenance and construction of forest roads. In 2004 about 65 million euros was allocated for these improvement works or about 5 euros per hectare.

Environmental grants (the METSO program) are also available under the Forestry Act and are designed to cover the cost of managing forest values over and above what is defined in the Act as being within the landowner's responsibility. This could include projects to restore drained habitat, for mapping of valuable habitat, or to maintain and manage valuable habitat. Over 1997-2004 9.5 million euros have been allocated under this funding.

By 1939 there were already 300 operational FMAs and about the same number of forest advisors who gave professional help to the forest owners. Already by the end of the 1930s over half the growing stock was in private forests. Since then Finland's growing stock volume fell after the war till about the 1960s due to the loss of east Karelia, onerous war reparations and to service the post-war resettlements. From the early 1970s growing stock volume has steadily increased. The volume growth in private forests has been particularly strong and is now over 2/3^{rds} of all stock in Finland. While in 1920 annual increment across the whole forest was about 54 million m3, it is now about 97 million m3 a year with over 60 million m3 being the increment of forest in private hands. (*Decades of Private forestry in Finland.* 2008)

Forestry research and development. The establishment of the Forest Management Tapio in 1907 was the beginning of what is now an extensive array of interlinked research and promotional organisations, partly government funded and partly funded by industry levy or industry directly. The Finnish forestry industry itself spent about 230 million euros (A$380 million) on research in 2004, double the figure of about five years before (about 90% of this is from the pulp and paper industry). The entire forestry cluster's investment in R&D by 2004 was about 500 million euros (A$820 million) annually. The main organisations involved in forestry industry research are -

- **Metla**, the government funded Finnish Forest Research Institute, which alone employs over 900 staff. Metla is an independent organisation which operates under and is funded through the Dept of Agriculture and Forestry. It is Europe's biggest forest research institute.
- **VTT**, the Technical Research Centre of Finland, is the biggest contract research centre in Northern Europe. About 30% of its 230million euro budget is from the state. It is controlled by the Ministry of Employment and the economy. It has the breadth of research activity of the CSIRO in its heyday. It has specialist sections working on bioenergy, pellet technology, forest applications, raw materials handling and operational logistics

- **Mesäteho**, the industry research body, which does research for forest industry members, Metsähallitus (manager of the state forests) and sector associations. As well as industrial product and process development, research includes trials to improve energy wood harvesting and handling systems.
- **KCL**, Oy Keskuslaborotorio, is wholly owned by the pulp and paper companies and produces technical and economic research data, and provides laboratory and pilot production services. It was founded in 1916 and now provides one of the most diverse ranges of research services in the world.
- **TTS**, the Work Efficiency Institute, established in 1924 and tests or compares equipment including forestry tractors, bioenergy boilers, and processing heads. It has a forestry section which is involved in developing better handling systems and more economic systems for forestry management.
- **Universities and Polytechnics**. Five of Finland's universities offer forests products technology courses. Two offer forestry courses. 13 Polytechnics offer courses for working in forestry, papermaking and the wood products sectors. The courses at the seven universities include postgraduate research.
- **Industrial companies**. Most companies in the forest industry sector conduct their own R&D in-house. Collectively these will total many hundreds of staff.

(*Decades of Private forestry in Finland* 2008)

G**overnment funding and coordination of R&D**. Funding for forestry research and development may come from industry, or via one of a number of structures operating under various ministries, depending on whether it is judged basic (theoretical) research or of a more applied nature.

The Finnish government, in consultation with forestry industry stakeholders developed overarching research programs that many of these organisations are conducting research under. This includes the **National Forest Program 2010**, which is under the control of and funded by the National Technology Committee Agency – TEKES. This is the coordinating body for the funding of industrial applied research by the Finnish government. TEKES was founded in 1983 and now dispenses about 465 million euros a year (A$760 million) to fund complete programs (packages of finance and expert services) aimed at the most important targets of the future of Finnish business and industry.

