EFORWOOD

Sustainability Impact Assessment of the Forestry - Wood Chain

Project no. 518128-2

EFORWOOD

Tools for Sustainability Impact Assessment

Instrument: IP

Thematic Priority: 6.3 Global Change and Ecosystems

Deliverable PD4.2.5
Report on conditions and consequent timing of technological developments in processes relevant to case studies

Due date of deliverable: Month 24
Actual submission date: Month 30

Start date of project: 011105
Duration: 4 years

Organisation name of lead contractor for this deliverable:
Building Research Establishment (BRE), U.K.

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	X
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

AUTHORS:

Building Research Establishment, BRE, United Kingdom
Geraldine Lea
Geoff Cooper
Chris Holland
Ed Suttie

Oy Keskuslaboratorio – Centrallaboratorium Ab, KCL, Finland
Katri Behm

KCPK, the Netherlands
Jobien Laurijessen

Technical Research Centre of Finland, VTT, Finland
Arto Usenius
Jorma Froblom
Margareta Wihersaari

Pöyry Forest Industry Consulting Oy, POYRY, Finland
Hannele Lehtinen
Pia Nilsson

Technical University in Zvolen, TUZVO, Slovakia
Marian Babiak
Rudolph Kropil

CONTENT

1. INTRODUCTION (responsible : BRE)

This report is part of an EU project called EFORWOOD, which aims to provide methodologies and tools that will integrate Sustainability Impact Assessment of the whole European Forestry Wood Chain (FWC). This deliverable has been produced by Module 4, which focuses on the processing and manufacturing stages of FWC in Europe. This output follows on from PD 4.2.3 *Report on review of technology development trends within various processes* (produced in Month 15 - January 2007)
The report has been written by several persons, so the reader should take this into account while reading the report. The company responsible for each chapter is shown at the beginning of the main sections each heading.

This report will contribute to analysis of the impact of technology development trends on module specific models and to identifying the conditions for and timing of implementation of the technological changes and development of response functions.

This report will provide background for:
PD4.2.6 Conceptual outline of response functions and draft response functions for case studies (Month 26)
PD4.2.7 Report on conditions and consequent timing of technological developments in processes including the identification of country differences and obstacles to adopting changes relevant to whole Europe (elaboration of PD 4.2.5 for whole Europe) (Month 30-36)

1.1 Drivers for change

Drivers for change fall into 4 broad categories

- Sociological which are mainly consumer driven. They relate to changes in household sizes, consumer demand for specific value added products, and those which are seen as "greener" or less of a health hazard.
- Economic, which balance costs of changes to technology against the benefits in terms of lower production costs and/or increased profit ie cost benefit analysis. Reduction of waste to reduce costs of disposal is an area of particular importance.
- Environmental to improve the quality of the environment, by reducing the use of fossil fuels, reducing emissions to air and water
- EU legislation and policy includes various requirements and/or objectives:
    - Increased recycling, a target of 15% for timber and about 56% for paper
    - Reduction of emissions of SO_2, NO_x, PM, VOCs, and O_3 (Ambient Air Quality Directive and Large Combustion Plants Directive)
    - Limiting emissions of formaldehyde from wood-based panels
    - Improving the use of wood and wood-based products from sustainably managed forests (Green (public) Procurement) (forest and wood certification)
    - Prevention of illegal logging
    - Increased use of renewable energy

1.2 Technologies

Technologies can impact in more than one area of FWC manufacturing.
Level of development of technologies – relates to time scale for introduction:

- Developed and already in use general manufacturing - still to be introduced to SMEs
- Developed and already in best practice – still to be introduced in general manufacturing
- Developed to small scale trials – introduction into best practice
- Research level.

2 PULP AND PAPER (responsible: KCL)

2.1 Use of enzymes

Use of enzymes in pulping processes can both reduce energy consumption in refining and/or improve fibre properties. Effects on refining were tested in pilot trials in early 2000s, and also mill scale trials were conducted shortly after that. The trials proved that use of enzymes in refining is a viable and applicable method in mill conditions, with 10-15% energy saving potential in reject refining and about 4% in total pulping system /1/. The method requires a storage tank or tower before refining, so this will cause some investment costs, e.g. for a thermomechanical pulping (TMP) process with daily capacity of 400t/d, the investment costs would be approximately 500000€ /1/. There have been estimations, that the maximum uptake of enzyme-aided pulping could be 20-30% by 2010, 30-60% by 2020 and 50-80% by 2030 /1/.

Expected time	By 2015	By 2025
technology in all SMEs		
technology generally adopted		(X)
technology adopted in best practice	(X)	X
technology in industrial trials	X	

When compared to traditional TMP pulping, enzyme-aided refining does not increase consumption of other chemicals, but instead decreases energy consumption and thus energy costs, and as a consequence may decrease fossil CO_2, NO_x and SO_2 emissions /1/. Emissions to water are difficult to estimate before large scale trials are complete, but there might be small increases in emissions when enzymes are used. Enzymes should not provide any threat to occupational safety and health.

Driver for change to new technology		Applicability	Comments
Economic	improved profit	*****	less power bought
	production cost savings	*****	less power bought
Environmental	decreased use of fossil fuels	*****	
	reduced energy demands	*****	
	fewer emissions and waste	***	Due to smaller electricity consumption.

Reference:/1/ *Kallioinen, A. Pere, J. Siika-aho, M. Lehtilä, A. Mälkki, H. Syri, S.& Thun, R.* Biotechnical methods for improvement of energy economy in mechanical pulping. VTT Research notes 2183, Espoo, Finland, 2003. Available in the internet: http://www.vtt.fi/inf/pdf/tiedotteet/2003/T2183.pdf

2.2 Development of bio-refinery plants

The concept of bio-refinery is still discussed, and at present there is no common and widely accepted definition for this concept. Modern pulp mills are already bio-refineries of a sort, but if bio-refinery should include e.g. production of transportation fuels, more studies and research are needed. The time-scale for bio-refineries is difficult to estimate, but by 2025 there might be some industrial trials.

Expected time	By 2015	By 2025
technology in all SMEs		
technology generally adopted		
technology adopted in best practice		
technology in industrial trials		X

Estimated benefits from bio-refineries are promising. New products could be produced in form of chemicals, fuels, additives, etc., bringing added value to the process. At the same time less fossil fuel would be needed, and even external energy for local consumers could be produced. The raw material requirements could be lower, so recycling possibilities could increase. The technology could even provide pharmaceuticals, so added value and social acceptance could be gained. However, these technologies would need more studies and trials.

Driver for change to new technology		Applicability	Comments
Consumer demands	move to greener energy	**	
	pressure for local energy production	**	
Economic	improved profit	***	
	added value	***	
	exploitation of by products	**	
Environmental	decreased use of fossil fuels	***	

2.3 Improvement of black liquor utilisation

Two black liquor utilisation technologies were presented in deliverable PD 4.2.3. Black liquor gasification has been tested in small scale trials, but large scale mill trials would require big investments (approximately 200-300 million €) and maybe 5 years of successful operation before becoming widely accepted. At the moment it is difficult to expect that kind of trial in the near future. The small scale trials have given inconsistent information about the benefits of this technology. There is also a question about safety, since the process is highly pressured and includes oxygen, so there is a risk for explosions. Thus black liquor gasification is not further analyzed in this deliverable.

Separating lignin from black liquor is more likely to be adopted in common use in the forest industry than black liquor gasification technology. Several small scale trials have been completed, and one can expect some (perhaps 5-10) mill scale trials by 2015. Depending on the results of those trials, the technology may be adopted as best practice in some point, but it is very hard to predict that before the large scale trials have been done.

Expected time	By 2015	By 2025
technology in all SMEs		
technology generally adopted		(X)
technology adopted in best practice	(X)	(X)
technology in industrial trials	XX	XXX

The separated lignin is most likely to be consumed in the same mill as energy source. Thus it would replace fossil fuels. It is also possible, that the technology would improve the profit of the mill, since adoption the technology can increase production capacity. Some demands to use more renewable energy may come from consumers or legislation, and here lignin will provide one solution, even though it is already used efficiently in pulp mills in energy production from black liquor. The technology will not be likely to affect social aspects.

Driver for change to new technology		Applicability	Comments
Consumer demands	move to greener energy	**	
	pressure for local energy production	**	
Legislation	European legislation	**	
	national legislation	**	
Economic	improved profit	*****	Increased production
Environmental	greater use of renewable fuels	*****	
	decreased use of fossil fuels	*****	
	reduced energy demands	*****	
	reduce transport impacts	**	Less transportation of fossil fuels

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
Investment costs	Smaller fossil fuels consumption
Safety risks in gasification?	Improved production capacity
	Increased profit

2.4 Changes to lime kiln technology

Improvements in lime kiln technology aim mainly at decreasing air emissions and increasing efficiency of the process. Improved technologies will be adopted depending on the need for new equipment. If technologies can be applied with old machinery, they will become widely accepted sooner than in cases where totally new machinery is needed. It is estimated that the technology will be adopted at some scale by 2025.

Expected time	By 2015	By 2025
technology in all SMEs		
technology generally adopted		
technology adopted in best practice	(X)	(X)
technology in industrial trials		

Legislation will affect the rate of adoption of the technologies when in addition to CO_2 other emissions to air are controlled more strictly. Improving efficiency of the lime kiln will enable savings in production costs and improve profit. Improvements in the lime kiln technology should not affect social aspects.

Driver for change to new technology		Applicability	Comments
Legislation	European legislation	*****	Air emissions
	national legislation	*****	Air emissions
Economic	improved profit	***	
	production cost savings	****	
Environmental	fewer emissions and waste	****	

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
Investment costs	Decreased emissions
	Increased efficiency
	Improved profit

2.5 Changes to recovery boiler technology

Improved recovery boiler technologies minimize air emissions and improve energy production. The recovery boiler produces particularly NO_x emissions, but they can be decreased using several technologies. Deliverable 4.2.3 presented Selective Non-Catalytic NO_x reduction SNCR-technology, but there are even more efficient ways to reduce NO_x emissions from the recovery boiler. Well designed air staging conditions and vertical air systems have a great potential in that area, enabling perhaps a 40-60% reduction in NO_x emissions in the best cases. Implementation of this technology requires some investments in the furnace size and materials. In vertical air systems, primary air is fed into the furnace the same way as in traditional boilers, but the secondary and tertiary air levels of traditional boilers are now replaced by air feeding vertical fingers. They strongly promote mixing in the furnace and result into very low emissions.

Industrial trials of vertical air systems are expected to be complete before 2015, and the technology has a possibility to become generally adopted by 2025, if the results of the mill trials are promising. Also improved energy production with increased steam pressure and temperature might be adopted with similar time scale.

Expected time	By 2015	By 2025
technology in all SMEs		
technology generally adopted		(X)
technology adopted in best practice	(X)	(X)
technology in industrial trials	XX	XXX

The technology will be affect environmental aspects, but it is likely that legislation will also require NO_x emissions to be decreased even further. Reducing the use of fossil fuels will be possible with this technology, and can lead to better acceptance from society.

Driver for change to new technology		Applicability	Comments
Consumer demands	other	**	Better acceptance
Legislation	European legislation	*****	NO_x–emissions
	national legislation	*****	NO_x–emissions
Economic	production cost savings	**	
	exploitation of by products	**	
Environmental	greater use of renewable fuels	*****	improved energy production
	decreased use of fossil fuels	*****	improved energy production
	reduced energy demands	*****	improved energy production
	fewer emissions and waste	*****	

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
Investment costs	Less emissions, especially NO_x
	Increased energy production
	Less fossil fuels needed

2.6 Changes in effluent treatment

Effluent treatments in Totally Chlorine-free TCF or Elemental Chlorine-free ECF kraft mills are mainly based on activated sludge treatment, as presented in PD 4.2.3. There are several chemical treatment options for tertiary treatment if "normal" treatment capacity is not enough. There will be more trials in pilot and mill scale, and some of the treatments may be generally adopted before 2015.

