EFORWOOD
Tools for Sustainability Impact Assessment

Response factors: Background, practical implications and their use in ToSIA

Shane Porter, Katie Johnson, Katie Livesey, Katri Behm, Jobien Laurijssen, Arto Usenius, Jorma Froblom, Margareta Wihersaari, Pia Nilsson, Juulia Rouhiainen, Marian Babiak, Rudolph Kropil and Elisabeth Bergnor

EFI Technical Report 82, 2011

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Publisher: European Forest Institute
Torikatu 34, FI-80100 Joensuu, Finland
Email: publications@efi.int
http://www.efi.int

Editor-in-Chief: Risto Päivinen

Disclaimer: The views expressed are those of the author(s) and do not necessarily represent those of the European Forest Institute or the European Commission. This report is a deliverable from the EU FP6 Integrated Project EFORWOOD – Tools for Sustainability Impact Assessment of the Forestry-Wood Chain.

Preface

This report is a deliverable from the EU FP6 Integrated Project EFORWOOD – Tools for Sustainability Impact Assessment of the Forestry-Wood Chain. The main objective of EFORWOOD was to develop a tool for Sustainability Impact Assessment (SIA) of Forestry-Wood Chains (FWC) at various scales of geographic area and time perspective. A FWC is determined by economic, ecological, technical, political and social factors, and consists of a number of interconnected processes, from forest regeneration to the end-of-life scenarios of wood-based products. EFORWOOD produced, as an output, a tool, which allows for analysis of sustainability impacts of existing and future FWCs.

The European Forest Institute (EFI) kindly offered the EFORWOOD project consortium to publish relevant deliverables from the project in EFI Technical Reports. The reports published here are project deliverables/results produced over time during the fifty-two months (2005–2010) project period. The reports have not always been subject to a thorough review process and many of them are in the process of, or will be reworked into journal articles, etc. for publication elsewhere. Some of them are just published as a "front-page", the reason being that they might contain restricted information. In case you are interested in one of these reports you may contact the corresponding organisation highlighted on the cover page.

Uppsala in November 2010

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EFORWOOD
Sustainability Impact Assessment
of the Forestry - Wood Chain

Project no. 518128

EFORWOOD

Tools for Sustainability Impact Assessment

Instrument: IP

Thematic Priority: 6.3 Global Change and Ecosystems

Deliverable D4.2.11
Response factors: Background, practical implications and their use in ToSIA

Due date of deliverable: Month 44
Actual submission date: Month 46

Start date of project: 011105
Duration: 4 years

Organisation name of lead contractor for this deliverable: BRE, KCL, INNVENTIA AB, KCPK, PÖYRY, TUZVO and VTT

Final version

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)	

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1 INTRODUCTION

This report is a deliverable of the European Commission’s project called EFORWOOD, which aims to provide methodologies and tools that will integrate Sustainability Impact Assessment of the whole European Forestry Wood Chain (FWC). It has been produced by Module 4, which focuses on the processing and manufacturing stages of FWC in Europe.

This report represents a merged objectives of several reports originally planned in the 18-months appropriate period. These are

- PD 4.2.8 *Draft report on theoretical response functions with practical implications*
- PD 4.2.9 *Sequel to the report on conditions and consequent timing of technological developments in processes in relationship to response functions*
- PD 4.2.13 *Response functions and reality of manufacturing processes and technologies adoption*

The need to merge these reports was a joined decision by M4 and the project’s co-ordinator in order to maintain a level of cohesiveness and reflect the changes in the development of ToSIA and related supporting tools and methodologies.

The purpose of this report is to provide a background to response functions and give examples of how they estimate changes in sustainability impact assessment and how these changes are likely to be implicated in the real world. The report begins with introducing the topic of response factors, how they have developed and how they are to be used in EFORWOOD with background information explaining the reasons they are useful in this project in their new/changed form (i.e. changed from response functions to response factors). The main body of the report gives a number of case studies from all three material streams (i.e. solid wood, pulp & paper, and bio energy) in which the response factors have been used to estimate environmental, economic and social changes for the reference futures A1 and B2 for the years 2015 and 2025. Discussion of the multitude of implications of the changes suggested by the response factors is supported by each case study giving an example of a new technology which may present changes in sustainability impact assessment. The report also considers how advances in certain technologies may also have an effect on each of the processes mentioned in the case studies.

This report is interlinked with PD 4.2.6 *Conceptual outline of response functions and draft response functions for case studies*, PD 4.3.8 *Draft description of response function framework and examples* and PD 4.2.12 *Sustainability Indicators for FWC; Background of approaches for reference futures.*

2 RESPONSE FACTORS: THE BACKGROUND

2.1 Original label: Response functions

A response factor is a term which has been developed from response functions. Response functions are used for mathematically describing the impact of a parameter change to a system. As described in PD 4.2.6 *Conceptual outline of response functions and draft response functions for case studies* response functions could be linear or non-linear, cyclical or non-cyclical or in special cases discontinuous. The shape of the function would be determined by the nature of the system. Within the EFORWOOD project the response function were to be used to envisage the change in sustainability impact assessment for the various case studies for the reference futures A1 and B2 for the years 2015 and 2025 (see Chapter 3). The nature of the case studies implied that the majority of the response functions would be linear non-cyclical functions such as in Figure 1 below.

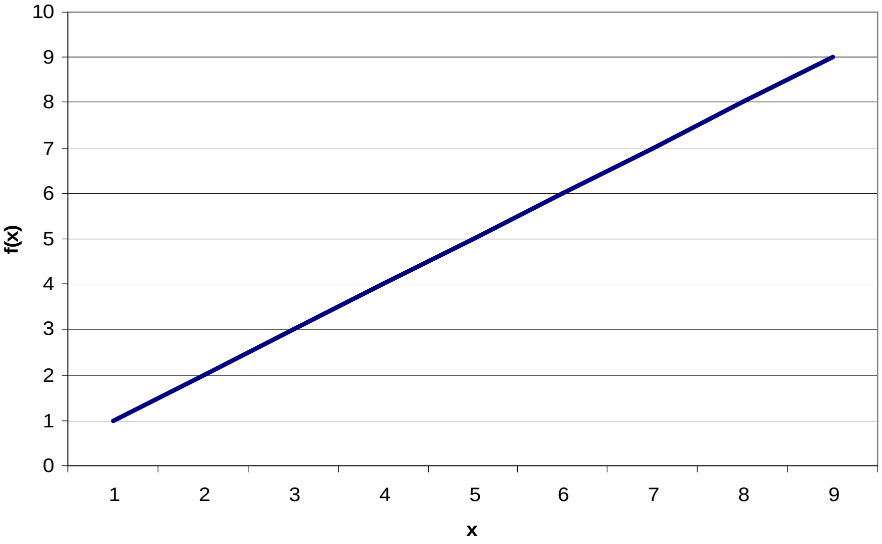

Figure 1 - Example of a linear non-cyclical function[1]

The development process of response functions included SWOT analysis, impact maps, trend fitting and cross-impact matrices; it is described in detail in PD 4.2.6 *Conceptual outline of response functions and draft response functions for case studies*. One of the particular limitations of obtaining response functions was due to the vast number of indicators appropriate to each process. It was therefore necessary to identify and prioritise the most relevant indicators and to differentiate the response from the system in terms of magnitude and direction. The approach adopted in generating response functions is described below[2]

1. defining crucial issues that influence a process (e.g. fine paper production), based on the reference future descriptions

---

[1] PD 4.2.6 *Conceptual outline of response functions and draft response functions for case studies*

[2] PD 4.2.6 *Conceptual outline of response functions and draft response functions for case studies*

2. selecting and quantifying those issues that change in the reference futures -> process drivers
3. developing a projection for each indicator of a process
    a) taking an indicator
    b) selecting the process drivers that have an impact on this indicator
    c) finding the interdependencies between the indicator value and the selected drivers
    d) generating the indicator value projection

Response functions were not the only means of estimating the changes in sustainability impact assessment and the other main method used in the project is described in the following section 2.2.

2.2 Use of EFI GTM[3]

The European Forest Institute's Global Trade Model (EFI GTM) is a forest sector models that integrates the dynamics of timber supply, forest industry, forest resources and forest product market demand. The main function of the EFI-GTM is to provide a 'consistent analysis of how and by how much production, consumption, imports, exports, and prices of round wood and forest industry products may change over time as a consequence of changes in external factors like economic growth, forest biodiversity protection, energy prices, trade regulations, transport costs, exchange rates, forest growth, forest management, and consumer preferences'[4] .

Deliverable D1.4.7, *Reference futures and Scenarios for the European FWC*, describes how a consistent set of input allows the EFI-GTM model to quantify indicators under the reference futures. The output values from these EFI-GTM model runs (having used 2005 as the 'base-year data') allow the base-year data to be manipulated in order to provide values for the reference futures. Figure 2 illustrates ETI-GTM models relationship with data flow within EFORWOOD.

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[3] The following section of work has been adopted from *PD 4.2.12 Sustainability Indicators for FWC: Background of approaches for reference futures.*

[4] *D1.3.1 Documentation of the Forest Sector Model*

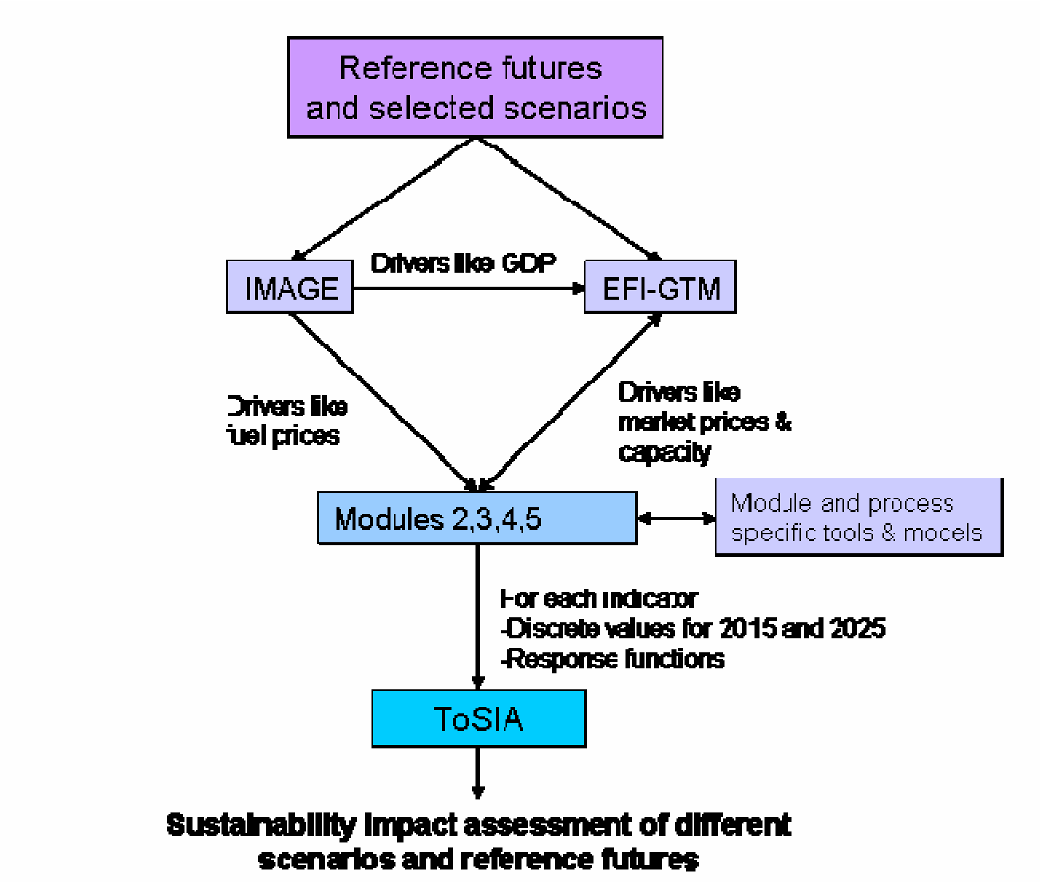

Figure 2 - Process of data flow in EFORWOOD

2.3 Response factors

The original plan for ToSIA was to include processing of two differing scenarios, one with fixed data points, and the other with response functions and therefore allowing continuous analysis.