Programs are based on initiatives by TEKES customers and strategic focus areas. In practice the industry in Finland is small enough that industry, research and government are able to work very efficiently to achieve good results. The programs are planned in open seminars of stakeholders, and each funded program has a steering group of representatives from funding bodies and stakeholders. In 2008 TEKES is involved with 26 new or ongoing programs. The research component and delivery of forestry programs is outsourced by TEKES to organisations like Metla, VTT, or Metsäteho.

The National Forest Program has many objectives, including to improve efficiency of forestry operations, and particularly the cost-effective harvesting and handling of early thinnings. The original program running from 1999- 2010 was revised and renewed in early 2008. Other projects of program components being funded through TEKES include work on small wood-to-electricity gasification plants, biofuel production, and business opportunities (for Finland) from climate change.

(pers.com T. Makinen VTT)

Forest Management Associations. The development of more organised marketing and value adding of private forest product has been continuous since the initial forest grower groups came into existence in 1907. While methods of selling by private owners were often criticised even up to the start of WW2, a number of crucial steps were taken pre-war from which important institutions and systems have evolved. In 1921 a Forest Centre was created for private forest owners. Over the 1920s it traded and exported round wood and did some milling and export of sawn wood. In the 1930s it became the forest sales department of the Central Union of Agricultural Producers. In 1934 it became Metsälitto Group Oy, and in 1947 this became a cooperative owned by private forest owners. The cooperative with its 130,000 members is still the parent company of Metsälitto Oy which is now one of the world's largest timber processing and paper-making companies. Its profits still help underpin the functions of the Union of farmers and forest owners (MTK), and the FMAs. Metsäliitto Oy has a turnover of about 8.4 million annually and employs about 30,000 people. It is active throughout Europe and it it markets its products worldwide. The cooperative and a subsidiary handle wood procurement for the Metsäliitto Oy mills.

The forest management associations provide private forestry administration at the local level on one hand, and act as a powerful lobby group though the Union of Farmers and Forest owners on the other. The FMAs had long been in existence as representative and marketing organisations were now to become formally integrated into the system. They were provided with a permanent system of funding and made responsible for many administrative and service functions to forest owners though the **Act Concerning Forest Management Associations** which was first published in 1950 and passed into law soon after. The obligatory forest management fee included in the Act drew active debate and strong criticism. The current Act of 1999 states that the purpose of FMAs is to promote the profitability of forestry practiced by forest owners, and the realisation of the other goals that they have set. FMAs are administered by a council elected for four years by postal vote. In turn a board is elected that represents different part of the area and all forest owners. There were about 130 FMAs in 2004 but the number is slowly falling as smaller associations decide to merge so that services to growers can be improved.

At present private forestry administration and promotion are regulated by the **Law on the Forestry Development Centre and Forest Centres**, which became valid in 1996. The 13 Regional Forestry Centres are responsible for monitoring the legality of FMA association operations. Each FMA collects a fee from forest owners in its area. The fee income must be used to promote forestry. In the main this is through provision of services such as forest planning and advice, harvesting and forest management service, and timber sales service. Income is collected for some additional services such as acting for absentee landowners.

(*Decades of private forestry in Finland* 2008)

Family forest owners lobbying power. The Central Union of Agricultural Producers and Forest Owners (MTK), occupies a multi-story building in central Helsinki. It is a powerful lobby group both at national and EU level. Within Finland it strives to communicate the positive aspects of forestry and counter any misinformation. It maintains an office in Brussels, has close links with the Nordic Forest Owners association, and with the EU family forest owner association CEPF. At the international level it is a member of IFFA, the International Family Forestry Alliance.

MTK is financed from a number of sources: rent from other office space in the central Helsinki multi-storey building it owns, revenues from the newspaper it publishes three times a week – the sixth largest in the country with a readership of about 350,000, dividends from the holdings it has in the pulp and paper conglomerate Metsälitto Oy, and from its membership. MTK has two councils and two boards, one each for farmers and forest owners. The forestry board members are elected for three year terms from representatives nominated by the 9 regional forest grower unions. Boards of these unions are from the regional membership of the 135 FMAs located in all parts of the country.
MTK has a staff of about 150, of which about 100 work on the newspaper. The other 40-50 are experts and specialists in the range of areas important to the forestry industry. MTK works to maintain good contact with the government and with research organisations. It provides input into policy formation affecting farmers and forest owners, and into research priorities. It has a seat on the Metla board and is involved with the Economic Research Institute. It is often a stakeholder in forest industry research programs and when possible is involved in informal working groups developing forestry project proposals. MTK plays an important role in maintaining the importance of forestry in Finland and the EU, and in ensuring its ongoing viability.