Expected time	By 2015	By 2025
technology in all SMEs		
technology generally adopted	(X)	
technology adopted in best practice		
technology in industrial trials	XX	

The biggest drivers for even better effluent treatments are legislation and pressures from NGOs. Naturally the image of companies will be better if emissions are reduced. Tertiary treatments have to be cost effective, though, in order to be generally adopted.

Driver for change to new technology		Applicability	Comments
Consumer demands	other	****	NGOs
Legislation	European legislation	****	
	national legislation	****	
Environmental	fewer emissions and waste	****	

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
Investment costs	Less emissions
	Better social acceptance

2.7 Development of fibre fractionation

Fibre fractionation is expected to be tested in industrial trials probably by 2015. The possibility of using raw material more efficiently and improving paper properties are promising. Depending on the results of industrial trials, the technology may be adopted in best practice or generally by 2025.

Expected time	By 2015	By 2025
technology in all SMEs		
technology generally adopted		(X)
technology adopted in best practice	(X)	(X)
technology in industrial trials	X	

The most important drivers for fibre fractionation are efficiency in raw material use and possible cost savings, since each fraction of fibres can be treated separately. The separate fibre fraction treatments may save energy, but the fractionation process uses large amounts of water. The technology will not affect social aspects, but it can improve paper properties and thus benefit fibre products in general.

Driver for change to new technology		Applicability	Comments
Consumer demands	other	***	improved paper properties
Legislation	European legislation		
	national legislation		
	other		
Economic	added value	****	more efficient raw material use
	production cost savings	**	smaller energy consumption in e.g. refining
Environmental	reduced energy demands	***	

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
Investment costs	Improved efficiency of material use
Higher water consumption	Improved paper properties
	Production cost savings

2.8 Development of closed water loops

Water consumption has decreased in pulp and paper mills considerably during the past decades. The water can be recycled in the mill more and more efficiently because of improved cleaning technologies. It is likely that the water consumption per ton of product will decrease even further. However, totally closed water loops are not likely to be adopted in geographic areas, where surface water supply is good. Even though closed water loops reduce water consumption and may decrease emissions to water, there are many possible side effects so this technology is highly controversial. Around the world there are already some mills with closed water cycles, but since large adoption of the technology is not expected in Europe, it is not necessary to consider this technology in this report.

2.9 Water treatment - ultra filtration and removal of calcium and magnesium

This technology is quite controversial and the adoption to industrial scale is impossible to predict and will not be considered further here.

2.10 Development of stratified forming techniques for paper and board making

Stratified forming improves layer purity of papers and boards and enables savings in raw material costs. It is likely, that this technology will be tested in industrial trials by 2015 and may be adopted more widely by 2025.

Expected time	By 2015	By 2025
technology in all SMEs		
technology generally adopted		(X)
technology adopted in best practice		(X)
technology in industrial trials	X	

Savings in raw material costs will be possible with this technology, and the purity of layers might give additional benefits by creating different layer properties. The technology will not affect social aspects, and it is not likely to provide clear benefits to other industries.

Driver for change to new technology		Applicability	Comments
Consumer demands	other	***	improved paper properties
Economic	production cost savings	****	more efficient raw material use

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
Investment costs	Savings in raw material costs
	New/improved paper properties

2.11 Improvement of measurement and control of pressure in pressing boards and paper

On-line measurement and control of pressure in wet pressing has been tested in pilot trials and may be tested on a mill scale by 2015. Depending on the results of the mill scale trials, this technology might be adopted more widely by 2025, but this is difficult to estimate. Another possible improvement in the wet pressing section is impulse drying, where pressing is combined with high temperature treatment. Similar time scale can be expected for that technology.

Expected time	By 2015	By 2025
technology in all SMEs		
technology generally adopted		(X)
technology adopted in best practice	(X)	(X)
technology in industrial trials	X	

On-line controlling of pressing could improve efficiency of water removal, may reduce amounts of web breaks in some cases, and possibly would equalize the sideward quality of the paper. These improvements could save production costs and bring some added value to the paper. This technology should not affect social aspects in any way. Impulse drying could also improve paper/board surface qualities.

Driver for change to new technology		Applicability	Comments
Economic	improved profit	**	Less web breaks
	added value	***	Equalized sideward quality of paper, improved surface quality
	production cost savings	***	Energy savings in drying section
Environmental	decreased use of fossil fuels	*	
	fewer emissions and waste	*	From energy production

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
Investment costs	Improved energy efficiency
	Improved paper properties
	Savings in production costs

2.12 Improved drying technology – high intensity driers – impingement drying

Improved drying decreases production costs and may increase process speed. High intensity driers and impingement dryers, where hot air is directed towards the paper, are being tested and will be tested further, and may be adopted by 2015. Infra red dryers for coated papers are already widely used and are not discussed further in this document.

Expected time	By 2015	By 2025
technology in all SMEs		
technology generally adopted	(X)	(X)
technology adopted in best practice	(X)	
technology in industrial trials	X	

Traditional drying section requires huge amounts of energy. Shortening the drying section with more efficient technologies would also decrease space requirements. These would lead to machinery and energy costs savings. At the same time, less fossil fuel would be needed for heating, so emissions might be reduced also. Social aspects should not be affected.

Driver for change to new technology		Applicability	Comments
Economic	production cost savings	*****	
	other	**	Decreased space requirements
Environmental	decreased use of fossil fuels	****	
	reduced energy demands	*****	
	fewer emissions and waste	***	From energy production from fossil fuels

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
Investment costs	Savings in production costs
	Decreased energy consumption

2.13 Change in use of existing coating techniques for papers and boards – curtain and spray coating

Curtain coating is more likely to be generally adopted than spray coating, since it has more benefits than spray coating. Curtain coating is already used in some mills, and it can be generally adopted by 2015. However, since coated papers are being replaced by uncoated papers, it is not wise to expect curtain coating to be adopted in all of the industry.

Expected time	By 2015	By 2025
technology in all SMEs		
technology generally adopted	X	X
technology adopted in best practice		
technology in industrial trials		

Curtain coating and spray coating technologies are non-contact methods, so they allow lower strength for base papers, so requirements for the raw materials are also lower. Thus recycled fibres can be used. Non-contact method also causes fewer breaks, so the amounts of paper produced can increase, and the company will gain increased profit. These methods also provide better coverage of coatings, which will allow thinner coating and cause savings in production costs. Spray coating uses nozzles which must be changed quite often, but curtain coating does not require any equipment that would wear out quickly, so the material costs and amounts of waste will be reduced. Multilayer coating is also possible. Since the layers may be dried simultaneously, it will allow savings in energy consumption. Also there is a possibility of decreasing the moisture content of the coating mix which will reduce energy consumption.

Driver for change to new technology		Applicability	Comments
Consumer demands	pressure for recyclability/reuse	**	DIP may be used in base paper
	changes in packaging needs	**	
	other	**	Better product properties for e.g. printing
Economic	improved profit	****	
	added value	****	
	production cost savings	****	
	other	***	Better coverage -> less coat weight
Environmental	decreased use of fossil fuels	***	
	reduced energy demands	****	
	fewer emissions and waste	***	Less waste, since no parts that wear in curtain coating
	other	****	No parts that wear in curtain coating

Improvements in coating technology will not affect social aspects. However, since de-inked pulp (DIP) may be used in base papers, this technology might improve consumer acceptance. The coating can provide better barrier properties than traditional coating, so less packaging will be required. The coated paper may be a bit problematic in recycling, since the coating may act in different ways in recycling process. If the coating process is across the entire width of the paper, small amounts of coating mix will be collected as a by-product from the edges of the paper. This coating mix surplus might be difficult to utilize. Another option is to leave a thin edge of the paper uncoated, trim it and recycle the edge.

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
Investment costs	Savings in production costs
Problems in recycling of the product	New/improved paper properties
	Lower quality of raw materials acceptable
	Increased production amounts
	Less waste from the coating process

3 RECYCLED PAPER (responsible: KCPK)

3.1 Alternative wires for recovered paper

In summary, the new concept entails the substitution of metal wires for paper bales with alternative equivalents in form of plastic wires and paper ropes. This will reduce the impact of the non recyclable and non paper fractions in recovered paper and help prevent accidents.

Currently this technology is on the level of industrial trials. Industrial trials have shown that PET wires can be a good alternative to metal wires for the reason stated above.

Expected time and level of uptake
The expected level of uptake of this technology in 2015 and 2025 is extremely difficult to predict, since the technology is not implemented by the paper producing industry itself but by its suppliers: the recovered paper processing companies/collectors. Benefit for the paper producing industry are large and expected to be larger with increasing raw material prices and increasing costs of waste disposal. However, large scale implementation

is only expected under new EU legislation (A). If not, it will be hard to get the technology implemented at all (B).

Expected time	Currently	By 2015	By 2025
technology in all SMEs			A
technology generally adopted			
technology adopted in best practice			
technology in industrial trials	X		B

Drivers
Benefits for the paper industry are becoming larger with increasing raw material (recovered paper) prices, since PET wires have lower weights then metal wires. As costs of waste disposal increase benefits for the paper industry will be higher. Furthermore, new EU legislation will require traceability of the raw materials, which will encourage the use of PET wires as compared to metal wires, as they can be better printed.

Obstacles
An obstacle towards large scale introduction of this technology is that it is only beneficial if all recovered paper bales processed in a mill have the same type of wires. Since most mills obtain their raw material sources from different suppliers, all potential suppliers would need to adopt this system more or less simultaneously. Since suppliers can also be outside of Europe this will be hard to accomplish without legislation.

Contribution to Sustainable Development
This new concept contributes to economical aspects by the savings in production costs (from decreased waste disposal), to environmental aspects by the prevention of landfill waste and to social aspects through increased occupational health by the prevention of accidents that occurred in the paper industry during the last few years because of springing metal wires.

Results of adoption of new technology	
Cons	Pros
Extra costs for rebuilding the recovered paper presses	Decreasing production costs
	Decreasing waste disposal
	Better traceability possible
	Less accidents

3.2 Recovered paper sorting and quality control by sensor development

Various types of sensors are currently under development, from laboratory scale to full mill size trials and market introduction.
1. Image analysis sensors to assess the composition (newsprint/magazine/boards) of recovered paper stream to be de-inked on-line; raw material variations can propagate from the pulper to the paper machine and the efficiencies of processes are affected by these fluctuations.
2. A volatile compound sensor is also under development; this sensor allows the identification of chemical and microbiological contaminants. It can be used to control raw material at the factory gate but also to control chemical substances in the final paper products intended for contact with food.
3. Another sensor, using NIR (near infrared) spectrometry, is under development, based on a coring device to control paper bales directly at delivery. The sensor will determine humidity percentage, unusable material presence and ratio and raw material compositions according to EN 643.

Expected time and level of uptake
The expected level of uptake of these technology is expected to increase towards 2015 and 2025; the quality of recovered paper is decreasing (we are further down the recycling loop) and we need to exploit recovered paper of lower quality to meet the increasing demand for recovered paper. Since we expect quality to decrease over the years, the use of sensors to measure recovered paper quality at the mill gate can become more useful. Besides, controlling devices will replace human sorting and the ongoing automation process in paper mills.

Expected time	Currently	By 2015	By 2025
technology in all SMEs			
technology generally adopted			X
technology adopted in best practice	X	X	
technology in industrial trials			

Drivers
Decreasing recovered paper quality can be a driver towards the further utilisation and implementation of quality control sensors in the paper industry. Currently many sorting activities are still performed by humans; the use of sensor fits the increasing automation in sorting lines.