With time, the development of ToSIA and its scenarios required rethinking of the use of both approaches. Fixed data points emerged as a more feasible option due to the particular difficulty with synchronising all the changes between the modules. These fixed models have now become known as the reference futures and are described in Chapter 3. It was also decided to use the EFI-GTM runs for all modules instead of response functions relevant to each module as these runs provide a common basis for calculations to ensure consistent and reliable data.

Partners in EFORWOOD were given authority to select the most appropriate models and response functions when generating the data points for reference futures. Hence, it was decided that in some adjusted form response functions were still required within EFORWOOD. To avoid confusion with the initial use of ‘response functions’ it was decided to rename these to ‘response factors’.

Response factors can now be accurately described as ‘assumptions as percentage scale’ that have to be designed for use within ToSIA in order to quantify how technological change will modify future scenarios.

The following section adopted from *PD 4.2.12 Sustainability Indicators for FWC; Background of approaches for reference futures* provides background information on the interpretation of the reference futures indicator values, and presents a ‘step-by-step’ guide to the M4 work on response factors. The main issues addressed are calculations and methodologies applied and the benefits and limitations of some of the approaches considered and used.

2.3.1 Social indicators

Indicator 10 – Employment
The initial approach used for estimating this indicator was the analysis of historic data. However, as there are two reference futures to deal with (descriptions of reference futures A1 and B2 are provided in Appendix B) employment figures need to be specified for both futures. As guidance is provided by the EFORWOOD project, the results of the EFI-GTM runs were finally agreed upon instead of the extrapolation of values from the historic data.

Indicator 11 – Wages and Salaries
For wages and salaries, the guidance produced by the EFORWOOD scenario team indicates they follow the same pattern as GDP development in a country. The guidance document for this work only provides total European and Eastern European figures on future wages increase (based upon GDP increases), thereby not taking into account differences between Western, Southern and Northern Europe. However, these figures were followed in order remain consistent across all modules.

Indicator 12 – Occupational accidents
Unfortunately, historic or current figures for accident rates (fatal and non-fatal) were unavailable for Eastern European countries, however, for the countries for which data was available trend lines were created, which were expected to be logarithmic. To avoid numbers below zero (due to a sharp decrease in the numbers of accidents in a short amount of time) the assumption has been made that in 2060 (Northern, Western, Eastern) and in 2100 (Southern) the accidents will be stable at 500 accidents. This is actually a rather hypothetic assumption. By creating the trend lines with the assumed stabilisation mentioned above, data was able to be retrieved for both futures. It was assumed that there would be no difference in health and safety regulations in the two reference futures. As fatal accidents are very low, and no clear patterns in historic data were found, an agreement was arrived at between the partners in which the fatal occupational accidents would not change in the either the A1 or B2 futures. Therefore it has been assumed that both futures will have the same figures as in 2005.

Indicator 15 – Persons employed part-time or self employed
As these values are representing the proportion of persons employed in part-time contracts, employees with a contract of limited duration and those self employed (rather that absolute numbers) it was decided among experts and M4 partners that

these values would not change in the reference futures. Therefore these figures remain the same as those in 2005.

2.3.2 Environmental indicators

EFI-GTM runs were not able to assist M4 partners in the calculation of environmental indicators for futures 2015 and 2025; instead, module partners and stream experts came to an agreement concerning how to approach this task, deciding that all materials will use the same approach and development on this low level of detailing (unless otherwise stated).

The percentage changes (i.e. reference factors) for individual indicators were deliberated in several meetings and the main decisive elements were

- the general trends in the particular industry
- industry representatives' opinions and statements
- the reference future descriptions themselves

Table 11 shown in Appendix A illustrates the selected environmental indicators and their changes in reference futures A1 and B2.

2.3.3 Economic indicators

Within M4 there are a large variety of processes with differing characteristics. Different drivers (e.g. GDP growth, wood price or oil price) have disproportionate influences on individual processes, thus, different methods are used in the selection and quantification of process drivers and the economic indicators for reference futures must be compiled separately for every process (or in some cases process groups). *PD 4.2.6. Conceptual outline of response functions and draft response functions for case studies* provides further clarification of this issue. To be able to calculate reference future values for economic indicators the main drivers for the each process group and indicator have been defined in Table 12 which is located in Appendix A at the back of this report, illustrating that the EFI-GTM runs have enabled the calculation of the majority of economic indicators.

As there is no information concerning the development of some productive costs provided by the EFI-GTM data, it has been assumed that these values remain the same as in 2005. In addition, it has also been assumed that there have not been any political changes in the reference futures and that the corporate taxes, other taxes or charges do not change.

3 REFERENCE FUTURES

ToSIA will run three versions of data-sets. These are:

- base-year 2005
- two ‘reference future’ cases (called A1 and B2 for years 2015 and 2025)

Both reference futures are from the IPCC: “Special Report on Emissions Scenarios” (D1.4.7 *Reference futures and Scenarios for the European FWC*). The two reference futures used in EFORWOOD are neither a prediction nor a forecast, but are used to create a consistent image of a future. The reference futures encompass a significant portion of underlying uncertainties in the main driving forces. These drivers cover a wide range of key characteristics such as demographic change, economic development, and technological change. The text below outlines the main issues which influence the drivers for the indicator values for each reference future in 2015 and 2025. The full description of the reference future storylines can be found in Appendix B.

Reference future A1

1. Rapid economic growth
2. Global population peaks in mid-century and declines thereafter
3. New and more efficient technologies
4. Low awareness of environmental issues
5. Convergence among regions, increased cultural and social interactions due to globalisation
6. Cheap wood raw material is imported to Europe means less harvesting in European forests
7. Heavy industry moves to Eastern Europe and the developing world
8. High consumption of paper, particularly lighter papers (weight decreases by 50%)
9. New forests are planted in areas previously used for agriculture
10. Recycling rate for paper is stagnant
11. Increase in demand for packaging

Reference future B2

1. Intermediate levels of economic development
2. Continuously increasing global population
3. Relative to A1 there is less of a technological change
4. Environmental protection and social equity are important social considerations
5. Proliferation of local solutions to economic, social and environmental sustainability
6. High raw material prices and high demand for European round wood
7. Increased demand for cheaper and lower quality goods
8. Production remains in European region but labour is coming from CEE countries
9. Lower consumption of paper, lighter packaging only
10. Recycling and recovery rates are higher than today
11. Lighter and tailored packaging

4 CASE STUDIES

This section demonstrates the practical implications of response factors. BRE, as the main author of this report, decided to use a number of case studies using processes where base-data sets are already known. These results are analysed and discussed in terms of their 'real world' consequences.

Each partner within M4 has been asked to provide a case study of a process. Within each case study, base-year data (2005) has been used in order to calculate indicator values for reference futures A1 and B2 for the years 2015 and 2025.

The case studies provided by the M4 partners start by briefly describing the process being analysed. The indicator values have then been presented in table format and graphs have been produced to show the implications of the response factors. Only indicator values which have been discussed by the M4 partner are presented in the main body of this report (full set of indicators are in Appendix C).

Furthermore, an example technology has been selected for each process susceptible to more changes during sustainability impacts in the reference futures. Each technology is briefly described, the estimated future uptake of the technology in the region and some of the effects of the adoption of the technology are discussed.

4.1 *Coated woodcontaining paper in Western Central Europe*

Partner: KCL
Region: Western Central Europe

Coated woodcontaining paper is typically used for magazines or catalogues. It consists of mechanical pulp (55% of fibres), bleached softwood kraft pulp (35 %) and de-inked pulp (10 %). The amount of fillers and pigments in the paper is 35 % of the dry weight. Paper is typically produced in a mill which is integrated to mechanical pulping and de-inking processes but used kraft pulp is purchased market pulp. The process yield is 0.87 of carbon, which means that 13% of incoming carbon in fibres (e.g. bark) is used for energy production in bark and sludge boilers. The economic, social and environmental indicators values shown in Table 1 are those which have been chosen as points of discussion[5]. The indicator values are calculated per ton of carbon input.

Table 1- Sustainability indicators for coated woodcontaining paper in Western Central Europe for the reference futures A1 and B2 for 2015 and 2025[6]

	2005	A1 2015	A1 2025	B2 2015	B2 2025
2.1.4 - Average cost - energy costs	101	85	66	84	67
18.2 - Energy use	2741	2441	2186	2441	2186
18.2.1.2 - Energy use - Heat from fossil sources	3698	3022	2469	3022	2469
18.2.3.3 - Electricity use - from the grid	1175	1061	960	1061	960
19.1 - Greenhouse gas emissions	570	499	441	499	441
19.1.1. Greenhouse gas emissions from machinery	386	315	257	315	257
21.1 - Water use (freshwater intake by industry) [relevant for industry]	17.4	15.7	14.2	15.7	14.2
24.1.1 - Water pollution - organic substances (biochemical oxygen demand)	0.30	0.30	0.30	0.28	0.25
24.1.2 - Water pollution - nutrients (nitrogen, phosphorus) as Nitrogen or TKN (Total KJELDAHL Nitrogen)	0.15	0.15	0.15	0.13	0.12
24.2.1 - Non-greenhouse gas emissions into air - CO	0.09	0	0	0	0

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[5] The full table provided by KCL can be found in Appendix C; Table 13.