One program that has been implemented by MTK is the development of a business model for farmer cooperatives to begin a business in biomass supply or bioenergy production. The national target for renewable energy in Finland is 38%, up from the present 30%, and there is good scope for the forest owners who own the biomass to benefit from filling some of the gap. MTK sells the proven business franchise to farmers and assists them with the set up process. Usually only 10 forest owners though in some cases there are 20-50. They contract to supply chip and may buy in chip from other forest owners within a 30 km radius of the plant.
This scheme was started in about 1998. Most of the new start-ups are now of about 1-5 MW capacity for towns and villages, though the earlier ones were often of about 350kW or less and were for businesses, schools and old folks homes. MTK provides support for each cooperative for 5-10 years and gains some income per MWh of energy generated. (pers.com, L.Jyhla and Ilpo Mattlila, MTK)

Selling systems. At present between 100,000 and 150,000 timber sales are carried out annually, with most of these being from the 440,000 holdings of family-owned forest. An average sale is of about 430m3 of round wood. The total volume of round wood sales from private forests is over 45 million m3 (not including energy wood) and it makes up about 86% of the supply of timber to industry. These sales are either of material at the roadside or as sales of standing timber. Up to the 1980s about 50% of harvesting was not fully mechanised, with chainsaws, tractors and even horses still in use. Since the 1970s, with increasing development of specialist machinery and year-round harvesting, selling timber standing has increasingly become the norm. Roadside sales by 2004 had fallen to about 20% or about 8-10 million m3. (*Decades of private forestry in Finland* 2008)

In a standing sale the buyer fells and extracts the trees as specified in the forest harvesting agreement. The seller receives payment as a stumpage price, with the agreement specifying unit prices, roundwood volume, timber specification and quality requirements, the harvesting period and the methods for measurement and payment.

The buyer for a second or third thinning or final harvest will often be one of the big three Finnish companies: Stora Enso, UPM Kymmene or Metsäliitto Group. In this case all the timber extracted will go to the range of processing plants these groups own: pulp and paper making, ply production, and milling. The energy wood fraction from the stand will also be taken and used by them, or sold on. This may include stumps. If the buyer is a more specialist organisation such as a local sawmill who may only be interested in larger diameter logs then there will be several buyers organised for the other product extracted. (pers.com Pekka Hintikka 2006)

Mechanisation. By the end of the 1990s fully mechanised harvesting and extraction made up 95% of all operations. By 2005 the Finnish Forestry Yearbook states that there were about 1400 harvesters and 1600 forwarders doing commercial roundwood removal, and about 1400 timber transport trucks shifting the product. Electronic aids have played an increasing role, allowing communication between buyers and the harvester to change specifications of length and diameter in an instant, or to change the destination of small diameter logs from ply mill to pulp mill or to bioenergy plant depending on price. The transport trucks will use GPS systems to collect roadside logs on instruction from the buyer. They use self-loading trucks which can also weight. This system means the ability to work separately from the harvest team, and also through the dark winter months and nights.
Still by 2005 there were about 100,000 owners, or one in four owners of forest, who do their own felling and extraction. The owners of smaller forest lots (less than 5-10 ha) will not harvest each year and on average forest owners doing their own work only spend two working days a year. It may be for largely clean-up work such as clearing storm-blown trees. They will usually use a chainsaw, a tractor and a trailer equipped with a forestry crane and grapple. A few still use a horse.
(*Decades of private forestry in Finland* 2008)

Forestry Profitability. The overall profitability of the operation of private forestry in Finland has been continually tracked. Several issues need to be appreciated.