Obstacles
New EU legislation that requires the traceability of raw materials makes it easier to recognise the source of raw materials. This will also mean that quality problems can be more easily linked directly to the suppliers, which reduces the need for mill gate quality controls.

Contribution to Sustainable Development
The sensors will contribute to saving in production costs by increasing the quality of the raw material, the control and removal of unusable material and reducing the time needed for manual control of recovered papers. Furthermore it will lead to increased recyclability and thereby secure recycling of paper in the future.

Results of adoption of new technology	
Cons	Pros
Reduction of employment, due to further automation of manual sorting	Decreasing production costs (raw material costs and labour costs)
	Increased recyclability

3.3 Enzymatic Upgrading Of Recycled Paper

Due to the increasing recycling of paper, the quality of fibres decreases and the amount of fines and organic compounds increases at a rate of 1% per year, as a result of recycling paper with an already recycled component. This results in a decrease of production (decreased de-watering), lower efficiency of process and functional chemicals, and a decrease of the quality of the end product. Recycled paper and board can be upgraded by adding virgin fibres, large quantities of chemicals or removing fines from the pulp and discarding the fines into waste. These measures are both from an economical and ecological point of view less favourable. Results from recent research has shown that specific enzymes are able to modify fibres and fines in such a way that strength of paper can be increased, de-watering of pulp can be enhanced, and the efficiency of chemicals can be improved. The recycled paper industry demands very specific technological developments of the enzyme preparations. Enzymes are needed to improve de-watering as with every cycle the drainability decreases. This implies specific enzymes targeting the small fines causing the problems. Secondly, enzymes are needed to improve fibre quality and so maintain recycled paper quality.

Expected time and level of uptake
The expected level of uptake of this technology is expected to increase towards 2015 and 2025; the quality of recovered paper is decreasing (we are further down the recycling loop) and we need to exploit recovered paper of lower quality to meet the increasing demand for recovered paper. The benefits that the use of enzymes could bring to the recovered paper industry are large; upgrading its fibre raw material quality and also reducing energy use at the same time. The costs of the use of enzymes, however, are currently still higher than the benefits its use brings. The use of enzymes is common in other industries, e.g. the food industry, which might accelerate its

application in the paper industry. It can be expected that with increasing R&D efforts and industrial trials, the costs of the use of enzymes in the paper industry could go down in the near future.

Expected time	Currently	By 2015	By 2025
technology in all SMEs			X
technology generally adopted		X	
technology adopted in best practice	X		
technology in industrial trials	X		

Drivers
With increasing energy costs, the use of enzymes that decrease the water retention values of the recovered fibres, will be enhanced. Furthermore, decreasing recovered fibre qualities will enhance the use of enzymes.

Obstacles
The price of enzyme application is currently an obstacle towards its use throughout the paper industry. Another obstacle might be the incomplete understanding of the effects of enzymes in the paper industry on the longer term

Contribution to Sustainable Development
Enzyme technology in the recovered paper industry might lead to savings in production costs and less use of fossil fuels and chemicals (by better dewatering and less chemical use), to increased profit (by increased machine speed) to better recyclability and less waste (due to improved recovery of raw material), more renewable raw materials and improved properties considering end use (by improvement of the fibre properties).

Results of adoption of new technology	
Cons	Pros
Costs of the enzymes	Decreasing production costs
Incomplete understanding of the effects of enzymes on the long term.	Decreasing energy use
	Decreasing chemical use
	Better recyclability
	Decrease of waste
	Increase in renewable raw material inputs

3.4 Production of secondary fuels from recovered paper industry rejects

In many countries in Europe, waste disposal is restricted and very expensive. Rejects from paper industry can contain mineral debris, sand, metal particles, glass etc. but the largest part is combustible substances consisting of mainly fibrous material, plastic and wood. By pressing and drying the sorted reject stream, dense energy pellets with energy contents comparable to coal can be produced. The processed material can also be used as a fuel in a loose fluffy form. Fluff and pellets can be used as an alternative fuel in energy plants or other industries (i.e. cement industry).

Expected time and level of uptake
The level of uptake of this technology in 2015 and 2025 can be very large as the technology is neither new nor extremely complicated. The industry-wide uptake of this technology will be the result of external drivers (like energy prices and waste legislations/ landfill policies) and is hard to predict. It is assumed in this report that the technology will be adopted in all SMEs by 2025, however, we include in this case the option that several smaller plants will combine their reject streams and have energy production at a central site.

Expected time	Currently	By 2015	By 2025
technology in all SMEs			X
technology generally adopted		X	
technology adopted in best practice	X		
technology in industrial trials			

Drivers
The two main drivers of large scale implementation of this technology are energy prices and costs of land filling (influenced by waste policies, that are (currently) national, not EU, and legislation). Increasing energy prices and land filling costs will both enhance the production of secondary fuels out of recovered paper industry rejects. In our projection, we assumed both of them to increase towards 2025.

Obstacles
Increasing land filling bans put more materials on the market, increasing the competition and reducing profitability. Improvements in collection and sorting activities might reduce the amount of contamination already in the input of the mill. As a consequence, the output of contamination in the form of rejects can become very small (which is of course a desirable development, but not favouring this particular technology).

Contribution to Sustainable Development
This new concept contributes to economical aspects by the savings in production costs (from decreased waste disposal) and to environmental aspects by the prevention of landfill waste and the replacement of fossil fuels.

Results of adoption of new technology	
Cons	Pros
Increasing investments	Decreasing production costs
Non-core business	Prevention of landfill waste
	Increasing energy generation and the replacement of fossil fuels.

3.5 Deinking sludge rejects as an alternative raw material for other applications

In many countries in Europe, waste disposal is restricted and very expensive. Deinking sludge is a reject of paper mills that have a deinking process, the sludge contains approximately 50% non-organic elements as inks, coatings adhesives, dyes and fillers and approximately 50% of organic cellulose fibres. The de-inking sludge can be treated in special installations by means of an exothermic reaction into meta-kaolin and calcium carbonates, calcium oxide, heat, vapour, and CO_2. The mineral product produced in this process is a good alternative material for use in the cement industry.

Expected time and level of uptake
The level of uptake of this technology in 2015 and 2025 is expected to be very large even though the technology is rather new and not very simple. The industry-wide uptake of this technology will mainly be driven by external developments (e.g. developments in the cement/construction market and land fill costs/policies). It is estimated, in this report, that the technology will be adopted in all relevant SMEs by 2025, however, we include in this case the option that several smaller plants will combine their de-inking streams and have material production at a central site.

Expected time	Currently	By 2015	By 2025
technology in all SMEs			X
technology generally adopted		X	
technology adopted in best practice	X		
technology in industrial trials			

Drivers
The two main drivers of large scale implementation of this technology are added value generation (dependent on the developments in the cement industry) and costs of land filling (influenced by waste policies, that are (currently) national, not EU, legislation). De-inking sludge amounts are expected to increase with the increasing use of (de-inked) recovered paper.

Obstacles
The production of alternative materials for use in the cement industry is a non-core business exercise. It probably will also need the cooperation of several de-inking mills.

Contribution to Sustainable Development
This new technology contributes to economical aspects savings in production costs (from decreased waste disposal) and to environmental aspects by the prevention of landfill waste and the replacement of virgin materials.

Results of adoption of new technology	
Cons	Pros
Increasing investments	Decreasing production costs
Non-core business	Prevention of landfill waste
	Increasing energy generation and the replacement of fossil fuels.

4 SAW MILL INDUSTRY (responsible: VTT - Arto Usenius)

4.1 Scanning of internal properties of stems and logs for characterisation wood raw material and for optimisation of sawing operations

Sawing yield very much depends on the size and quality of the logs. Sawing set up should be determined based on the size and quality of the log to be sawn. The conversion value of good quality log may be double compared to the value of low quality log. Currently only geometrical properties of stems and logs are measured providing data such as small and large end diameter, length, taper and shape of the log. In some cases logs are graded visually into quality classes. Information about internal quality is not available.

Much R/D effort in different countries in the last years has been concentrated on developing commercially available scanners for internal log characterisation for sawmill implementations. Some scanner systems have been implemented in industrial environment however mainly to trace how to use the systems in real life business.

Expected time	2007	2015	2025
technology in all SMEs			
technology generally adopted			X
technology adopted in best practice	X	X	
technology in industrial trials	X		
R/D phase	X		

New technology will enable precise characterisation of the logs and stems. Scanners are based eg on x-ray technology combined with true shape data through laser applications. Depending on the system configuration, scanners provide different levels of detailed information about knottiness, individual knots, density, annual ring orientation, moisture content etc. Scanners can be implemented at log sorting station, cross cutting terminals for stems and also just before sawing machines.

Scanners provide data for planning systems and process control for sawing optimisation. The scanner results provide precise shape co-ordinate description of the log or stem, internal characterisation of the log including all features affecting on the quality of sawn timber products like knottiness. Description of the knots may be given with different levels of accuracy. Rough accuracy gives only the total volume of the knots. In the most sophisticated cases all the features of every individual knot is described. Scanning, image processing and mathematical reconstruction algorithms generate virtual logs or stems. Virtual logs are input data for sawing simulator which mathematically converts logs into sawn timber or components. The best sawing set up will give maximum value yield of demanded products with high prices.

Driver for change to new technology		Applicability	Comments
Consumer demands	customer oriented products	******	
	competitive product prices	**	
	fitness secondary conversion	****	
	more homogeneous products	*****	
Economic	improved profit	******	
	added value	******	
	production cost savings	**	
	minimising by products	*	
	minimising waste	**	
	other	**	
Environmental	saving wood raw material	******	
	reducing amount of waste	***	
	reducing energy demand	**	

4.2 Measuring systems for characterisation and grading of sawn timber as well as supporting secondary conversion

Sorting by dimensions and quality grading are very essential parts of sawmill processes. Grading provides more homogenous batches or groups of sawn timber or components. Different grades are sold at different prices. Customers demand certain dimensions and grades based on their final products.

Grading is currently visually made by human graders especially at small mills. Manual work is very stressful and mistakes may cause large economic losses. It's difficult for a human grader to learn and adapt to new grading rules fast. This is why automated grading is replacing human grading especially at bigger sawmills where the production volumes are high. Colour and B/W cameras are used. Limited parameters are measured. Current systems do not support further conversion and upgrading sawn timber into components.

Much R/D effort in different countries in the last years has been concentrated on developing commercially available scanners for internal log characterisation for sawmill implementations. Scanner systems have been implemented in the industrial environment with good results, however big steps are still expected in the future such as the capability to detect wood properties which are difficult to measure.

New technology implementation: Multisensor scanning systems are provided with several sensors like RGB-camera, IR-camera, microwave detector, ultrasound detector, x-ray camera etc. in order to detect all wood properties of interest. Data fusion – combining information from different sensors together ensures high resolution, detection and identification. System configuration depends on the type of wood raw material and products and the size of the mill. Information produced can be exploited in grading and processing. Low cost systems for SMEs should be developed.

Expected time	2007	2015	2025
technology in all SMEs			X
technology generally adopted		X	
technology adopted in best practice	X	X	
technology in industrial trials	X		
R/D phase	X		

New technology will enable precise characterisation of sawn timber. Scanners are based on different technologies. Scanners provide data for planning systems and especially for process control and grading of sawn timber. The scanner results provide precise shape co-ordinate description of the sawn timber and internal characterisation of the sawn timber piece including all features affecting on the quality of sawn timber products like knottiness, wane edge, rot, splits, checks, mechanical damage, annual ring orientation etc... Description of quality features may be provided with lower or higher accuracy. Scanning, image processing and mathematical reconstruction algorithms generate virtual timber pieces. Virtual sawn timber is the input data for the grading simulator which mathematically calculates different quality grade options for sawn timber or component piece.