[6] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

	2005	A1 2015	A1 2025	B2 2015	B2 2025
24.2.2 - Non-greenhouse gas emissions into air - NOx	0.78	0.67	0.58	0.67	0.58
24.2.3 - Non-greenhouse gas emissions into air - SO2	0.26	0.23	0.19	0.23	0.19
27.2.1 - Waste to material recycling	14.8	14.8	14.8	16.4	18.0
27.2.3 - Waste to landfill	3.5	3.5	3.5	1.9	0.2

The response factors assume that energy efficiency will increase slightly every year. This will enable less electricity to be purchased and fewer fossil fuels to be used for heat production. As a result of this energy costs and greenhouse gas emissions will be decreased. Figure 3 shows the decreasing amount of fossil fuels being used compared to the use of energy from renewable sources.

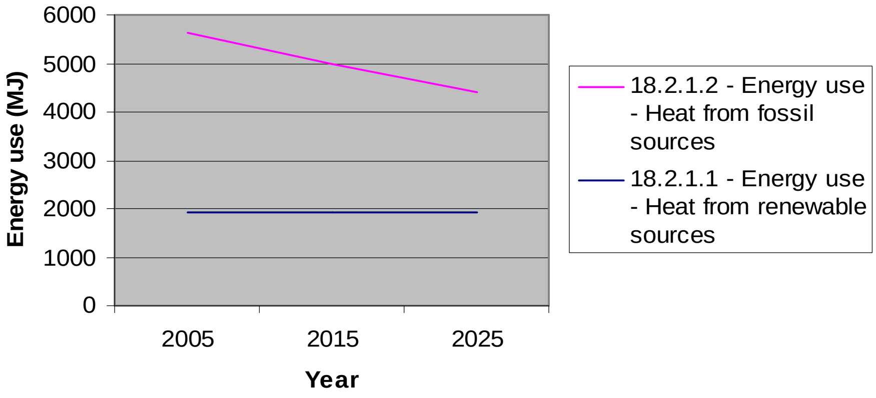

Figure 3 - Estimated use of fossil fuels compared to renewable sources

In addition to the decrease in the use of fossil fuels, NO_x and SO_2 emissions to air will also decrease because of lower energy consumption. This is shown in Figure 4.

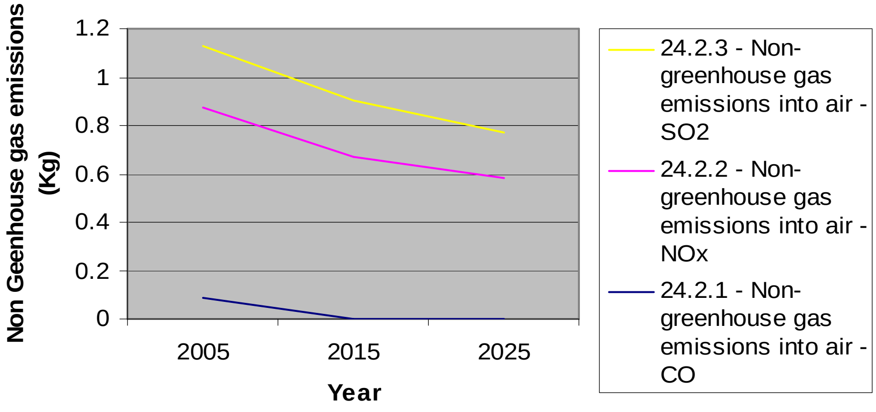

Figure 4 - Decreasing non-greenhouse gas emissions due to lower energy consumption

Water consumption is also likely to decrease yearly, but in reference future A1 there will be similar amounts of water pollution than in year 2005. In reference future B2, more attention will be given to environmental topics therefore emissions to water can be expected to decrease slightly, as illustrated in Figure 5.

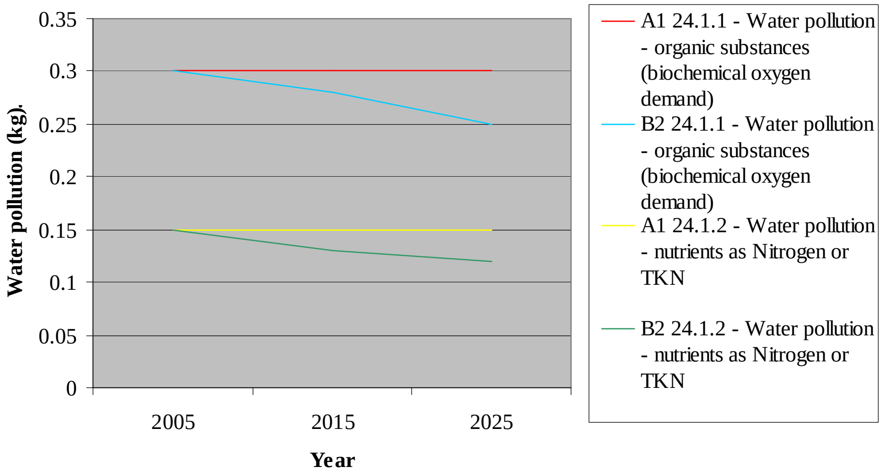

Figure 5 - Decreasing water pollution in B2 future due to increased environmental awareness

Although the amount of waste will remain similar, the recycling rate will increase in reference future B2, with less going to landfill; this is shown in Figure 6.

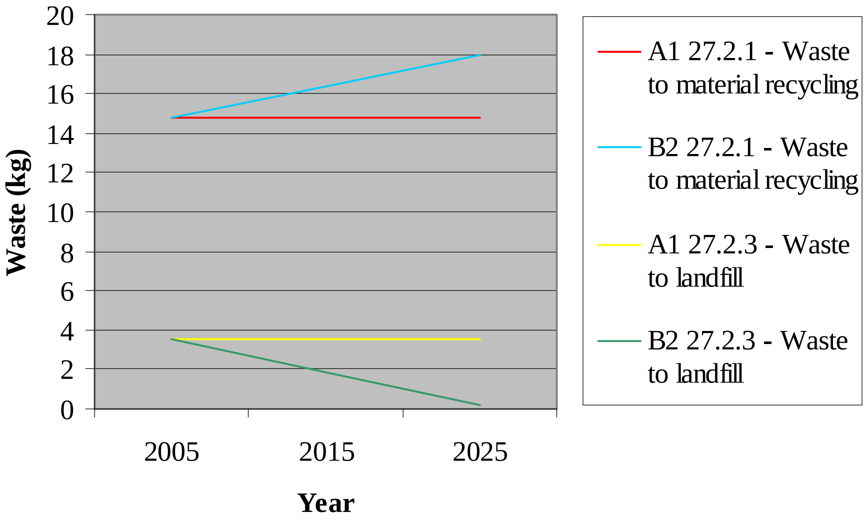

Figure 6 – Decreasing volume of waste going to landfill and increasing volume of waste being recycled

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

Curtain and spray coating are non-contact coating methods which give smooth coating surface and good printing properties of paper. Multilayer coating can be produced with low amounts of waste and effective, simultaneous drying of all coating layers. Non-contact coating causes less web-breaks in the paper machine and allows lower strengths for base-papers, which enables increased use of recycled fibers in the base paper. Further descriptions and list of drivers on this technology can be found in PD 4.2.7 ‘*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*’.

This technology is currently in the industrial trial phase but is expected to be adopted by some small and medium enterprises by the year 2010 although it is not expected to be generally adopted before the year 2025 as shown in Figure 7.

Region	Expected Time	2005	2010	2015	2020	2025
Western / Central Europe	Research & Development phase					
	Industrial Trials	▨				
	Adopted In some SME’s		▨	▨	▨	▨
	Generally Adopted					

Figure 7 - Changes in use of existing coating techniques for paper and boards future uptake

Practical consequences of implications:

- Both coating technologies are non-contact technologies, which will decrease the amount of web breaks and allow weaker base papers to be used. Fewer web breaks increase production amounts of a mill, increase profitability and create better compatibility.
- A non-contact coating technology allows fibres of lower quality to be used. As a consequence, share of recycled fibres and de-inked pulp may be increased. Mechanical pulping consumes high amounts of energy, so if some of mechanical pulp can be replaced with DIP (de-inked paper), energy savings may be as a consequence of curtain coating implementation.
- Product properties will be improved since curtain coating creates better coverage and smoother paper than many other coating technologies. This might add some new end-use possibilities of coated paper, bringing new clients and increasing the profitability of the mill.
- Less waste is created in the paper machine, since curtain coating doesn’t have any equipment that would wear out quickly. This will decrease the waste disposal costs.
- Social acceptance of paper might be improved with this technology since recycled material can be used in greater amounts.

4.2 Cartonboard mill in Western Central Europe

Partner: KCPK
Region: Western Central Europe

Cartonboard mill fibre furnish consists of 30 % deinked paper (DIP), 50 % recycled paper and 20 % kraft pulp. Cartonboard is, in Western Central Europe, typically produced in a mill which is integrated to de-inking processes but non-integrated to virgin pulp. Kraft pulp is therefore purchased as market pulp. The fibre raw material input is therefore 80% recovered paper and 20% market pulp. The process yield is 0.88 of carbon, which means that 12% of incoming carbon in fibres (e.g. bark) is used for energy production in bark and sludge boilers. The economic, social and environmental indicators values shown in Table 2 are those which have been chosen as points of discussion[7].

Table 2 - Sustainability indicators for a Cartonboard mill in Western Central Europe for the reference futures A1 and B2 for 2015 and 2025[8]

	2005	A1 2015	A1 2025	B2 2015	B2 2025
2.1 - Production cost	411.84	403.53	413.46	398.88	395.28898
2.1.1 - Average cost - raw materials from FWC	176.88	230.09	256.67	224.55	234.22764
2.1.2 - Average cost - raw materials from outside FWC	84.48	88.76	85.5	89.39	86.146676
2.1.3 - Average cost - labour costs	26.4	28.97	30.73	28.98	31.0524
2.1.4 - Average cost - energy costs	66.88	53.55	39.74	53.15	40.565305
10.1 - Employment - absolute number	0.0004189	0.0004147	0.0003971	0.0004151	0.0004013
11.1 - Wages and salaries - total	15.8	21.2	27.2	19.3	23.1
12.1 - Occupational accidents - total	1.162E-05	7.39E-06	6.32E-06	7.40E-06	6.39E-06
12.1.1 - Occupational accidents (non-fatal) - absolute numbers	1.162E-05	7.39E-06	6.32E-06	7.40E-06	6.38E-06
18.2.1.2 - Energy use - Heat from fossil sources	3417.92	2793	2282	2793	2282
18.2.3.3 - Electricity use - from the grid	520.96	471	426	471	426
19.1 - Greenhouse gas emissions	2082.08	1751	1480	1751	1480
19.1.1. Greenhouse gas emissions from machinery	1812	1481	1210	1481	1210
21.1 - Water use (freshwater intake by industry) [relevant for industry]	89	80	73	80	73
24.1.1 - Water pollution - organic substances (biochemical oxygen demand)	10	10	10	9	8
24.2.1 - Non-greenhouse gas emissions into air - CO	0.0176	0	0	0	0
24.2.2 - Non-greenhouse gas emissions into air - NOx	0.02112	0	0	0	0
27.1.2 - Hazardous waste	0.352	0	0	0	0
27.2.1 - Waste to material recycling	73.04	73	73	81	89
27.2.3 - Waste to landfill	59.84	60	60	52	44

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[7] The full table provided by KCPK can be found in Appendix C; Table 14.