1. The forest holding is usually inherited and is rarely the main source of income, but may be primarily a holiday haven for town dwellers. Management may be more of a stewardship approach for maintaining the holding for future generations. There may be tax considerations, or a liking for being independent for fuel or building material.
2. There are considerable silvicultural and development costs in managing a productive forest holding properly. Most forest owners regard their forest as a 'growth asset', with regular management being rewarded by improved value.
3. The growth rates of Finnish forests are very low by Australian standards, at an average of around 4m3/ha/year even with two or three thinnings, resulting in rotation lengths of 60-120 years. The three main commercial species are Norway pine, Sitka spruce and birch.

Over time the net returns from forestry operations on average have varied between about 40€/ha and about 100 €/ha (A$164/ha). Over the period of 1975-2005 the average return to capital from private forestry holdings was about 3%. However the economic value of family-owned forestry to the country as a whole has been enormous, and is at the centre of Finland's remarkable economic development since WW2. The real timber sales income of family forest owners expressed in 2004 money values was 1.6 billion euros/year over 1997-2004. Most of this money stays in rural areas, as two-thirds of forest owners still either live on their property or nearby.

(*Decades of private forestry in Finland* 2008)

Tax. In Finland forestry taxation has been an important forest policy tool. From 1922 to 1992 taxation was based on a property tax approach where the forest holding was taxed on an estimate of yield and the tax was paid annually. The specific tax reductions allowed for specific forest improvement work made the system effective at encouraging investment in better management. From 1993 the taxation on forestry has been on the difference between income and allowable expenses. This difference is taxed at the capital gains tax rate of 29%. The new tax system is supposed to treat family forestry more fairly than the previous property tax system.

Forestry and the national economy. The family forest sector is well supported by government, well serviced by applied research, and competently overseen by grower-governed FMAs, who also represent the interests of the growers via a highly organised and influential lobbying process. This sector is central to Finland's prosperity. From 60% of the forest area it provides about 86% of the roundwood going to the forest industries, as well as an increasing volume of energy wood going to dispersed energy plants. This economic contribution can be easily seen in the figures -

- About 10 million ha or over 70% of family-owned forest is mapped and covered by detailed plans. Over 90% is certified under the Finnish certification system, recognised by the PEFC international certification system.
- Finnish forest industries directly employ nearly 4% of the labour force, or 90,000 people, with 70,000 in the forest industry and 20,000 in the forests.
- In 2004 the forest sector produced over 7% of Finland's GDP.
- In 2007 about 20.7% of exports were from the forest sector, totalling about 10.85 billion euros (A$17.8 billion).
- Forestry and the forest industries combined make up the most important industrial sector in most of the country. In nearly all provinces of Finland the forest sector is either the most important or second most important sector.
- During the period 1993-2004, carbon sequestration averaged 6 million tonnes per year.
- The use of by-products of forestry and timber processing as fuel produce 23% of Finland's primary energy, 20% of Finland's electricity and over 75% of domestic and industrial thermal energy needs.

The forestry cluster. The forests and the forest industries are part of a greater sector called the forestry cluster. This combines with the forestry and forest products processing industries a broader sector which services, supplies the forest industry and further value-adds forest products. Included within the forest cluster are -
<u>machinery and equipment</u> – Finnish pulp and paper machinery has a third of the global market. Industry procurement of machines and equipment is 90% domestic.
<u>chemical industry</u> – the industry is Finland's second biggest user of chemicals. 10-20% of the sector's output is used by the industry
<u>wood construction</u> – Finland leads in utilising wood in building, and in new products
<u>electronics and engineering</u> – 10% of output goes to the forest industry
<u>automation and information technology,</u>
<u>research and education</u> – Finland leads in research, and trains 50% of Europe's paper engineers, and 16% of Europe's wood products graduates.

plus the areas of logistics, printing, services (consulting). Other industries (such as the textile industry) have significant sales to the forest industries.

The Finnish share of industrial countries' exports of forest cluster products is about 8%. Finland's forest cluster's share of GDP is about 10%, share of industrial output about 30%, share of exports is nearly 40%, its work force is about 200,000, and its overall growth rate is 3-4% annually.