Scanners are very good tools for data collection providing data and information for overall planning systems concerning harvesting, production and sales operations in short and log term.

Driver for change to new technology		Applicability	Comments
Consumer demands	customer oriented products	******	
	competitive product prices	***	
	fitness for secondary conversion	****	
	more homogeneous products	*****	
Economic	improved profit	*****	
	added value	******	
	production cost savings	**	
	minimising amount by products	*	
	minimising waste	***	
	other	**	
Environmental	saving wood raw material	******	
	reducing amount of waste	***	
	reducing energy demand	**	drying batches

4.3 Upgrading of sawn timber into value added components

Saw mill companies are currently selling standard sawn timber, bulk products, at low prices. Bulk production is easier and not so demanding as manufacturing value added products. New technology implementation offers a good opportunity to transfer from bulk production towards production of sawn timber with precisely defined properties according to the actual customer's requirement.

There are several concepts for upgrading sawn timber. For example: the sawmill is provided with machine vision system and smart decision making system with optimisation algorithms for grading and selecting sawn timber pieces into different classes. Some of the classes continue in traditional way and the final product is sawn timber for example high quality sawn timber. Low quality sawn timber pieces are converted into smaller pieces giving value added components with high price.

Expected time	2007	2015	2025
technology in all SMEs			X
technology generally adopted		X	
technology adopted in best practice	X	X	
technology in industrial trials	X		
R/D phase	X		

In the first phase of the manufacturing the sawn timber piece is evaluated by machine vision system providing precise map of surface defects affecting the quality of final potential products. This mathematically described piece is virtually converted into value added product using all potential manufacturing options. That option resulting best possible profit is selected for use. The processing may consist of cross-cutting, ribbing and edging phases.

Driver for change to new technology		Applicability	Comments
Consumer demands	customer oriented products	******	
	competitive product prices	**	
	fitness secondary conversion	****	
	more homogeneous products	*****	
Economic	improved profit	******	
	added value	******	
	production cost savings	**	
	minimising by products	*	
	minimising waste	**	
	other	**	
Environmental	saving wood raw material	******	
	reducing amount of waste	***	
	reducing energy demand	**	

4.4 Flexible manufacturing systems for sawmills

Present production systems are effective, however they are very much volume and bulk production orientated emphasising the minimisation of costs. They are not flexible and production of components with specified quality features and properties is impossible. Manufacturing produces products which are not wanted and ordered.

Future production systems consist of following integrated key elements:
Control and optimisation of information and material flows in planning and production systems.
Intelligent, flexible and self learning measuring, production and logistic systems.
Integrated information systems covering entire conversion and delivery chains.
Creation and utilization of the feed back information in order to make business self learning.
Advanced mechanics for complex manufacturing.

Expected time	2007	2015	2025
technology in all SMEs			X
technology generally adopted			X
technology adopted in best practice		X	
technology in industrial trials	X		
R/D phase	X		

The main drivers are to:

improve and support customer orientation
improve quality of the products
increase flexibility in manufacturing
increase profitability.

Driver for change to new technology		Applicability	Comments
Consumer demands	customer oriented products	******	
	products with specified properties	******	
	competitive product prices	**	
	fitness secondary conversion	*	
	more homogeneous products	*****	
Economic	improved profit	******	
	added value	******	
	production cost savings	**	
	minimising by products	*	
	minimising waste	**	
	other	**	
Environmental	saving wood raw material	******	
	reducing amount of waste	***	
	reducing energy demand	**	

4.5 Adaptive production and business processes

Learning and teaching is currently a human activity and is very much depends on the nature, capability and will of the people. The procedure is very sensitive. Feed back information is not created. Business and production is not adaptive or self learning. This situation means ineffective use of human resources and of machinery.

New technology solutions and their implementation will provide smart, self learning and adaptive business, measuring, production and logistic processes and systems. The creation and utilization of feed back information will make business self learning.

Expected time	2007	2015	2025
technology in all SMEs			
technology generally adopted			X
technology adopted in best practice	X	X	
technology in industrial trials	X		
R/D phase	X		

Planning operations for production, harvesting and sales as well as process control are supported by decision support models or software. These systems need input data and they provide numerical instruction for different processes i.e. parameter values for machinery. The model systems also predict the output from the process concerned i.e. dimensions and quality of sawn timber. Normally the output is not measured. In the adaptive system the output is measured. This output is compared with the predicted one. If both of these outputs are exactly same the prediction is perfect. If there is a large difference between these two outputs, parameters or algorithms have to be changed. Adaptive systems contain these kinds of loops.

Driver for change to new technology		Applicability	Comments
Consumer demands	customer oriented products	******	
	competitive product prices	**	
	fitness secondary conversion	****	
	more homogeneous products	*****	
Economic	improved profit	******	
	added value	******	
	production cost savings	**	
	minimising by products	*	
	minimising waste	**	
	other	**	
Environmental	saving wood raw material	******	
	reducing amount of waste	***	
	reducing energy demand	**	

4.6 Information systems and intelligent material flow control

Forest –Wood chain provides a lot of data and information. Data is gathered but only locally used and then the data is lost. It is not possible to link together products with their properties, wood raw material and processing parameters, which are very important for planning operations. Information systems about forest operations, production, machinery, sales and marketing are isolated and not communicate with each other.

In the future a "company global" information system will cover the whole chain –from the forest to the end products and business processes. Integration of data throughout whole conversion chain can be achieved by marking wood raw material, logs, in the forest and storing data in an information system. Marking can be eg by electronic tag which provides address in the information system. When a piece is passing a process phase the tag is read and the measured data stored in the information system. The linked data and information is available for planning systems and process control ensuring precise management of business processes.

Expected time	2007	2015	2025
technology in all SMEs			X
technology generally adopted		X	
technology adopted in best practice	X	X	
technology in industrial trials	X		
R/D phase	X		

Driver for change to new technology		Applicability	Comments
Consumer demands	customer oriented products	**	
	competitive product prices	*****	
	fitness secondary conversion	**	
	more homogeneous products	*****	
Economic	improved profit	******	
	added value	******	
	production cost savings	**	
	minimising by products	*	
	minimising waste	**	
	training	****	
Environmental	saving wood raw material	******	
	reducing amount of waste	***	
	reducing energy demand	*	

4.7 Traceability

Currently, no information is available about the origin of wood raw material. In the future, marking pieces with visible or non-visible markings in the forest and forwarding this information to the customers and end users will allow traceability this is strongly linked to marking of pieces and information systems presented in 4.6.

Expected time	2007	2015	2025
technology in all SMEs			X
technology generally adopted		X	X
technology adopted in best practice	X		
technology in industrial trials	X		
R/D phase	X		

Traceability is very important in order to prevent illegal sales of wood raw material. Traceability offers good tool to forward information from producers to further conversion and end users.

Driver for change to new technology		Applicability	Comments
Consumer demands	customer oriented products	***	
	competitive product prices	**	
	fitness secondary conversion	**	
	more homogeneous products	**	
	customer service	*****	
Legislation	preventing illegal sales	******	
Economic	improved profit	*	
	added value	**	
	production cost savings	*	
	minimising by products	*	
	minimising waste	**	
Environmental	saving wood raw material	******	
	reducing amount of waste	***	
	reducing energy demand	**	
	other		

5 PLYWOOD INDUSTRY (responsible: VTT - Jorma Froblom)

5.1 New technologies in Plywood industry

In Project Deliverable 4.2.3 Report on review of technology development trends within the various processes, chapter 4.2 “Plywood industry”, subchapters only describe new technological improvements in Plywood industry. The possible new products are described in Module 5.

These new technologies in plywood industry are:

1. Log scanners and peeling
2. Introduction of new peeling parameters
3. Introduction of more automated veneer scarfing lines
4. Introduction of automated dry veneer scanning
5. Development/introduction of automatic composing
6. Introduction of automatic patching
7. Automation.

They are already introduced in best practice and are expected to be introduced in use general manufacturing by 2015 and to SMEs between 2015 and 2025. Some new automation, ICT –systems and x-ray and machine vision systems are at research level and is expected to be introduced from small scale trials into best practice in the near future.

More detailed descriptions of these technologies are presented in P.D. 4.2.3, Chapter 4.2.

Level of development of Technologies → **Drivers for change ↓**	**Developed and already in use general manufacturing - still to be introduced to SMEs**	**Developed and already in best practice – still to be introduced in general manufacturing**	**Developed to small scale trials – introduction into best practice**	**Research level** ICT, x-ray RGB
Time scale for Introduction → **New technologies →**	2015, SME 2025 All technologies 1-7	2005 All technologies 1-7	2005 1, 4, 7	2010→
Social; overall evaluation	**	**	*	**
1. increase occupational health	** 1)	* 1)		
2. increase consumer acceptance		-		
3. influence on manpower needed	** 3)	* 3)		
4. increase the regional employment rate, and/or		* 4)		
5. increase production of bio-based excess energy e.g. in form of pellets for local society.				
Economic; overall evaluation	**	***	***	***
1. increase the profit			** 1)	*** 1)
2. give additional value to products			** 2)	*** 2)
3. have savings in production costs			** 3)	*** 3)
4. have savings in transportation costs, and/or				
5. increase the exploitation of by-products			** 5)	
Environmental; overall evaluation	***	**	**	*
1. increase the use of renewable fuels			* 1)	
2. decrease the need of fossil fuels			* 2)	
3. decrease energy consumption			* 3)	
4. cause less emissions and/or waste			* 4)	
5. use more renewable raw materials				
6. require less transportation, and/or				
7. increase the recyclability and reusability of products and co-products				
Legislation; overall evaluation	**	*	*	*
1. REACH				
2. Biocidal products directive				
3. IPPC	* 3)			
4. Illegal logging	* 4)			* 4)
5. Renewable energy – biomass discussions	* 5)			
6. Ecolabel discussions (wood based furniture)	* 6)			
7. European Pollutant Release and Transfer Register				
8. VOCs				
9. Wood dust	* 9)			
10. Formaldehyde	* 10)			
11. Waste discussions	* 11)			

Importance of drivers:
* = small; ** = medium and *** = very important

6 PANEL BOARD INDUSTRY (responsible: Pöyry)

6.1 Time scale

The panel board related techniques - powder coating, dry gluing, replacement of urea formaldehyde resin with methylene diphenyl diisocyanate (MDI), mat pre-heating, development of light and super light medium density fibreboard (MDF) and particle board, introduction of dyed MDF technology, new process control and measurement device technologies – are all techniques, already adopted in relevant best practice mills. Thus, it is probable that all of them are generally adopted in 2015. In addition, it is probable that there are also other new technologies available then and especially in 2025.

6.2 Expected level of uptake

It is probable that these technologies, when relevant, are also used in the majority of relevant SMEs in 2015. In addition, it is probable that there are also other new technologies available then and especially in 2025.

6.3 Development of powder coating

Powder coating technology is already used in best practice and is expected to be introduced into general practice and the majority of SMEs by 2015.

Powder coatings	
Drivers in consumer demand: - effects on health	- No risk / reduced risk for emission of hazardous substances when newly processed products are used inside houses.
Technology's effect on economic aspects: - improved profit production cost savings	- Through savings in energy and environment related costs.
Technology's effects on environmental aspects: - reduced energy demand - fewer emissions and waste - reduce transport impacts	- This technique produces less waste than the conventional one. - It reduces energy demand because there is no need for drying process – even though the product must be heated up. - Reduced transport of hazardous chemicals.
Technology's effects on social aspects: - occupational health - consumer acceptance	- Less solvents and volatile organic compounds
Possible changes in risks and costs in the industry as a whole?	-

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
- Investment costs	- Reduced risk for emission of hazardous substances - Savings in energy and environment related costs - Less waste - Reduced energy demand - Reduced transport of hazardous chemicals

6.4 Dry Gluing

Dry gluing technology is already used in best practice and is expected to be introduced into general practice and the majority of SMEs by 2015.