[8] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

The EFI-GTM run suggests that production costs of cartonboard in WCE are not changing too much in the different reference futures although there is a slight decrease in most cases and only a small increase in A1 2025. Some of the different components of the production costs do however show large changes. We see a vast increase in raw material costs (from within FWC) in all futures and the largest increase in A1 (2025) as seen from Figure 8.

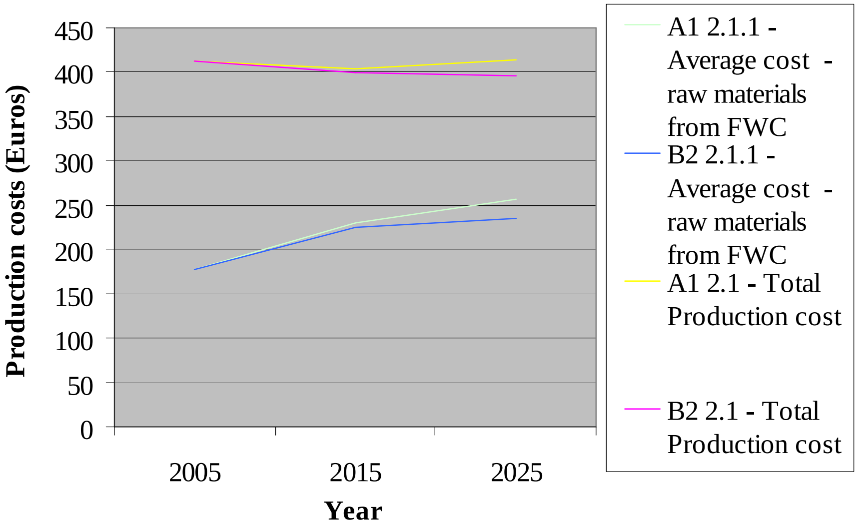

Figure 8 - The changing costs in production[9]

Figure 9 highlights the decrease in employment per ton of product due to increased labour productivity in all reference futures.

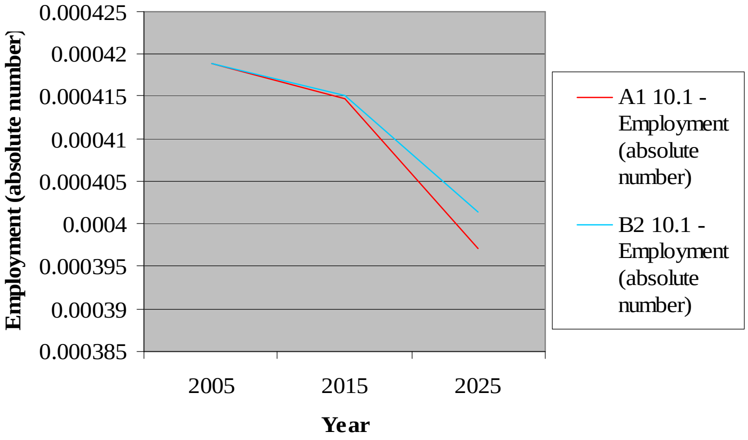

Figure 9 – Decreasing future employment figures

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[9] Note: this is not an official Pöyry forecast - the prices are based on the scenario descriptions and related numbers received from EFI-GTM

Figure 10 shows the increase in wages and salaries for all reference futures with a greater increase shown under the conditions of the A1 reference future.

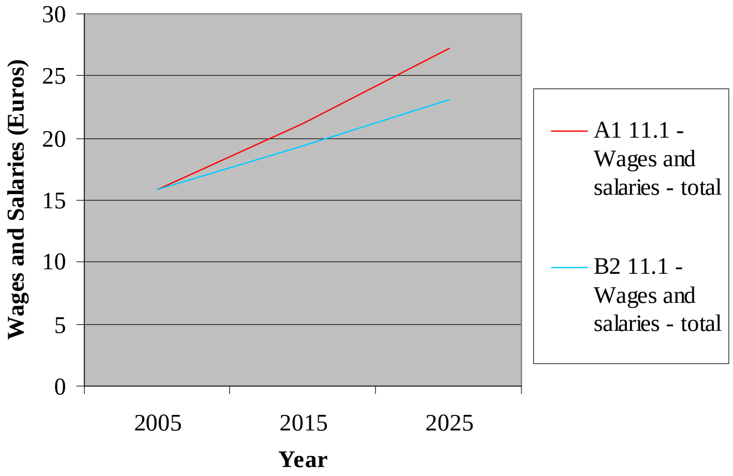

Figure 10 - Increasing future wages

The EFI-GTM run also estimates that the number of non-fatal accidents is decreasing in all future scenarios, and as the number of fatal accidents is already very low in 2005 it will remain at this low incidence level. The response factors anticipate a yearly increase in energy efficiency. This will enable less electricity to be purchased and less fossil fuel to be used for heat production. Energy costs and greenhouse gas emissions will be decreased because of this as shown in Figure 11. In addition to this NO_x and SO_2 emissions to air will be decreased because of lower energy consumption.

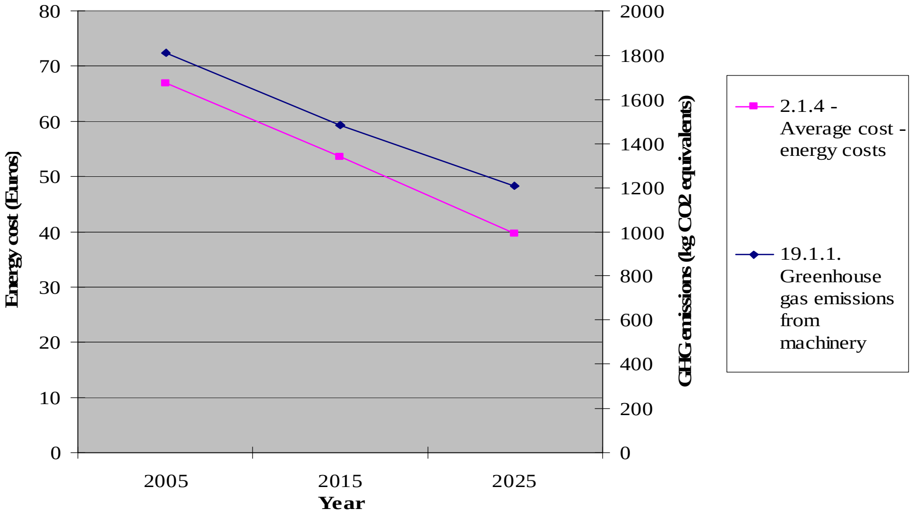

Figure 11 – The decreasing energy costs and greenhouse gases due to energy efficiency[10]

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[10] Note: this is not an official Pöyry forecast - the prices are based on the scenario descriptions and related numbers received from EFI-GTM

Water consumption is likely to decrease yearly, but in reference future A1 there will be similar amounts of water pollution than in year 2005. In reference future B2, more attention will be given to environmental topics and thus also emissions to water can be expected to decrease slightly.
The amount of waste will remain similar, but as recycling rate will increase in reference future B2 and the amount of waste sent to landfill will decrease, as shown in Figure 12.

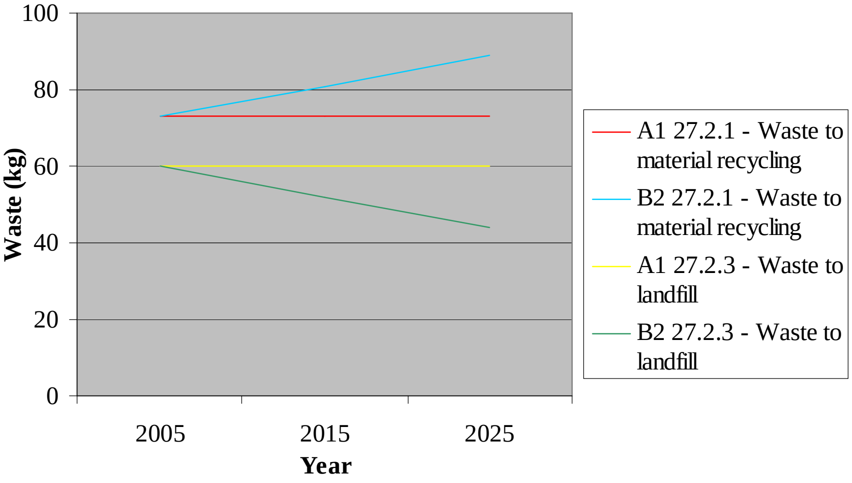

Figure 12 – The changing volumes of waste in futures A1 and B2

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. Further descriptions and list of drivers on this technology can be found in PD 4.2.7 *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*

This technology is currently in the research and development stage, there are currently industrial trials on this technology. It is expected to be adopted in some small and medium enterprises by 2010 and is expected to be generally adopted by the year 2015 as shown in Figure 13.

Region	Expected Time	2005	2010	2015	2020	2025
Western / Central Europe	Research & Development phase	▨				
	Industrial Trials	▨				
	Adopted In some SME's	▨	▨			
	Generally Adopted			▨	▨	▨

Figure 13 -Alternative wires for recovered paper future uptake

Practical consequences of implications:

- Production costs –waste disposal costs will be decreased, due to lighter weight of waste materials (metal vs. plastic/paper).
- Decrease of waste (tons) due to lighter weight of waste materials (metal vs. plastic/paper).
- Less waste to landfill.
- Prevention of accidents with springing metal wires will reduce overall accident rate.

4.3 Cartonboard mill in Baden-Württemberg

Partner: Pöyry
Region: Baden-Württemberg

The mill analysed here is a cartonboard model mill situated in Central-Europe. The main raw materials of the mill are deinked, recycled paper based pulp (DIP) 30%, non-deinked recycled paper based pulp 50% and kraft pulp 20%. The deinking process is integrated in the cartonboard mill, where as the kraft pulp used is market pulp.

The main product of the mill is white lined chipboard (WLC), sometimes also called "recycled / recovered boxboard". In this model mill the WLC has the top layer made from bleached kraft pulp, the middle layers are non-deinked recycled pulp and the back layer is made from DIP. The top surface has three layers of white pigment coating and on the reverse there is also a layer of pigment coating. Thanks to the pigment coating on the top surface of the boxboard, WLC has excellent printing properties.