(*Key to the Finnish forest industry* 2006) (*Finnish forests in a nutshell* 2008)

Websites in Finland. Energy (district heat) www.energia.fi. Energy policy www.ktm.fi. Energy conservation www.motiva,fi. Legislation www.finlex.fi. Agriculture and forestry policy www.mmm.fi. Research www.tekes.fi. Environmental policy www.ymparisto.fi. Statistics www.stat.fi.

3. Detail on Finland's R&D process in bioenergy development

In Finland the National Technology Agency TEKES in 1999 funded **The Wood Energy Technology Programme** for five years to develop more efficient technology for the large-scale production of wood chips. In 2002 it was extended to include a sub-programme on small-scale production and use of wood fuels. As of January 2004 the programme consisted of 44 research projects, 46 industrial projects and 29 demonstration projects. 27 research organisations and 53 enterprises participated. During the 5 year period of the programme the use of forest chips quadrupled. Forest chips had become a credible fuel even for large CHP plants. The total cost of the programme was 42 million euros of which 13 million was provided though TEKES. The Ministry of Trade and Energy provided investment funding for the new technology employed in the demonstration projects. This included the development of the baling technology that makes it possible for uncomminuted biomass to be transported and stored cost effectively.

With the development of far greater use of forest chips the demand has risen ahead of supply, and by 2003 the cost of chips was rising despite the more efficient production systems, with chips delivered at the plant averaging 10€/MWh. This is the cost/t of supply including normal operating margins.

While many aspects of the programme were specifically dealing with producing forest chip from coniferous boreal forest, many aspects of the machinery and logistics were directly relevant to the Australian situation, including to chipping thinnings from small dispersed woodlots of monoculture eucalyptus farm forestry.

- Moisture is the critical fuel quality, and should be kept low to realise full energy potential, at least below 40%. In storage, to avoid loss of drymatter and OH issues with fungus, below 25%. The effect of moisture content is greater than the effect of wood properties. Vaporisation consumes 0.7 kWh/kg of water. Reducing MC from 55% to 40% reduces the initial amount of water by half and the effective heating value rises 8%.
- After moisture content, effective heating value (kWh/kg of wood) depends on the chemical content of the wood. Lignin has a higher heating value than carbohydrates.

- Whole tree chipping is far more cost-effective than delimbing before chipping, and 15-50% more chip is produced, productivity of harvest is 15-40% higher, cost of procurement is reduced 20-40%. But chip quality suffers and machinery must be more robust.
- Chipping raises the bulk density of uncomminuted residues (here mainly pine branches and branchlets) from 0.15-0.2 to 0.36 to 0.46.
- Compared with other fuels the space volume of wood chip is large and so it is essentially a local fuel. For efficient transport over distance it would need to be pelleted or converted to pyrolysis oil.
- The ash content of wood is low – less than 0.5% in pure pine chip, but it is up to 3-5% in conifer barks and 3-6% in needles. Needles are a nuisance in the combustion process as they contain alkali metal chlorides. Depending on combustion conditions the alkali metal chlorides can corrode the heat transfer surfaces of the boiler.
- Biomass should be kept as clean as possible at harvest, and not dragged along collecting soil or stones.
- The production chain cost structure is highest with small stem volume thinnings, rising steeply once whole tree volume goes below about 0.15m3. For smallest average stem volumes chainsaw felling was more cost effective, though development of accumulating feller-buncher heads have changed the economics significantly for these thinnings.
- Producing conifer forest chips only uses about 3% of the energy produced from combustion.
- Bark has been now recognised as an important fraction of forestry biomass. It makes up about 12% of overall coniferous industrial roundwood volume. Up to 1.5% of wood is removed during softwood debarking and becomes part of the bark volume.
- Chipping at the landing is the principal point of conversion of the whole tree to chip. It is important to not have separate stages of the process too dependent on each other. A particular problem is with chip transport. This can be solved by chip going into large (60m3 in Finland) winch-on open-top container bins.
- A critical aspect is that the supply of chip has to be either constant or able to be substituted for by some other equivalent fuel. In Finland it is peat.
- Maintaining large stockpiles of chip is rarely done. Instead it is normal to have stocks of seasoning whole trees in all weather access able to be chipped when needed.

(*Developing technology for large scale production of forest chips* 2004)