Dry Gluing	
Drivers in consumer demand:	- No large changes in consumer demand, the main drivers are in production
Technology's effect on economic aspects: - improved profit - production cost savings	- Reduced energy and raw material costs
Technology's effects on environmental aspects: - reduced energy demand	- Reduced energy and glue consumption when applied on dried MDF panels.

- fewer emissions and waste	- Reduced formaldehyde emissions due to reduced use of glue.
Technology's effects on social aspects: - occupational health	- Reduced formaldehyde emissions due to reduced use of glue - Dry process is easier to keep clean
Possible changes in risks and costs in the industry as a whole?	-

Risks and costs in risks to the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
- Investment costs	- Reduced risk for emission of hazardous substances - Savings in energy and raw material costs due to reduced energy and glue demand

6.5 Methylene diphenyl diisocyanate (MDI)-resin as substitute of urea-formaldehyde

MDI-resin as substitute of urea-formaldehyde	
Drivers in consumer demand: - legislation - health effects	- Less formaldehyde in the product - Formaldehyde has been reclassified to a confirmed carcinogen to humans - Pending EU decisions regarding indoor air quality limits will be the main factor to determine the impact of new regulations on panel industry. - Germany is currently implementing rigorous testing procedures and stringent limits for building products and formaldehyde emissions. A result of this is for example the fact that within the last 2 years since the discussion started, OSB has moved way from formaldehyde containing resins towards MDI resins
Technology's effect on economic aspects: others	- Increased production costs
Technology's effects on environmental aspects: fewer emissions and waste	- Both in production and final product
Technology's effects on social aspects: - occupational health consumer acceptance	- MDI is more hazardous than UF before the product is dried. In dried product the situation is the opposite.
Possible changes in risks and costs in the industry as a whole?	- Less hazardous emissions but higher costs -> risk for decreased production

MDI technology is already used in best practice and is expected to be introduced into general practice and the majority of SMEs by 2015.

Risks and costs in the industry and any knock-on effects in related

Results of adoption of new technology	
Cons	Pros
- Higher production costs - More hazardous production material	- Reduced emission of hazardous substances in dry form both in production and in final product

6.6 MAT pre-heating

Mat pre-heating technology is already in use in general manufacturing and is expected to be in use in the majority of SMEs by .2015

MAT pre-heating	
Drivers in consumer demand: others	- Thicker panels
Technology's effect on economic aspects: production cost savings	- Reduced energy costs
Technology's effects on environmental aspects: - reduced energy demand	- Reduced energy consumption - Possibility to increase production capacity in current mills, because press capacity (which limits production) grows
Technology's effects on social aspects:	
Possible changes in risks and costs in the industry as a whole?	-

Risks and costs in the industry and any knock-on effects in related

Results of adoption of new technology	
Cons	Pros
- Investment costs	- Reduced energy consumption and costs - Possibility to increase production capacity in current mills

6.7 Hard thin skin/light core MDF panels, Super light MDF/insulation board

Light and super light MDF technology is already used in best practice and is expected to be introduced into general practice and the majority of SMEs by 2015

Hard thin skin/light core MDF panels, Super light MDF/insulation board	
Drivers in consumer demand: - others	- Thick and light panels
Technology's effect on economic aspects: - added value	- Less material utilised per m^3
Technology's effects on environmental aspects: - reduced energy demand - fewer emissions and waste - reduce transport impacts	- Reduced energy and raw material demand, due to reduced amount of material processed. - Less waste after the use - Reduced transport effects due to the lightness of the product.
Technology's effects on social aspects: - occupational health	- More ergonomic to handle.
Possible changes in risks and costs in the industry as a whole?	-

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
- Investment costs	- Reduced energy and raw material demand - Reduced transport effects - Less waste at the end of life stage - Product more ergonomic to handle

6.8 Light particle board

Light particle board technology is already used in best practice and is expected to be introduced into general practice and the majority of SMEs by 2015.

Light particle board	
Drivers in consumer demand: - others	- Thick and light panels
Technology's effect on economic aspects: - added value	- Less material utilised per m^3
Technology's effects on environmental aspects: - reduced energy demand - fewer emissions and waste - reduce transport impacts	- Reduced energy and raw material demand, due to reduced amount of material processed. - Less waste after the use - Reduced transport effects due to the lightness of the product.
Technology's effects on social aspects: - occupational health	- More ergonomic to handle.
Possible changes in risks and costs in the industry as a whole?	-

Risks and costs in the industry and any knock-on effects in related

Results of adoption of new technology	
Cons	Pros
- Investment costs	- Reduced energy and raw material demand - Reduced transport effects - Less waste at the end of life stage - Product more ergonomic to handle

6.9 Dyed MDF related technologies

Dyed MDF technology is already used in best practice and is expected to be introduced into general practice and the majority of SMEs by 2015.

Dyed MDF related technologies	
Drivers in consumer demand: - others	- “Limited design options”
Technology’s effect on economic aspects: - added value	- Increased production costs - Higher price of the final product
Technology’s effects on environmental aspects: - fewer emissions and waste	- No separate painting / surface treatment needed - No surface treatment chemicals, reduced use of solvents (please see also “Powder coating”)
Technology’s effects on social aspects: - occupational health	- Reduced use of solvents
Possible changes in risks and costs in the industry as a whole?	- Increased production costs - Less process stages in value chain

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
- Investment costs - Increased production costs	- Reduced energy and raw material demand - Reduced transport effects - Less waste at the end of life stage - Product more ergonomic to handle

6.10 Process control and measurement device technologies

This technology is already used in best practice and is expected to be introduced into general practice and the majority of SMEs by 2015.

Process control and measurement device technologies	
Drivers in consumer demand: - others	- more uniform quality
Technology's effect on economic aspects: - production cost savings	- more uniform quality
Technology's effects on environmental aspects: - reduced energy demand - fewer emissions and waste	- smooth run and better control of processes give: - increased amount of first quality products - narrower tolerance limits - better saw-cut -more even panel surface and thus less grinding/polishing needed
Technology's effects on social aspects: - occupational health	- increased meaningfulness of the work
Possible changes in risks and costs in the industry as a whole?	

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
- Investment costs	- Smooth and better control of processes - Increased amount of first quality products - Reduced energy demand - Reduced amount of reject, waste and emissions

7 JOINERY INDUSTRY (responsible: BRE)

7.1 Wood welding

7.1.1 Time scale

The wood working industry technique of wood welding is at an advanced stage of pilot trials in Europe and it is highly probable that by 2015 there will be a number of viable businesses wood welding either using reduced volumes of adhesive or no adhesive at all.

7.1.2 Expected level of uptake

This technology is highly relevant to the needs of modern forest products businesses and the use of wood in construction. A large number of SMEs will have adopted this technology and will be producing the materials and/or will be manufacturing using the modified wood substrates into the joinery and wood working markets – adding significant value to this chain by 2015. In addition other modification technologies will have emerged and be available for adoption by 2025.

Wood welding	
Drivers in consumer demand: – Effects on health – Effects on the environment	– No or reduced risk of emission in buildings when wood welding is used to join timber rather than conventional adhesives – At end of life welded wood can be recycled reused or sent for energy recovery
Technology's effect on economic aspects: – Diversity of products expanded – New businesses – New applications for glued wood	– Savings in adhesive costs – Reduce consumption of adhesives – Opportunities for new wood welded products to develop markets
Technology's effect on environmental aspects: – Fewer emissions and waste – Improved environmental profile	– Reduce transport and consumption of petrochemical based adhesives – The glued (welded) product can easily be recycled at end of life as there is no adhesive present in the glued product
Technology's effect on social aspects: – Occupational health – Consumer acceptance	– Less adhesives based on solvents and petroleum derivatives
Possible changes in risks and costs in industry as a whole?	– Better environmental profile for glued wood but at much higher cost

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
– Investment costs – Stability in wet conditions is poor – Long term durability is not known – Independent approvals needed	– Low or zero emissions – No petrochemical based adhesive – Decorative appeal – Can be readily recycled, reused or energy recovery with impact – Less waste

7.2 Short-burst microwaves for improved drying performance

7.2.1 Time scale

Microwave drying has been in existence for many years. Short bursts of microwaves initiate localised damage to the rays and surrounding tissues which result in improved drying of many refractory hardwood timber species. If longer bursts of microwaves are used, the voids created can be resin impregnated to enhance or change timber properties. The timber research technique of using short burst microwaves is in its very early stages in the UK, although it has been proved and investigated in some depth in Australia. Before industrial up-take of the technology in the UK, an in-depth study will be required. The technique lends itself to improving the drying of many refractory hardwood species which will be used predominantly in the joinery sector.

7.2.2 Expected level of uptake

If the technology is proven in the UK, the level of up-take would be expected to be country wide. The expected improvements in timber quality and the reduction of energy required to dry the material would be a large incentive to the industry.

Short burst microwave drying	
Drivers in consumer demand: – Improved timber quality – Effects on the environment – Reduced drying costs	- Less rejects - Reduced energy use - Improved quality
Technology's effect on economic aspects: – Reduced drying costs – Improved wood quality – New applications for wood if impregnated	- Enhanced environmental credentials - Improved durability - Possible to resin impregnate material to change properties - Enhanced movement characteristics
Technology's effect on environmental aspects: – Reduced energy use – Improved durability	- Less waste product - Reduced transport
Technology's effect on social aspects: – Consumer acceptance	- Reduced use of non-wood products

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
– Investment costs – Increased level of workforce skill	– Improved drying times – Improved movement characteristics – Reduced drying costs

7.3 Heat treatment (Thermally Modified Timber)

7.3.1 Time scale

The technology of heat treatment (thermal modification), is an active business now and can be adopted through licensing by any forest business. By 2015 this technology will be significantly important in the provision of durable and stable long life wood products for indoor and outdoor use as well as providing effective challenges to less sustainable substrates such as uPVC in window manufacture.

7.3.2 Expected level of uptake

This technology is highly relevant to the needs of modern forest products businesses and the use of wood in construction. A large number of SMEs will have adopted this technology and will be producing the materials and/or will be manufacturing using the modified wood substrates into the joinery and wood working markets – adding significant value to this chain by 2015. In addition other modification technologies will have emerged and be available for adoption by 2025.

Heat treatment	
Drivers in consumer demand: – Effects on health – Effects on the environment	- No or reduced risk of emissions in buildings when thermal modification of timber is used to enhance durability of timber rather than conventional techniques - At end of life TMT can be recycled, reused or sent for energy recovery
Technology's effect on economic aspects: – Diversity of products expanded – New businesses – New applications for wood	- New markets for stable and more durable wood based product - Reduced consumption of wood preservatives - Reduced maintenance painting activity - Outside BPD legislation?
Technology's effect on environmental aspects: – Fewer emissions and waste – Improved environmental profile	- Easy to handle and manage at end of life - Less waste product - Reduced transport
Technology's effect on social aspects: – Occupational health – Consumer acceptance	- Reduce emissions in production - Reduced use of non-wood products
Possible changes in risks and costs in industry as a whole?	- Fewer process stages in the value chain - Increased production costs - Replacing existing wood businesses? - Reduced maintenance painting activity

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
– Investment costs – No standards – Independent approvals needed	– Reduced emissions – No wood preservatives – Decorative appeal – Can be readily recycled, reused or energy recovery with impact – High dimensional stability – Low equilibrium moisture content – New opportunities for wood – Stable surfaces promote extended coating performance delivering extended maintenance intervals

7.4 Chemical modification (acetylation and furfurylation)

7.4.1 Time scale

The technology of chemical modification is an active business now and can be adopted through licensing by any forest business. By 2015 this technology will be significantly important in the provision of durable and stable long life wood products for indoor and outdoor use as well as providing effective challenges to less sustainable substrates such as uPVC in window manufacture.