The traditional role of boxboard is to protect the packed product. In addition, the box has an important role in sales promotion and branding. WLC is used in several applications, for example packing frozen food, cereals, shoes, toys etc. The economic, social and environmental indicators values shown in Table 3 are those which have been chosen as points of discussion.[11]

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[11] The full table provided by Pöyry can be found in Appendix C; Table 15.

Table 3 - Sustainability indicators for a Cartonboard mill in Baden-Württemberg for the reference futures A1 and B2 for 2015 and 2025[12][13]

	2005	A1 2015	A1 2025	B2 2015	B2 2025
1.1 - Gross value added	83	123	91	122	87
2.1 - Production cost	412	404	414	399	395
2.1.1 - Average cost - raw materials from FWC	177	230	257	225	234
2.1.2 - Average cost - raw materials from outside FWC	85	89	86	89	86
2.1.3 - Average cost - labour costs	26	29	31	30	31
2.1.4 - Average cost - energy costs	67	54	40	53	41
2.1.5 - Other productive costs	28	27	27	27	27
18.2.1.2 - Energy use - Heat from fossil sources	3418	2793	2282	2793	2282
19.1 - Greenhouse gas emissions	2082	1751	1480	1751	1480
19.1.1. Greenhouse gas emissions from machinery	1812	1481	1210	1481	1210
24.2.1 - Non-greenhouse gas emissions into air – CO	0.018	0.014	0.012	0.014	0.012
24.2.2 - Non-greenhouse gas emissions into air – Nox	0,021	0,017	0,014	0,017	0,014
27.2.1 - Waste to material recycling	73	73	73	81	89
27.2.3 - Waste to landfill	60	60	60	52	44

The EFI-GTM run anticipates that in both reference future A1 and B2 the gross value added is higher than in year 2005. In the reference futures, production costs stay roughly on the same level, as can be seen in Figure 14 and the increase in value added originates from higher prices of WLC[14].

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[12] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

[13] Note: this is not an official Pöyry forecast - the prices are based on the scenario descriptions and related numbers received from EFI-GTM

[14] Note: this is not an official Pöyry forecast - the prices are based on the scenario descriptions and related numbers received from EFI-GTM

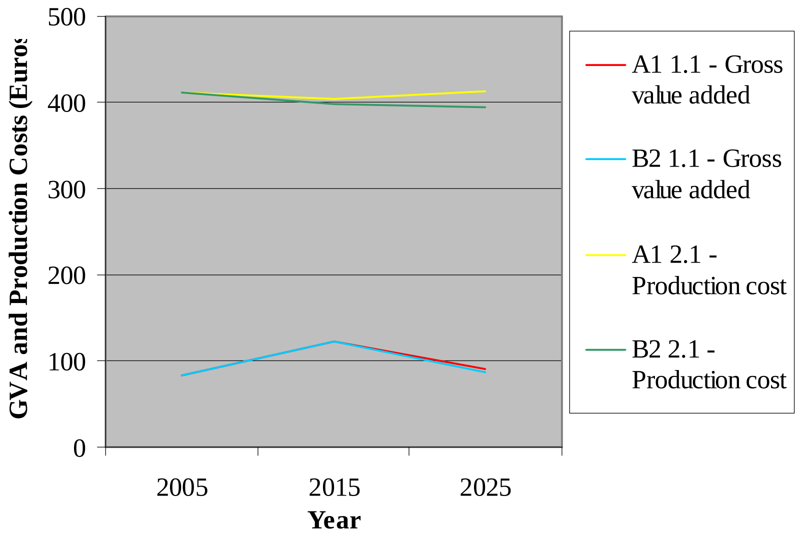

Figure 14 – Changing GVA and production costs in both futures[15]

The response factors show that in the reference future B2 the emissions to water (BOD and nitrogen) are slightly lower than in A1. The waste to landfill values are also lower than in A1, thanks to increased material recycling in B2 as illustrated in Figure 15.

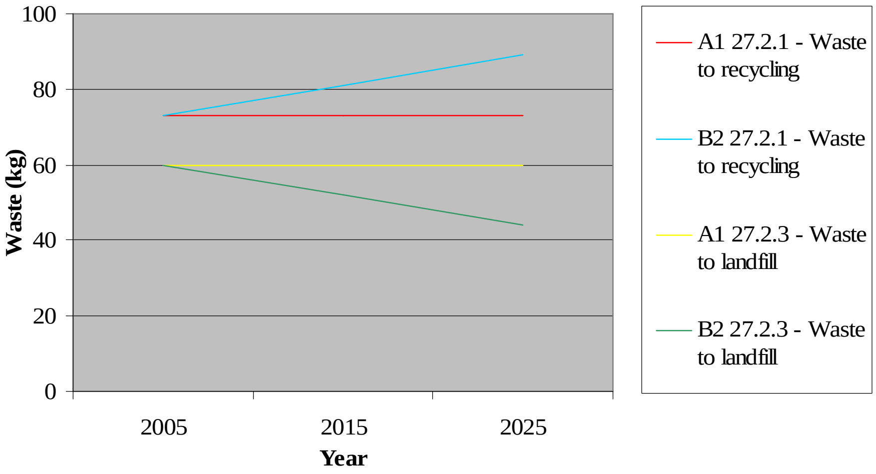

Figure 15 – The changing volumes of waste in A1 and B2 futures[16]

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[15] Note: this is not an official Pöyry forecast - the prices are based on the scenario descriptions and related numbers received from EFI-GTM

[16] Note: this is not an official Pöyry forecast - the prices are based on the scenario descriptions and related numbers received from EFI-GTM

4.3.1 Recovered paper sorting and quality control by sensor development

The use of sensor technology for sorting of recovered paper 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. Further descriptions and list of drivers on this technology can be found in PD 4.2.7 *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.*

This technology is currently overlapping between the research and development stage and the industrial trial stage with some SME's already having adopted this technology. Over the next 10 years the research and trials are anticipated to stop with the general adoption of this technology being expected around 2025. This expected uptake is shown in Figure 16.

Region	Expected Time	2005	2010	2015	2020	2025
Western / Central Europe	Research & Development phase	▨	▨			
	Industrial Trials	▨	▨	▨		
	Adopted In some SME's	▨	▨	▨	▨	
	Generally Adopted					▨

Figure 16 - Recovered paper sorting and quality control by sensor development future uptake

4.3.2 Production of secondary fuels from recovered paper industry rejects

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 (Source: KCKP, PD 4.2.7). 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). Further descriptions and list of drivers on this technology can be found in PD 4.2.7 '*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*'

This technology is currently adopted by some SME's and is expected to be generally adopted by the year 2015 as shown in Figure 17.

Region	Expected Time	2005	2010	2015	2020	2025
Western / Central Europe	Research & Development phase					
	Industrial Trials					
	Adopted In some SME's	▨	▨			
	Generally Adopted			▨	▨	▨

Figure 17 – Production of secondary fuels from recovered paper industry rejects future uptake

Below a rough estimation of the technologies, if applied together, is given:
Effects on social indicators:

- The improved sorting technology can reduce employment, due to further automation of manual sorting.
- On the other hand, someone would have to take care of the secondary fuel production, so the net effects on employment can be either slightly positive or slightly negative.

Effects on environmental indicators:

- Both improved paper sorting technology and production of secondary fuels from rejects would increase material efficiency and decrease waste generation. In the values presented in table above, the amount of landfilled waste is estimated to remain constant from 2005 until 2025, so the use of these technologies would improve the situation.
- The use of industry rejects as a fuel reduced use of fossil fuels and emissions of fossil CO2. The values for reference future A1 as such, presented in the Table 3 show a similar pattern so the use of these technologies would further enhance the development.

Effects on economic indicators:

- Investments needed for these technologies would increase the capital costs of the mill.
- The mills production costs would decrease:
  - Landfill costs would decrease.

  - Raw material costs could decrease due to more efficient use of them. In the original reference future A1 values, the cost of wood based raw materials would rise.
  - Labour costs could either decrease or increase slightly. In the values presented in table above, labour costs are estimated to increase from 2005 to 2025
- In addition, the mill might get more sales if it sells the secondary fuels or the fuels could be used in onsite energy generation. However, the decrease in future energy costs, based on the background data of reference future A1 and EFI-GTM data is already now estimated to be substantial.

4.4 Container Board (Kraft Liner) mill in Nordic Countries

Partner: INNVENTIA AB
Region: Nordic Countries

The container board is typically produced from unbleached kraft pulp produced in an integrated kraft liner mill. It consists of 100 % virgin softwood fibres. Some qualities are including a white top liner, typically bleached hardwood kraft pulp, often purchased. The process yield is 0.4 of carbon, which means that 60 % of incoming carbon is used for energy production. The economic, social and environmental indicators values shown in Table 4 are those which have been chosen as points of discussion[17].

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[17] The full table provided by INNVENTIA AB can be found in Appendix C; Table 16.

Table 4 - Sustainability indicators for a Container Board (Kraft Liner) mill in Nordic Countries for the reference futures A1 and B2 for 2015 and 2025[18]

	2005	A1 2015	A1 2025	B2 2015	B2 2025
18.2.3.3 - Electricity use - from the grid	255	231	209	231	209
19.1 - Greenhouse gas emissions	493	481	472	481	472
19.1.1. Greenhouse gas emissions from machinery	63	51	42	54	42
21.1 - Water use (freshwater intake by industry) [relevant for industry]	17	15	14	15	14
24.1.1 - Water pollution - organic substances (biochemical oxygen demand)	1.4	1.4	1.4	1.4	1.2
24.1.2 - Water pollution - nutrients (nitrogen, phosphorus) as Nitrogen or TKN (Total KJELDAHL Nitrogen)	0.12	0.12	0.12	0.12	0.10
24.2.2 - Non-greenhouse gas emissions into air - NOx	0.36	0.29	0.24	0.29	0.24
24.2.3 - Non-greenhouse gas emissions into air - SO2	0.18	0.15	0.12	0.15	0.12
27.2.1 - Waste to material recycling	14.6	14.6	14.6	16.1	17.8
27.2.3 - Waste to landfill	7	7	7	5.5	3.8

According to the response factors energy efficiency is expected to slightly increase every year. This will enable less electricity to be purchased and fewer fossil fuels to be used for heat production and therefore greenhouse gas emissions will be decreased, as shown in Figure 18. Additionally NO_x and SO_2 emissions to air will be decreased because of the lower energy consumption.