7.4.2 Expected level of uptake

The technology of chemical modification is an active small scale business now and can be adopted through licensing by any forest business. By 2015 this technology is expected to be medium scale and significantly important in the provision of durable and stable long life wood products for exterior joinery.

Chemical modification	
Drivers in consumer demand: – Effects on health – Effects on the environment	- No or reduced risk of emission in buildings - At end of life can be recycled, reused or sent for energy recovery
Technology's effect on economic aspects: – Diversity of products expanded – New businesses – New applications for wood	- New markets for stable and more durable wood based product - New production facilities across Europe - More effective products with extended maintenance intervals - Enhanced wooden joinery businesses - Reduced consumption of wood preservatives - Outside Biocidal Products Directive (BPD) legislation?
Technology's effect on environmental aspects: – Fewer emissions and waste – Improved environmental profile	- More wood based products used in joinery and other end uses - Easy to handle and manage at end of life
Technology's effect on social aspects: – Occupational health – Consumer acceptance	- Reduced emissions to workers and indoor air - More vibrant forest based businesses and their rural communities
Possible changes in risks and costs in industry as a whole?	- High costs of product? - Increased production costs

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
– Investment costs – Timber imported into EU – No standards – Independent approvals needed	– Reduced emissions – No wood preservatives – Can be readily recycled, reused or energy recovery with impact – High durability – High dimensional stability – Low equilibrium moisture content – New opportunities for wood – Stable surfaces promote extended coating performance delivering extended maintenance intervals

7.5 Surface oils

7.5.1 Time scale

The technology of surface oil treatment is an active business now and can be adopted through licensing by any forest business. By 2015 this technology will be significantly important in the provision of durable and stable long life wood products for indoor and outdoor use as well as providing effective challenges to less sustainable substrates such as uPVC in window manufacture.

7.5.2 Expected level of uptake

This technology is highly relevant to the needs of modern forest products businesses and the use of wood in construction. A large number of SMEs will have adopted this technology and will be producing the materials and/or will be manufacturing using the modified wood substrates into the joinery and wood working markets – adding significant value to this chain by 2015. In addition other modification technologies will have emerged and be available for adoption by 2025.

Surface oils	
Drivers in consumer demand: – Effects on health – Effects on the environment	– No or reduced risk of emission in buildings – At end of life can be recycled reused or sent for energy recovery
Technology's effect on economic aspects: – Diversity of products expanded – New businesses – New applications of glued wood	– Enhanced 'natural' joinery products
Technology's effect on environmental aspects: – Fewer emissions and waste – Improved environmental profile	– Stable wood surfaces – Improved performance of wood surfaces – Reduced waste due to premature failure
Technology's effect on social aspects: – Occupational health – Consumer acceptance	– Improved products for consumers
Possible changes in risks and costs in industry as a whole?	– Long term performance of products – Higher costs – True value of benefits not established

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
– Investment costs – No standards – Unknown performance – data is been generated – Independent approvals needed	– Reduced emissions – No wood preservatives – Decorative appeal – Can be readily recycled, reused or energy recovery with impact – Dimensional stability – Improved environmental profile?

7.6 DMDHEU (dimethyldihydroxymethyleneurea) treatment by vacuum

7.6.1 Time scale

The use of DMDHEU as a reagent for wood modification is an active business now and can be adopted through licensing by any forest business. By 2015 these technologies will be significantly important in the provision of durable and stable long life wood products for indoor and outdoor use as well as providing effective challenges to less sustainable substrates such as uPVC in window manufacture.

7.6.2 Expected level of uptake

This technology is highly relevant to the needs of modern forest products businesses and the use of wood in construction. A large number of SMEs will have adopted this technology and will be producing the materials and/or will be manufacturing using the modified wood substrates into the joinery and wood working markets – adding significant value to this chain by 2015. In addition other modification technologies will have emerged and be available for adoption by 2025.

DMDHEU	
Drivers in consumer demand: – Effects on health – Effects on the environment	– Reduced risk of emissions in buildings – At end of life can be recycled, reused or sent for energy recovery
Technology's effect on economic aspects: – Diversity of products expanded – New businesses – New applications	– New markets for stable and more durable wood based product – More effective products – Reduced consumption of wood preservatives – Factory controlled – better reliability and uniformity of product – Enhanced wooden flooring, outdoor wood and decking businesses
Technology's effect on environmental aspects: – Fewer emissions and waste – Improved environmental profile	– Stable and hard wood surfaces – Improved performance of wood surfaces – Reduced waste
Technology's effect on social aspects: – Occupational health – Consumer acceptance	– Improved products for consumers
Possible changes in risks and costs in industry as a whole?	– Long term performance of products – Higher costs Replacing existing wood businesses?

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
– Investment costs – No standards – Long term performance is been generated – Independent approvals needed	– Reduced emissions – No wood preservatives – Can be readily recycled, reused or energy recovery with impact – High dimensional stability – Improved hardness – New opportunities for wood – Coating performance is enhanced on stable substrate

7.7 Green Gluing of timber (Polyurethane)

7.7.1 Time scale

Green gluing is a natural progression from conventional dry gluing made possible by polyurethane adhesives with excellent grab at high moisture contents. Though a relatively new concept many trials have taken place demonstrating the potential for the technology. The technology is poised for industrial trials on joinery components within the UK. Several feasibility studies haven taken place regarding industrial costing and commercial benefits. The feasibly trails have been built on work to demonstrate the potential of the technology, not only for joinery components but for glue laminated structural components. There is one study currently drawing to a conclusion that is expected to result in a pilot production plant within the next 5 years. Therefore, by 2015 the technology is expected to be increasing adopted for the production of joinery blanks for a range of joinery end uses, primarily of hardwood origin. The use for structural application has been well studied and trialled and several major sawmills have explored the possibility of using the technology to aid production and one sawmill has already adopted the use for specific end use products, which can not be discussed for client confidentiality reason.

7.7.2 Expected level of uptake

Because of the many processing benefits green gluing offers the level of uptake is expected to be to be considerable, particularly for industries that already defect cut and laminate as part of their current production processes. The two major examples would be the window industry and furniture manufacture, much of the production for both is from laminated material. Many manufactures already have the plant and equipment that is necessary for green gluing therefore for many industries investment cost is not the inhibiting factor, that comes in identifying the products that can best carry the cost of the re-engineering processes but many already carry this cost as part of their current production. Structurally one company is already green gluing for specific applications, a second is making both structural and non-structural components (cladding/flooring) and several others are exploring the potential. In both joinery and structural applications it is the potential to add value to a modest starting resource that will drive the market and adoption of the technology

Green gluing of timber	
Drivers in consumer demand: – Effects on resource – Effects on the environment	- The ability to add value to the resource. - Improved stability - Reduced waste stream - Better use of the standing timber resource
Technology's effect on economic aspects: – Diversity of products expanded – Value adding to resource – New applications for glued wood	-The use of minor species previously considered unsuitable due to long size or log shape. -The use of low qualities materials previously deemed unsuitable due small dimension or defects. -Structurally it can offer potential for better performing structural elements
Technology's effect on environmental aspects: – Less waste – Improved environmental profile	- Better whole log utilisation greater potential to use the whole standing timber supply - Added value to the resource leading to better managed hardwood forest leading to greater bio-diversity
Technology's effect on social aspects: – Consumer acceptance	- Increased value for money allowing cost effect purchasing of aspirational timber furniture, flooring, fittings stairs

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
- Investment costs for new start manufactures - Current market confidence	- Current manufactures of laminated joinery have the required plant -Better resource used with added value - Affordable products to a wider target audience - Greater used of small diameter hardwoods - Less wastage

7.8 Pattern Moulding – polymer pellet moulding

7.8.1 Time scale

This process pattern making using a polymer/laser technology is a well established process within engineering applications and allows complex shapes to be produced from CAD designs. The potential for this technology in the joinery industry is considerably less that in engineering, however, when teamed to computer controlled cutting and routing technologies offers the potential for complex and intricate shapes to be achieved that would previously have taken a considerable number of man hours of hand finishing by highly skilled craft men. The cross over from engineering has begun but is not envisaged to be a common component of the majority a joinery manufacturing facilities, due to cost and complexity, more a specialist tooling requirement.

However, the adoption of the technology in engineering will have some implications for timber as previously many cast engineering components were produced from timber patterns produced by skilled pattern makers. However, due the requirement for low or very low dimensional movement a limited number of timber species are suitable for pattern making. Timber of suitable quality is difficult to obtain. This has probably accelerated the adoption of this technology

7.8.2 Expected level of uptake

Within the joinery industry the levels of expected take-up are expected to be very low, with only manufactures of specialist timber designs or components needed this degree of technological sophistication in production.

The uptake in manufacturing engineering will be significant as it meet the requirement of that particular industry. It would be expected that all manufactures that produced items that required complex patterns for casting moulds had already adopted the technology and the only significant changes will be in computer technology in design.

7.9 Development of inside-out beams

7.9.1 Time scale

The timber research technique of producing inside-out beams (incorporating green gluing technology) is at an advanced stage in the UK. It is expected that by 2010 there will be a number of viable businesses using this technique to produce components such as structural beams, stair parts and roadside bollards. Using ‘Green’ gluing technology (bonding wood whilst the timber is ‘wet’) it is possible to convert small diameter hardwood and softwood stems into usable components, ensuring that a much larger percentage of the stem is utilised in comparison to normal processing methods.

7.9.2 Expected level of uptake

These technologies are highly relevant to the needs of modern forest products businesses and the use of wood in construction. A large number of SMEs will have adopted these technologies and be producing the materials and/or will be manufacturing using the modified wood substrates into the joinery and wood working markets –

adding significant value to this chain by 2015. In addition other modification technologies such will have emerged and be available for adoption by 2025.

Inside-out beams	
Drivers in consumer demand: – Effects on the resource	– Add value to a low value resource – Reduced waste
Technology's effect on economic aspects: – Increased management of small to medium sized forests – New business opportunities – New applications for small diameter stems	– Increased utilisation of stem – Reduced generation of co-products – Opportunities for new wood related product markets –
Technology's effect on environmental aspects: – Increased utilisation and less waste – Improved environmental profile New applications for bonded wood	– Increased utilisation of stem – Reduced generation of co-products – Opportunities for new wood related products markets
Technology's effect on social aspects: – Open up under managed woodland – Improved access for social activities	– Create a more diverse ecosystem – Encourage social interaction –

Risks and costs in the industry and any knock-on effects in related industries

Results of adoption of new technology	
Cons	Pros
– Investment costs – Long term durability is not known – Independent approvals required	– Improved utilisation of low value resource – Increase value – Decorative appeal – Can be readily recycled or reused – Less waste – Improved woodland management

8 FURNITURE INDUSTRY

Due to difficulties with work load at CEI-Bois a there is no input on the furniture industry in this report.

9 BIOENERGY (responsible: VTT)

The aim of this chapter is to give a short overview of the time scale of wood related bioenergy technology implementation that may have significant positive influence on certain sustainable criteria (Economical, Environmental, Social or Quality aspects).

Many research and technological development (RTD) goals can be defined for the biomass-to-energy sector:

- to lower production costs and to produce more energy – especially electricity – out of the already utilized biomass;
- to introduce (upgraded) biomass to new utilizer sectors;
- to enlarge the use of new biomass resources (eg. forest residue and waste);
- to substitute fossil fuels to enhance sustainability and reduce greenhouse gas emissions etc.