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[18] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

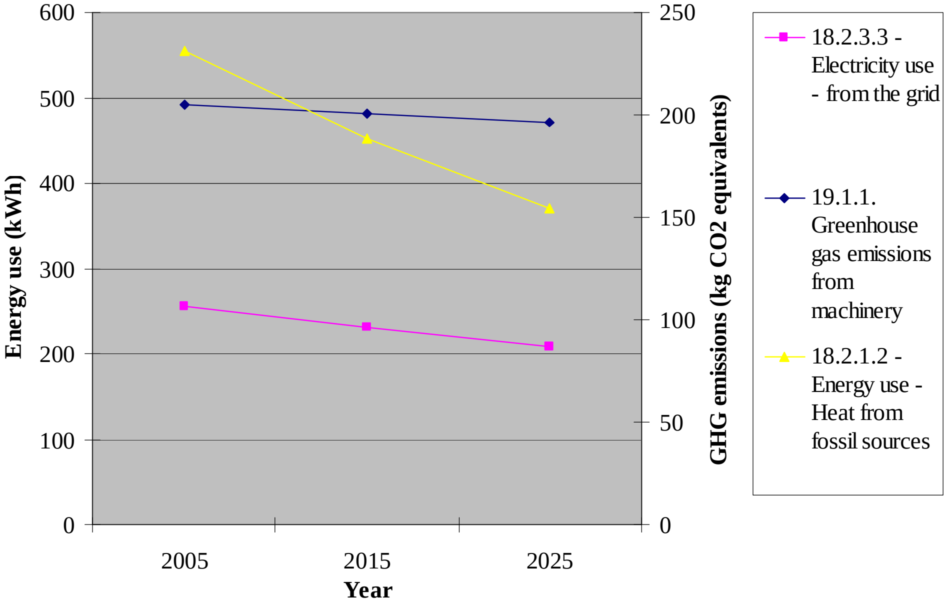

Figure 18 - The decreasing energy use and greenhouse gas emissions

Water consumption is also likely to decrease yearly, but in reference future A1 there will be similar amounts of water pollution than in year 2005. In reference future B2, more attention will be given to environmental topics and thus also emissions to water can be expected to decrease slightly as shown in Figure 19.

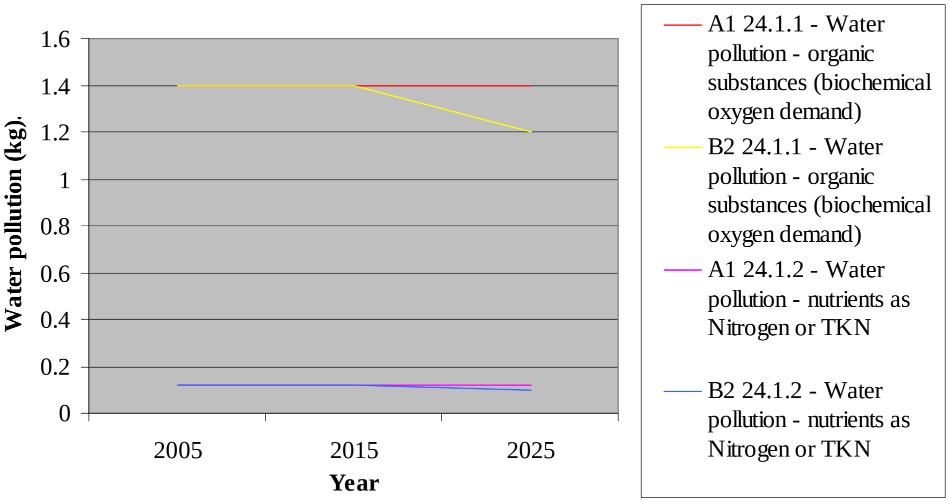

Figure 19 – The changing levels of water pollution in futures A1 and B2

It is anticipated that the amount of waste will remain similar; however, the recycling rate will increase in reference future B2 as demonstrated in Figure 20.

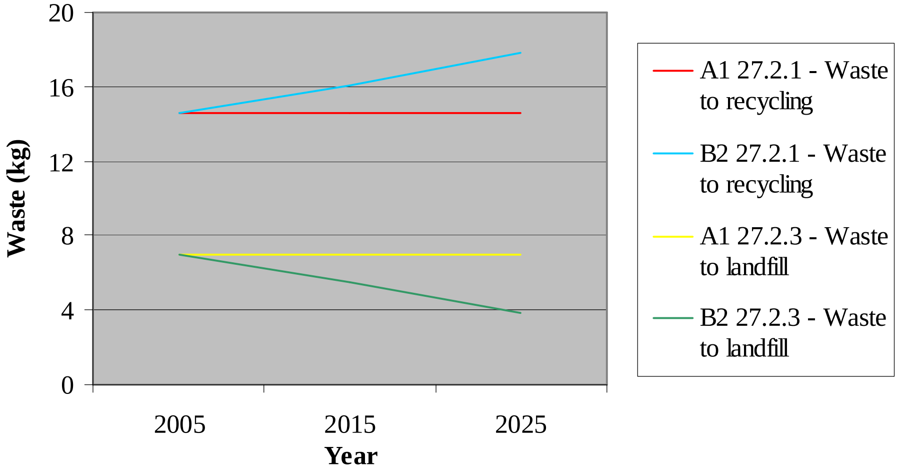

Figure 20 – The changing volumes of waste in futures A1 and B2

4.4.1 Improved drying technology; High intensity driers & impingement drying

Improved drying technology by using high intensity driers and impingement drying are technologies which are expected to 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 continue to be further tested. Further descriptions and list of drivers on this technology can be found in PD 4.2.7 *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.*

This technology is currently in the phase of industrial trials and is expected to be adopted by some SME's by 2015 with a general adoption occurring by 2025 as shown in Figure 21.

Region	Expected Time	2005	2010	2015	2020	2025
Western / Central Europe	Research & Development phase					
	Industrial Trials	▨	▨			
	Adopted In some SME's			▨	▨	
	Generally Adopted					▨

Figure 21– Improved drying technology; High intensity driers and impingement drying future uptake

Practical consequences of implications:

- Production costs – especially energy costs will be decreased, since the drying section will become more efficient. This will improve the profitability of the mill, and bring compatibility advance to those mills that can afford to implement the technology.

- Decreased energy consumption will decrease the emissions to air, since less on-site heat production is needed. This may also affect the amount of solid waste, since ash from boilers is one of the main waste fractions from a mill.
- Waste disposal costs may thus decrease as a consequence.
- Social aspects should not be affected by this technology.
- In some cases, drying of board can be a bottleneck in the production speed. Since this technology increases the drying efficiency, it might be possible to increase the production speed and increase the profitability of the mill.
- Space requirements will decrease, since there is a possibility to shorten the drying section of the board machine. This is particularly important when new mills are built: Decrease in space requirement might counteract to the investment costs of the technology.

4.5 Pellet Mill in Scandinavia

Partner: VTT
Region: Scandinavia

Wood pellets are cylindrical products (D=6-12 mm, length max. 4*D), pressed, for example, from saw dust. The binder is the natural lignin from the wood. Energy content ~ 4.7 MWh/t, moisture content ~10 % and density 0.65 t/i-m^3. Ash content 0.5 – 3 %. The process yield is 1.0 of carbon, which means that 100 % of incoming carbon in raw material (saw dust or chip) is used for the end product. The indicator values displayed in Table 5 have been calculated per ton of carbon input.

The main process stages of pellet production are crushing, drying, pelletising cooling and storage. A drying stage (high energy consumption and additional investment costs) is needed for wet raw material. As the resources of “traditional” raw material such as dry and wet saw dust (saw mill by-products) are very limited, pellet production must introduce new raw materials such as wood chip and possibly even forest residue. The model calculations for 2025 expect 50 % of the raw material to include higher ash content than traditional saw dust. This means that some of the pellets produced have higher ash content than saw dust pellets and can only be used in larger boilers.

The economic, social and environmental indicators values shown in Table 5 are those which have been chosen as points of discussion[19].

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[19] The full table provided by VTT can be found in Appendix C; Table 17.

Table 5 – Sustainability indicators for a Pellet mill in Scandinavia for the reference futures A1 and B2 for 2015 and 2025[20]

	2005	A1 2015	A1 2025	B2 2015	B2 2025
1.1 - Gross value added	202	157	93	169	112
2.1 - Production cost	241	423	559	384	471
2.1.1 - Average cost - raw materials from FWC	120	238	340	208	279
2.1.3 - Average cost - labour costs	17	20	23	18	19
2.1.4 - Average cost - energy costs	31	78	93	75	80
2.1.5 - Other productive costs	51	49	53	48	50
2.1.6 - Non-productive costs	22	38	51	35	43
10.1 - Employment - absolute number	0.0005291	0.0004629	0.0004115	0.0004629	0.0004115
11.1 - Wages and salaries - total	8.5	10	11.5	9	9.5
12.1 - Occupational accidents - total[21]	1.47E-05	8.16E-06	6.48E-06	8.16E-06	6.48E-06
12.1.1 - Occupational accidents (non-fatal) - absolute numbers	1.47E-05	8.16E-06	6.47E-06	8.16E-06	6.47E-06
12.1.2 - Occupational accidents (fatal) - absolute numbers	5.03E-09	4.45E-09	4.13E-09	4.44E-09	4.09E-09
18.2 - Energy use	788	1728	1846	1728	1846
18.2.1.1 - Energy use - Heat from renewable sources	1880	5080	5400	5080	5400
18.2.1.2 - Energy use - Heat from fossil sources	3698	3022	2469	3022	2469
18.2.3.3 - Electricity use - from the grid	244	296	324	296	324

Raw material price and pellet market price is assumed to change (grow) much faster than oil price because of increasing carbon emission costs. We assume carbon emission cost of 80 e/t 2025 in A1 and 60 e/t in B2 in this model calculation. Total production costs are expected to decrease due to increasing raw material costs and energy costs, as demonstrated in Figure 22.

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[20] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

[21] Indicator group 12 have been evaluated very roughly using the same accident frequencies per employer as for Coated woodcontaining paper in Western Central Europe

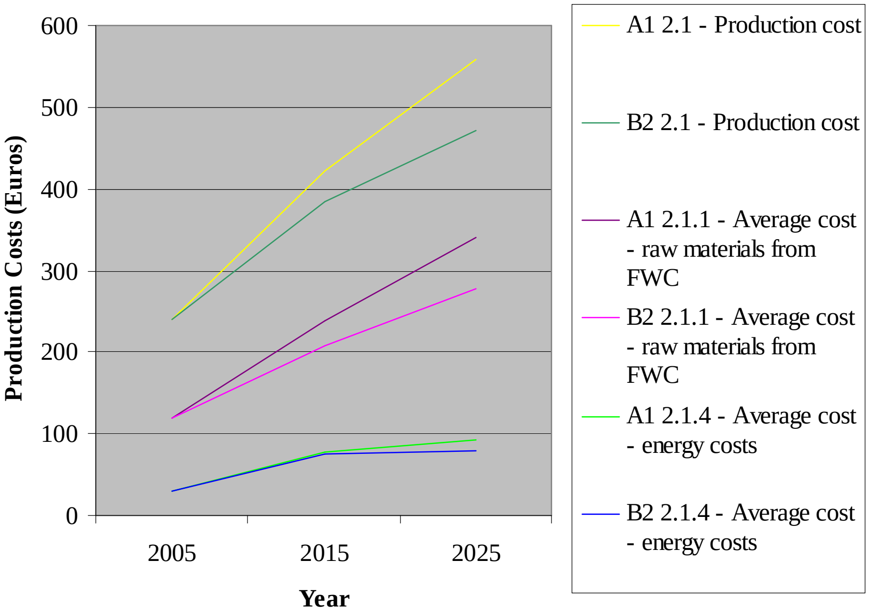

Figure 22 – The increasing cost of production due to material and energy costs

These drastically rising costs, and the assumption that they are increasing at a faster rate than pellet market prices increase, attribute to the decreasing gross value added to the product, as highlighted in Figure 23. In addition to this the energy efficiency for the drying process is expected to slightly increase (10 % until 2015, 20 % until 2025).

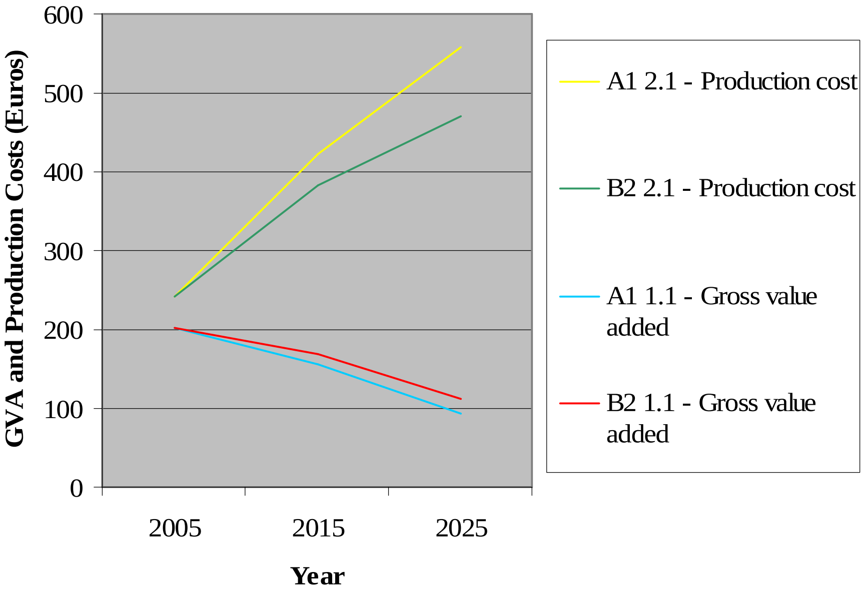

Figure 23 – The decreasing GVA due to increasing production costs

4.5.1 Pellet production from new raw material

The resources of dry saw dust (forest industry by-products) are very limited. To increase pellet production, utilisation of wet saw dust as well as introduction of completely new raw materials will be needed. The first and presently ongoing development is implementing a drying step to the pellet plant to be able to use wet saw dust in the process. When the supply of this additional raw material is in use completely new raw material are 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 (e.g. 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. Further descriptions and list of drivers on this technology can be found in PD 4.2.7 *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*.

This technology is currently in the phase of both research and development alongside industrial trials in the region of Scandinavia. Its adoption to some SME'S is expected by 2010 with a general adoption occurring in 2020 however this technology is expected to be continually developed and tested at least until 2025 as shown in Figure 24.

Region	Expected Time	2005	2010	2015	2020	2025
Scandinavia	Research & Development phase	▨	▨	▨	▨	▨
	Industrial Trials	▨	▨	▨	▨	▨
	Adopted In some SME's		▨	▨	▨	▨
	Generally Adopted				▨	▨

Figure 24 – Pellet production from new raw material future uptake Figure 8

Practical consequences of implications:

- Energy consumption (especially heat) will dramatically grow.
- The incoming raw material flow (wet tonnes) will increase by 50 % for the chosen process unit until 2025.

4.6 Parquet and glued boards in Eastern Europe

Partner: TUZVO
Region: Eastern Europe

In this case study the company produces parquet and glued boards. The production of parquet starts with pre-prepared beech sawn wood that is by pressing and surface finishing changed to parquet. For 1 m^2 we need 0.2 m^2 of sawn wood. The basic production takes 0.35 hour per m^2. In case of boards chips are pressed to 50 mm thick board. The press is heated by gas. The figures are in millions of. €, energy is in kWh. The economic, social and environmental indicators values shown in Table 6 are those which have been chosen as points of discussion.[22]

Table 6 - Sustainability indicators for the production of parquet and glued boards in Eastern Europe for the reference futures A1 and B2 for 2015 and 2025

	2005	A1 2015	A1 2025	B2 2015	B2 2025
18.2 - Energy use	110.5	110.5	110.5	110.5	110.5
18.2.1.1 - Energy use - Heat from renewable sources GWh	0	33.4	33.4	26.2	27.8
18.2.1.2 - Energy use - Heat from fossil sources GWh	82.3	48.6	49.5	56.1	56.4

As the prices of gas steadily increases, the new technology will replace gas for the heating of chips by wooden dust, as illustrated in Figure 25. This means savings in gas costs but a small increase of electric energy costs. The only exception will be in winter when there may be a shortage of dust and it will be necessary to heat with gas.

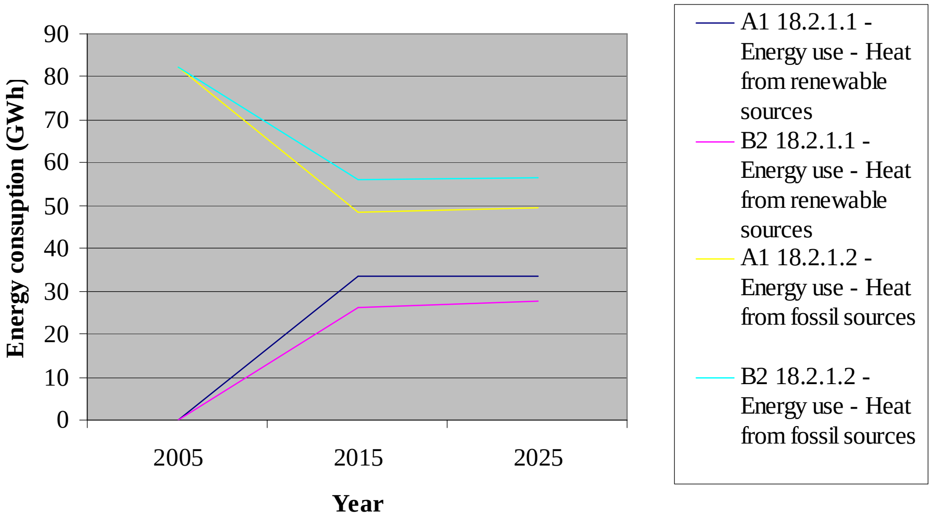

Figure 25 - The changing volumes of energy consumption in A1 and B2 futures

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[22] The full table provided by TUZVO can be found in Appendix C; Table 18.

4.7 Softwood Saw Mill (Large) in Baden-Württemberg

Partner: BRE
Region: Baden-Württemberg

A large softwood sawmill can be described as one which has a capacity of greater than 150,000 m^3 per year. Within the region of Baden-Württemberg the raw materials transported to the saw gate are short spruce logs. During this process the round wood is generally debarked, chipped, sawn, dried and graded. The sawing process generally produced output in the proportions of 30% chips, 10% dust, 5% wood residues and the remaining 55% being utilised as sawn timber as desired. The economic, social and environmental indicators values shown in Table 7 are those which have been chosen as points of discussion[23]. The indicator values given have been calculated per m^3 of output sawn timber.

Table 7 – Sustainability indicators for a large softwood sawmill in Baden-Württemberg for the reference futures A1 and B2 for 2015 and 2025[24]

	2005	**A1 2015**	**A1 2025**	**B2 2015**	**B2 2025**
1.1 - Gross value added	9	164.7	168.5	187.7	202.1
2.1 - Production cost	77.5	38.1	39.7	42.3	47.1
2.1.1 - Average cost - raw materials from FWC	63	62.0	65.2	70.3	79.8
2.1.3 - Average cost - labour costs	7	7.4	7.6	7.4	7.7
2.1.4 - Average cost - energy costs	1.5	1.4	1.2	1.4	1.2
18.2 - Energy use	4878.65	4671.99	4501.88	4671.997	4501.882
18.2.1.1 - Energy use - Heat from renewable sources	13236.02	13236.02	13236.02	13236.02	13236.02
18.2.1.2 - Energy use - Heat from fossil sources	720.72	588.88	481.16	588.88	481.16
18.2.2.2 - Energy use - Direct fuel use - fossil fuel	3061.24	2501.26	2043.71	2501.26	2043.71
18.2.3.3 - Electricity use - from the grid	151.433	136.95	123.85	136.95	123.85
19.1 - Greenhouse gas emissions	128.039	104.61	85.48	104.61	85.48
27.1 - Generation of waste in total	380.24	343.88	311.00	343.88	311.00
27.1.1 - Not classified as hazardous waste	349.82	316.37	286.12	316.37	286.12
27.1.2 - Hazardous waste	30.42	27.51	24.88	27.51	24.88
27.2.1 - Waste to material recycling	7.60	316.37	286.12	316.37	286.12
27.2.3 - Waste to landfill	342.2	0	0	0	0

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[23] The full table provided by BRE can be found in Appendix C; Table 19

[24] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

Due to the strict landfill policy that has already been introduced in Germany there will be no waste sent to landfill in either A1 or B2 futures. Instead waste material, which overall is decreasing, will now be diverted away from landfill towards recycling as illustrated in Figure 26.