The main technology to produce heat, power or cogenerate heat and power (CHP) from biomass is combustion. Cogeneration will widen to trigeneration or polygeneration which means that the product range will be wider than heat and electricity. Gasification already exists and can be seen as a technology possibly increasing its share in the future. Furthermore biomass can be upgraded to higher quality biofuels eg pellets or liquid/gaseous biofuels (for eg. traffic). In the future new technologies will make it possible to increase the power-to-heat ratio and the efficiency of power generation. Nevertheless, a considerable increase in the use of bioenergy cannot take place without forest industry support (Fagernäs et al 2006) which means that although the technology is available on the market the drivers for implementing it must be strong enough.

9.1 Implementing new technology within large scale energy production

There are many concepts already available to higher energy production power-to-heat ratio both applicable within forest industry and elsewhere in energy production. With advanced CHP technology, higher power-to-heat ratios can be achieved, thereby increasing the potential for electric power generation for a given heat demand. Furthermore, co-operation between industry and energy companies producing electricity as well as both steam and district heat at the CHP-plant further increase the possibility of producing high power-to-heat ratios (Marbe et al 2004). A significant increase in power-to-heat ratio could be accomplished through application of another new technology, integrated gasification-combined-cycle (IGCC) processes. The pressurized gasification technology needed for IGCC applications is currently being developed both for black liquor and for solid biomass residue. The technology has already been demonstrated (see section 2.3).
Tri- and polygeneration means the combined production of multiple energy products - moving beyond cogeneration of heat and power. Polygeneration can also be defined as the use of multiple primary energy inputs to create multiple energy outputs. In the case of the Forest industry this could mean electricity and heat at various temperature levels (steam, hot water, chilling mediums etc.), secondary products such as pellets and liquid fuels for eg transportation. Polygeneration systems may use a wide range of renewable and fossil energy sources (such as gas, coal, biomass and wastes), and utilise a variety of energy conversion technologies (including gasification and pyrolysis) and produce a range of products (including electricity and heat/cooling, gases and liquids). The scale of the plant can also vary, from very large centralised energy stations to small installations located within urban areas. Process integration and polygeneration are likely development trends because they are evaluated to be more cost and energy efficient than stand-alone or one product systems. Producing liquid biofuels (9.3.2) would probably pay an important role in integrated production systems like this.

Bioenergy systems with CO_2 capture and storage may be one way of making some of the technologies described above economically more attractive. If carbon (as CO_2) is captured from biomass-fired energy systems, the systems could in principle be negative CO_2 emitting energy systems. Furthermore, incineration technologies presently being developed, using oxygen (or an oxygen rich air) instead of air as incineration gas, makes the flue gases more CO_2-rich which may have positive affects on the costs of the CO_2 capture processes.

Expected time and level of uptake
Some of the technologies described above are complementary and eg polygeneration systems can be flexible and gradually developed. Because of this it is not easy to evaluate the time span and level of uptake for implementing new wood-to-energy production technology within large scale production. Only a rough estimation is given below.

Expected time	Currently	By 2015	By 2025
technology generally adopted		(x)	x
technology adopted in best practice	(x)	x	x
technology in demonstration stage	x	x	
technology in pilot stage	x	x	

Drivers
The main drivers of implementation of new technology is the energy (electricity) price, the expectations of future carbon dioxide emission prices as well as the growing market demands of liquid biofuels.

Obstacles
Uncertainty within traditional forest industry may make the (large) investments needed less attractive.

Contribution to Sustainable Development
Has to be further evaluated. Energy and CO_2-emission studies must be implemented case by case to ensure that eg the complex integrated systems are really improving sustainability.

See also Chapter 2.2 and 2.5.

9.2 Small scale CHP

Expected time and level of uptake
The future target for CHP plants is to develop applications for ever-smaller heat consumers because available large heat loads for district and industrial process heating are limited. Diesel and steam engines, and steam and gas turbines are now applied in small scale CHP of 200 kW – 3 MW electricity. Microturbines, solid oxide fuel cells, Organic Rankine Cycle and Stirling engines are presently demonstrated for smaller capacity classes. All of these options need standardized concepts and mass or serial production to obtain competitiveness without significant subsidies or other promotion measures (Fagernäs et al 2006).

Gasification of biomass and waste is seen as an attractive alternative to produce power and heat on the small scale. A few gasifiers have been successfully in operation for twenty years and a number of gasification processes are under industrial development at pilot and demonstration scale.

Expected time	Currently	By 2015	By 2025
technology generally adopted			(?)
technology adopted in best practice	(x)	x	
technology in demonstration stage	x		
technology in pilot stage	x		

Drivers
The main drivers of implementation of small and micro scale CHP technology is energy (electricity) prices and the development of electricity distribution networks that allow distributed resources (small scale producers) to feed electricity into the grid.

Obstacles
Electricity transmission and distribution networks have a long life span and will be renovated rather slowly. The price paid for electricity sold to the grid by small scale producers may remain low.

Contribution to Sustainable Development
Implementation of distributed resources and systems will eg lower energy distribution losses and promote economy and employment on local level.

9.3 Upgrading biofuels

9.3.1 Pellet production from new raw materials

The resources of dry and wet saw dust (forest industry by-products) are very limited. To increase pellet production, new raw materials will be needed. Instead of using forest residue directly as a fuel it may also be upgraded to pellets. The utilisation of new wood raw materials with poor properties (eg. higher ash content than saw dust) for pellet production might not be the best way to enlarge the production of upgraded fuels so there might be changeover to other technologies/fuels when saw dust resources do not allow pellet production to increase.

Expected time	Currently	By 2015	By 2025
technology generally adopted			
technology adopted in best practice			
technology in demonstration stage	(x)		
technology in pilot stage	x		

9.3.2 Liquid biofuels

Advanced or second generation liquid biofuels can be produced from lingo-cellulosic biomass feedstock like wood and black liquor. One possible approach is to produce synthetic gas (syngas) from solid biofuels. VTT in Finland is developing a process based on pressurized fluidized bed gasification followed by novel catalytic gas reforming technology. The process has been demonstrated in a 500 kW pilot-scale and industrial demonstration is projected for the time frame 2008-2010. The syngas may be used for producing Fisher-Tropsch liquids (McKeough & Kurkela 2005). In Sweden, the concept of extracting lignin from black liquor and exporting it from the pulp mill has received considerable attention during recent years. The exported lignin could be used to replace heavy fuel oil (McKeough & Saviharju 2005). The pyrolysis process is able to produce high yields of liquid products. A number of fast pyrolysis processes are under industrial development at a pilot or demonstration scale. Before commercialization the homogeneity of the produced oil needs to be proved. However, pyrolysis oil produced with fast pyrolysis has been estimated to be the most inexpensive liquid biomass based fuel (Fagernäs et al 2006).

Expected time	Currently	By 2015	By 2025
technology generally adopted			?
technology adopted in best practice		?	
technology in demonstration stage	x		
technology in pilot stage	x		

Drivers
The main drivers for producing liquid biofuels within forest industry is the market demand (boosted by eg. EU regulations) and the possibility for forest industry to develop new integrated production concepts and deliver new products.

Obstacles
Limited resources of low price biomass, competition with traditional (material) utilisation of wood biomass. Low energy output from present production concepts.

Contribution to Sustainable Development
Energy and carbon balances are not too advantageous for demonstrated liquid biofuel production processes. If biomass is withdrawn from eg CHP production to produce liquid biofuels it might be difficult to explain how the development will contribute to sustainable development.

See also chapter 2.2.

9.4 Waste-to-energy concepts

Modern waste-to-energy concepts will play an important role in advanced waste management business concepts. Integrated waste recycling and energy production concepts including eg utilization of fibre rich fractions as raw material within the pulp and paper industry, advanced packing waste management concepts and recovered fuel production are some of the possible concepts improving sustainability presented here.

9.4.1 Pre-gasification of waste derived fuels

Large power plants have a very efficient combustion process, efficient energy recovery (usually CHP) and are equipped with very efficient environmental control equipment. By integrating a waste gasificator to the existing process the use of fossil fuel (eg. connecting the gasifier to a boiler fuelled with powdered coal) can be decreased and greenhouse gas emissions lowered. The co-combustion of the (waste derived) product gas (produced in the gasification process) together with the traditional fuel (eg. coal) will be very efficient and will provide environmental benefits compared with using traditional waste incineration technology and concepts. A concept like this has been convincingly demonstrated in the Lahti (Finland) project, first of its kind in Europe (Wilen et al 2004). Furthermore, traditional waste incineration plants often have problems with finding customers for the produced energy, especially heat. This dilemma can be avoided by processes like this, integrated to existing power plants or industrial boilers.

Expected time	Currently	By 2015	By 2025
technology generally adopted			?
technology adopted in best practice	(x)	X	
technology in demonstration stage	x		
technology in pilot stage			

9.4.2 Co-firing (or co-gasification) of recovered industrial waste material

Fluidised bed combustion technology is suitable for co-combustion of different fuels. Packing waste (from stores and industry) or other processed solid recovered fuel fractions can be utilized as a co-fuel in existing FB (fluidised bed) or BFB (bubbling fluidised bed) boilers (fuelled with eg. a mixture of biomass, peat, coal and sludge) by making some changes in the fuel receiving and handling processes. The same kind of advantages as mentioned in 9.4.1 can be achieved also for this concept. This concept was the leading one in Finnish waste-to-energy business and recognised as BAT (Best Available Techniques) technology for small countries like Finland until EU regulations (coming into force 1.1.2006, monitoring emissions) made co-firing of waste fractions too costly. At the moment only a few power plants co-fire waste materials in Finland and 5 – 10 traditional waste incineration plants will be built in the next 5 – 10 years to meet the new landfill regulations.

9.4.3 Integration of WtE and recycling

A future path to increase both recycling and waste-to-energy (WtE) may be solutions that integrate recycling and WtE. It will be important for industry to secure optimal usage of recycled fibre by taking advantage of high-quality recycled fractions and using the remaining material for energy production.

One such concept focusing on recycling of liquid packaging (recycling the aluminium foil and producing energy) using gasification technology has been demonstrated by Corenso United Ltd in Finland (Wilen et al 2004).

Another possibility focuses on integrating the pre-treatment: the novelty of eg the Urban Mill concept introduced by Metso Paper lies in its combination of a small paper mill with using solid waste to generate energy. Pre-treatment of recycled material divides the waste stream into eg. a fibre-rich fraction (recycled fibre) that can be fed directly for pulping, other materials that may be recycled and a high-quality fuel for advanced waste-to-energy operations based on fluidized bed of gasification technology (Wilen et al 2004, Fagernäs et al 2006).

Expected time	Currently	By 2015	By 2025
technology generally adopted			?
technology adopted in best practice	(x)	X	
technology in demonstration stage	x		
technology in pilot stage			

See also Chapter 3.4.

9.4.4 References

Fagernäs L, Johansson A, Wilén Carl, Sipilä K, Mäkinen T, Helynen S, Daugherty E, Hermaan U, Vehlow J, Kåberg T, Rogulska M. Bioenergy in Europe. Opportunities and Barriers. VTT Research notes 2352. Espoo 2006.

Marbe, Å., Harvey, S. and Berntsson, T. 2004. Biofuel gasification combined heat and power-new implementation opportunities resulting from combined supply of steam and district heating. Energy 29:1117-1137.

McKeough, P. and Saviharju, K. 2005. Advances and possibilities in the utilisation of Black liquor and other pulping by-products. ABTCP-PI Conf. Sao Paulo, Brazil, 17-20 October 2005. 10 p.

McKeough, P. and Kurkela, E. 2005. Comparison of the performances and costs of alternative applications of biosyngas. 14th European Biomass Conference, Paris 17-21 October 2005. 4 p.

Wilén, C., Salokoski, P., Kurkela, E. and Sipilä, K. (2004). Finnish expert report on best available technique in energy production from solid recovered fuels. The Finnish Environment : 688. Finnish Environment Institute, Helsinki. 55 p.
(http://www.ymparisto.fi/download.asp?contentid=20630)

10 OTHER INDUSTRIES (responsible: TUZVO)

10.1 Isolation and development of wood protection chemicals from natural substrates

Isolation and development of wood protection chemicals from natural substrates is not entirely new. Extracts from sawmill residues of the naturally durable white cypress *Callitris glaucophylla* were tested for fungicidal activity in a series of laboratory bioassays. Sawdust from sapwood of *Eucalyptus maculate* was also used. Studies have shown that the resinous material extracted from the guayule plant (*Parthenium argentatum*, Gray) has both insect- and microbial-resistant properties. For controlling the stain and rot fungi, the efficacy of natural biocides used in agriculture and of new molecules isolated from fungi such as *Mycena* species with anti fungal properties was being investigated. Work involved the biological performance of water and organic solvent soluble extractives of four naturally durable wood species, namely; Matumi, Tamboti, Sneezewood and the Turpentine tree.

The pressure on ecologically friendly preservatives will lead to the development of new natural preservatives and to new effective techniques of their isolation and implementation. The withdrawal from classical inorganic compounds in wood preservation can be expected.

10.2 Introduction of laser cutting

Laser cutting has been and still is used for the production of flooring. Complicated parquets are effectively cut with use of CO_2 lasers. The cutting speed is relatively high for the "veneer" of the thickness of 5-7mm. More over the waste-less technology uses the system of positive – negative when parts of dark veneer (e.g. walnut) are placed into light veneer (e.g. maple). Utilization of power lasers offers even more possibilities. The great advantage of this technology is the ability to deliver a desired amount of energy to the place chosen. With the knowledge of the mass of wood evaporated with this amount of energy we can create three dimensional surfaces.

The precise cutting by laser can be also utilized for the products with high added value. The study of the relationship between the amount of energy delivered and the respective colour change can lead to the new technologies of surface finishing. The utilization of laser cutting for high thickness wood based materials is hardly to be expected.

10.3 Drying techniques such as use of microwaves

(see also section 7.2)

Microwave drying technology can substantially decrease the drying time. The research of the relationship between the absorption of microwaves and wood moisture content of wood indicate that the temperature and moisture distribution in wood can be much more effectively controlled by microwave or radiofrequency heating than by any other way of heating. The devices required are becoming cheaper and the price of energy increases. The effective delivery of energy can prevent from losses common in classical technologies.

The massive exploitation of these new technologies cannot be expected very soon. On the other hand their application for drying valuable assortments, like resonance wood for the production of musical instruments can be expected very soon.

10.4 Hydrothermal treatment – also for wood bending

Hydrothermal treatment of wood can be defined as a desired change of wood properties in order to prepare it for further processing or utilization. It could be steaming for veneer slicing, peeling, plasticization for bending, colour change etc. The depth of penetration with RF heating using i.e. the 27.12 MHz frequency is in the order of meters. The output of RF systems is usually from dozens of kW to 1500 kW. With output over 50 kW, the RF heating is usually more economical than MW heating. The most important area of using the RF heating in wood industry is drying of timber.
RF heating is massively used also in plywood production, where electrodes function simultaneously as press plates. The RF energy removes wet spots in veneer and equalizes the moisture without the creation of steam bubbles and interference of board lamination. The RF energy affects also the glue in plywood, fiberboard and chipboard.
The softening (plastification) time of wood, dried to 18-24 % with uniform moisture in the whole profile, is reduced by RF heating to a few minutes compared with standard steaming.

The above mentioned properties show that microwave and radiofrequency heating will find a broad application in wood processing technologies. The main reasons for this are increasing prices of wood and energy costs.

11 DISCUSSION (responsible: BRE)

The report is qualitative in nature but needs to indicate the form of response function which will be generated. The response functions will be investigated further in PD 4.2.7 and will:

- Need to be assessed by region rather than country eg western Europe, central Europe, eastern Europe
- Should be as best estimate and a maximum and minimum value

Response functions have been described in “Eforwood dynamics – position paper by J. Laurijssen, P. Nilsson and A. Hooimeijer as follows:

Sustainability impacts = scenario sustainability – baseline sustainability

where

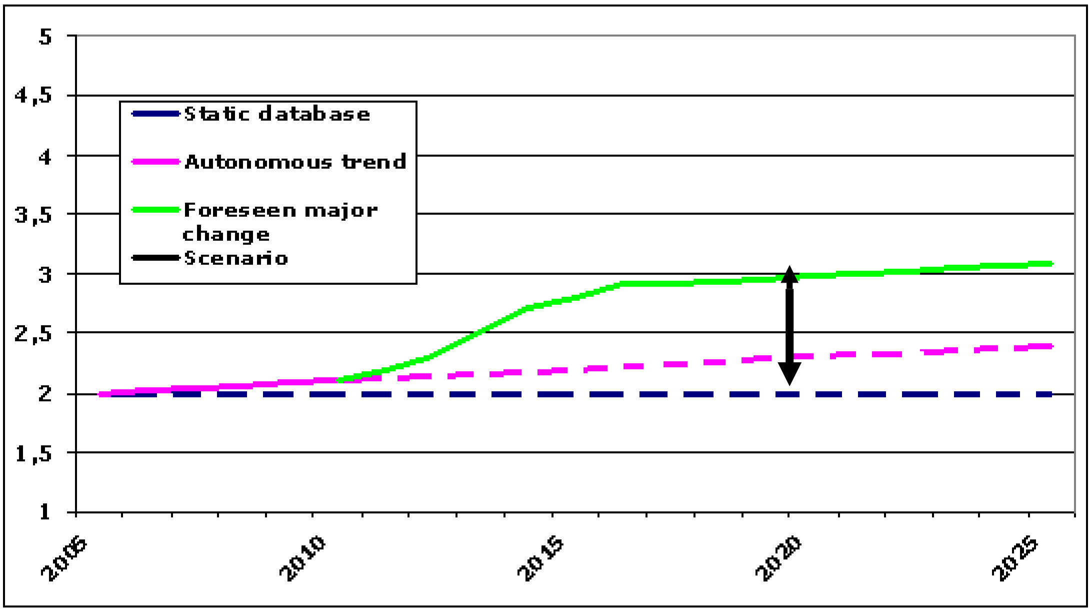
scenario sustainability = static database * autonomous trend factor* foreseen major changes * scenarios

and

baseline sustainability = Static database * autonomous trend factor* foreseen major changes

Static database refers to sustainability indicator data in the ToSIA reference year (2005)

Autonomous trend factor represents the change in data over the years without major changes in technology, economy etc. because of continuous *evolutionary changes.* Foreseen major changes represent the impact of expected technology and policy developments, product demands etc. within the value chains *(major changes).* Scenario’s represents the impact of all new policies, economic changes, etc. which are beyond the “foreseeable” changes. They deal with the so called “what if” questions *(Radical changes).*



It seems reasonable that uptake of technologies already used in best practice can be regarded as an autonomous trend. Introduction of technologies already in small scale trials in the industry if successful should be regarded as foreseen major changes. Any less developed technology would be a radical change. This can be tabulated for the different technologies (see summary section)

Response functions may not relate only to technology change but to economic pressures both within and from outside Europe and to legislative changes. Drivers for change will modify the rate of uptake of the technologies and vary in the different industry areas.

In the pulp and paper industry technology related to reduced power use is mainly driven by associated economic and environmental advantages such as decreased use of fossil fuels which also reduce emissions. Some changes to technology are driven by legislation relating air emissions such as NO_x.

In the recycled paper industry changes relate in the main to improving the quality of the recovered material and reducing waste. This is driven by increasing energy prices, legislation and costs of landfilling/waste disposal.

Sawmilling technology changes are towards improved quality and value of products and to meeting specific consumer demands for value added products and also towards reducing waste by better utilisation of the raw material. Methods which improve the traceability of the timber products are driven by legislation to prevent illegal logging and by Green (public) procurement.

In the panel board industry changes are in part driven by consumer demand for reduced emissions from newly manufactured boards. Other drivers are reduction of waste, glue use, and energy consumption.

In the joinery industry changes are also driven by consumer demand for reduced emissions in buildings and for more durable products. Legislation drives moves towards reduced consumption of wood preservatives which can be achieved with a number of the new technologies such as chemical and thermal modification of wood. These technologies also have the added benefit of improving the ability to recycle the timber at end of life and reduce amounts of landfill this is driven by legislation and costs of landfilling/waste disposal. They also improve stability of the timber and increase maintenance intervals for joinery so reducing use of petrochemical resources. Wood welding and inside-out beam technology also reduce waste by better utilisation of the timber resource particularly of small dimension and lower quality timber, and provide economic advantages by adding value.

The furniture industry cannot be discussed because of the lack of sources of data (see section 8).

In the bioenergy industry the main drivers for change are utilisation of 'waste' materials and the production of energy without the use of fossil fuels or with reduced dependence on fossil fuels. Production of pellets from forestry industry by-products will be limited by the availability of those low price products. Developments in bioenergy technology will be driven by energy (electricity) prices and the expectation of future CO_2 emission prices.

Other industries the isolation and development of natural biocides such as those from timber and plant extracts will be driven by legislation for use of less toxic products and by consumer demand for ‘greener’ preservatives. Laser cutting techniques are waste-less and offer high precision and the potential for value added products. Microwave drying and radio frequency heating use less energy than conventional methods and therefore offer cost savings.

12 SUMMARY

Changes within the different industries can be summarised as falling into the three categories, autonomous trends, foreseen major changes and very new technologies “scenario” in the table below.

Production area	Autonomous trend	Foreseen major change	Radical change
Pulp and paper	Change in coating techniques	Changes to effluent treatment	Bio refinery plants
	Improved drying technique	Use of enzymes	Separating lignin from black liquor
	Fibre fractionation	Improvement in measurement and control of pressing	
		Changes to lime kiln technology	
		Stratified forming techniques	
		Changes to recovery boiler technology	
Recycled paper	Use of sensors for recovered paper sorting and quality control		
	Use of enzymes to upgrade recycled paper		
	Production of secondary fuels from rejects		
	Deinking sludge as raw material for other applications		
Sawmilling	Use of scanning technology to optimise sawing, characterisation and grading of sawn timber	Use of alternative wires for recovered paper bales	
	Smart decision making for optimising value of products		
	Adaptive production and business processes		
Plywood industry	Log scanners		
	New peeling methods	Flexible manufacturing sawmilling systems Data transfer down FWC Traceability ITC systems	
	More automated veneer scarfing		
	Dry veneer scanning		
	Automatic composing		
Panel board industry	Powder coating	X-ray and machine vision systems	
	Dry gluing		
	Use of MDI glues		
	Light MDF and particle board		
	Mat preheating		
	Dyed MDF		
	Process control and measurement		
Joinery industry	Chemical modification		Use of short burst microwave drying
	Use of surface oils		

	DMDHEU treatment by vacuum		Inside-out beams
Other industries	Laser cutting		Use of natural substrates as preservatives
Bioenergy	New technology in large scale plants	Wood welding	Pellet production from new raw materials
	Small scale CHP		Liquid biofuels
			Integration of waste-to-energy and recycling
		Pre-gasification of waste derived fuels	

The expected rate of introduction within the industry is detailed in tables in the body of the report and will not be repeated here.

The drivers for adoption of technologies vary from industry to industry and include:
reduction of emissions
expectation of future CO_2 emission prices
legislation relating to air emissions such as NO_x.
increasing energy (electricity) prices
renewable energy legislation
utilisation of 'waste' materials production of energy
the ability to recycle the timber at end of life
costs of landfilling/waste disposal.
demands for value added products
better utilisation of the timber resource, reduction of waste
prevention of illegal logging
reduction of glue use
reduction of energy consumption
less use of traditional preservatives (legislation and consumer perception)
increase maintenance intervals for joinery so reducing use of petrochemical resources
reduced use of fossil fuels.