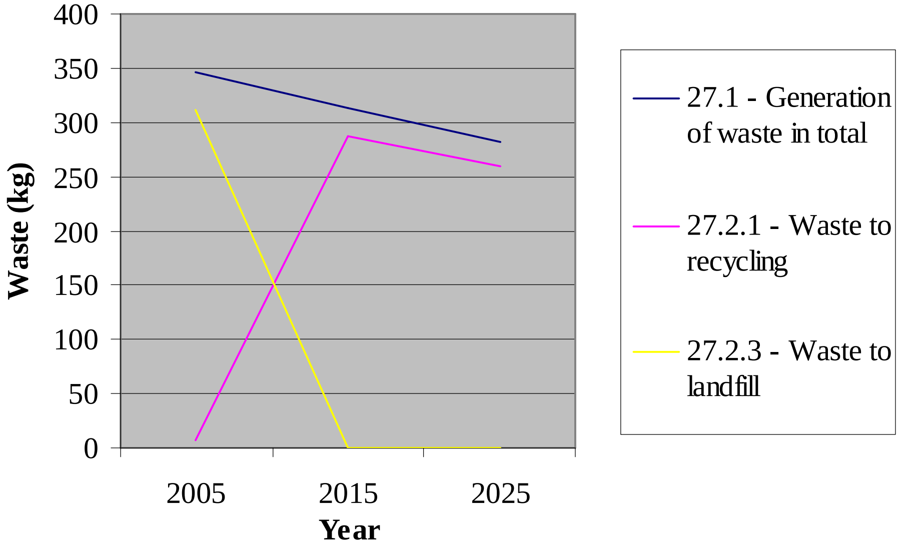

Figure 26 - Changes in volume of waste in futures A1 and B2

Energy consumption from fossil fuels will also decrease in both futures due to increasing energy efficiency and a greater environmental awareness, which will in turn create a decrease in greenhouse gas emissions as highlighted in Figure 27.

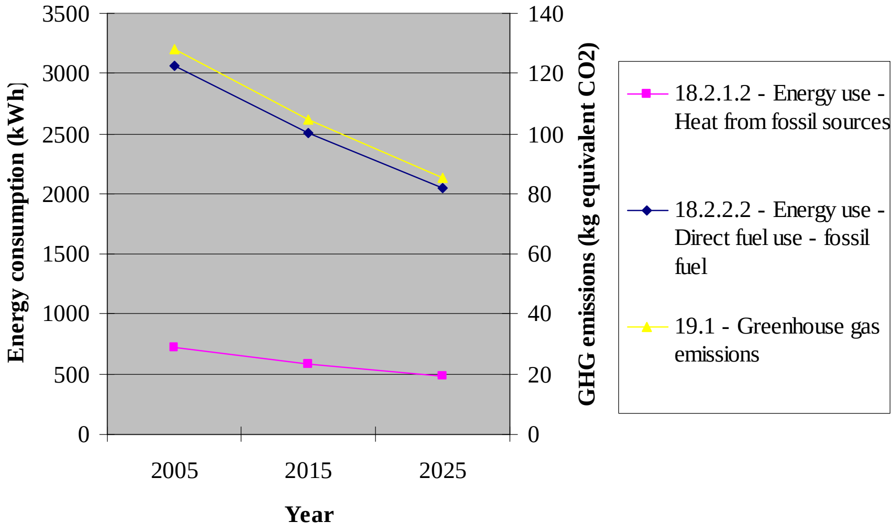

Figure 27 – The decreasing levels of fossil fuel consumption and therefore greenhouse gas emissions

Total production costs are expected to decrease in both futures, although more so in A1 due to the faster rates of technological development. The cheap raw material being imported into Europe in the A1 future, compared to the high raw material prices in B2 also contribute to the lower productions costs in A1 shown in Figure 28. Figure 28 also indicates the increasing GVA for softwood sawn timber in Baden-Württemberg. According to the EFI-GTM runs these increases are based on the price of sawn timber that is estimated to rise and, due to increased productivity, the decreasing production cost elements.

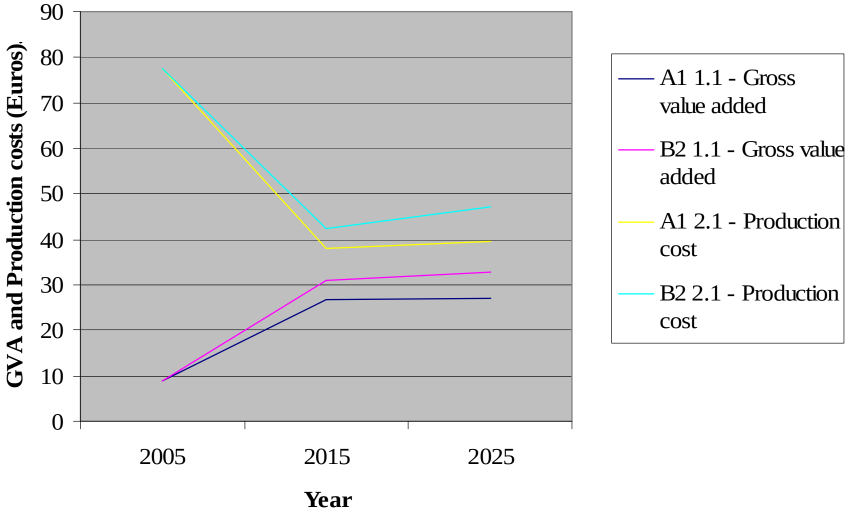

Figure 28 - Changing values of GVA and production costs

4.7.1 Acetylated wood

Acetylated wood is timber which has been treated with acetic acid altering the wood’s chemical structure, resulting in improvements in its durability, stability and resistance to insects and fungi. This enables the timber to withstand increased humidity and improve performance in exterior use. Further descriptions and list of drivers on this technology can be found in PD 4.2.7 *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.*

This technology in Baden-Wurttemberg is currently at the stage where it has been adopted by some SME’s. It is expected to be generally adopted in this region by 2010 as shown in Figure 29.

Region	Expected Time	2005	2010	2015	2020	2025
Scandinavia	Research & Development phase					
	Industrial Trials					
	Adopted In some SME’s	▨				
	Generally Adopted		▨	▨	▨	▨

Figure 29 – Acetylated wood future uptake

This timber modification would however potentially affect several of the indicators considered by ToSIA. Environmental indicators, such as energy use, would immediately increase as the moisture content of the timber needs to be low, and higher temperatures result in faster chemical reaction times. The majority of reactions of acetic anhydride with wood are thermally assisted. Research, however, also outlined that microwave heating might be used in the production of acetylated wood in order to reduce reaction times, improve the distribution of the bonded reagent within the wood and achieve more efficient removal of process chemicals and by-products from the timber[25]. If microwave heating was used to deliver energy this would dramatically increase energy consumption in sawmills.

In terms of social indicators, workers within sawmills would now be working with increased temperatures and numerous chemicals involved in the process of acetylation. Consequently, the likelihood of increase or changes of character of occupational accidents can be anticipated. Gross value added would also increase with the manufacturing of acetylated wood, along with production costs due to the increase in energy used and the cost of chemicals involved in the process.

The use of chemicals in the production of acetylated wood would also increase the volume of emissions produced by sawmills. Whether these chemicals would be emitted via water, air or be classed as hazardous waste the pollution levels and emissions from sawmills would undoubtedly increase.

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[25] Hill, Callum A.S. (2006) Wood Modification, Chemical, Thermal and Other Process, Wiley

4.8 *Value added wooden components in Western Central Europe*

Partner: VTT
Region: Western Central Europe
Value added wooden components are sawn timber products with specific quality requirements which are defined by individual customers. Requirements concern dimensions, knottiness, density, annual ring width etc. Components are produced in sawmills with sophisticated, flexible manufacturing processes including ICT- based planning and control systems like machine vision. Components are typically used in furniture and joinery industry and also in construction industries. The economic, social and environmental indicators values shown in Table 8 are those which have been chosen as points of discussion.[26] The indicator values are calculated per m^3 of logs.

Table 8 – Sustainability indicators for a the production of value added wooden components in Western Central Europe for the reference futures A1 and B2 for 2015 and 2025[27]

	2005	A1 2015	A1 2025	B2 2015	B2 2025
1.1 - Gross value added	18.877	17.563	13.202	21.340	18.324
2.1 - Production cost	48.545	52.015	58.147	57.043	66.193
2.1.1 - Average cost - raw materials from FWC	38.110	40.352	45.164	45.509	53.615
2.1.2 - Average cost - raw materials from outside FWC	0.000	0.000	0.000	0.000	0.000
2.1.3 - Average cost - labour costs	5.699	7.210	8.669	6.594	7.478
2.1.4 - Average cost - energy costs	0.819	0.842	0.771	0.825	0.769
2.1.5 - Other productive costs	3.918	3.612	3.543	4.115	4.331
2.1.6 - Non-productive costs	0.000	0.000	0.000	0.000	0.000
18.1 - On-site energy generation from renewables	36.82	36.82	36.82	36.82	36.82
18.1.1.1 - On-site heat generation from renewables - residues from process – inputs	132.56	132.56	132.56	132.56	132.56
18.2 - Energy use	170.23	151.60	135.76	151.60	135.76
18.2.1.1 - Energy use - Heat from renewable sources	477.21	477.21	477.21	477.21	477.21
18.2.3.3 - Electricity use - from the grid	37.67	34.02	30.78	34.02	30.78
19.1 - Greenhouse gas emissions	13.93	12.19	10.78	12.19	10.78
19.1.1. Greenhouse gas emissions from machinery	2.13	1.74	1.42	1.74	1.42

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[26] The full table provided by VTT can be found in Appendix C; Table 20.

[27] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

The price of the products is expected to decrease in the A1 reference futures. A radical drop, close to 25 %, can be seen between A1 2015 and A1 2025. Prices will be increased by 13 % between 2005 and B2 2015; however a clear drop is visible between B2 2015 and B2 2025, this is illustrated in Figure 30.

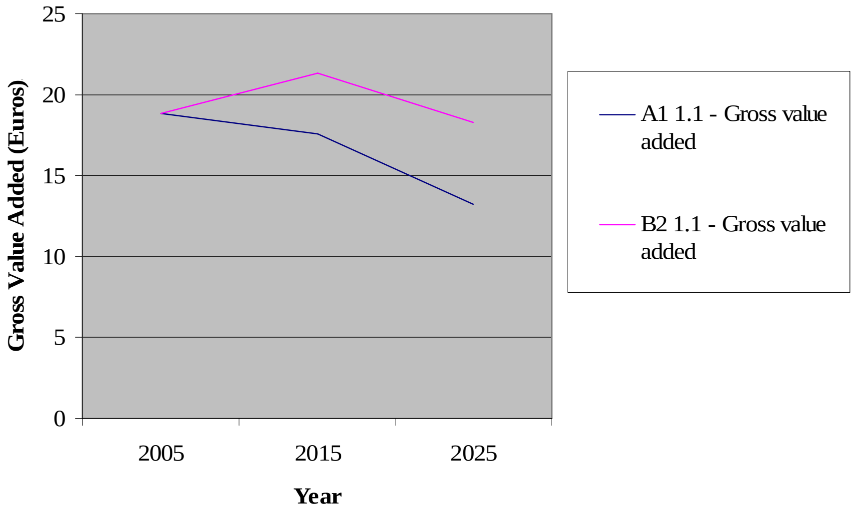

Figure 30 – Changing values of GVA

According to the EFI-GTM run production costs are estimated to increase in all reference futures compared to the year 2005 as shown in Figure 31. The biggest jump (36%) is between the reference futures B2 2025 and 2005. This is due to higher raw material prices and increase of labour costs.

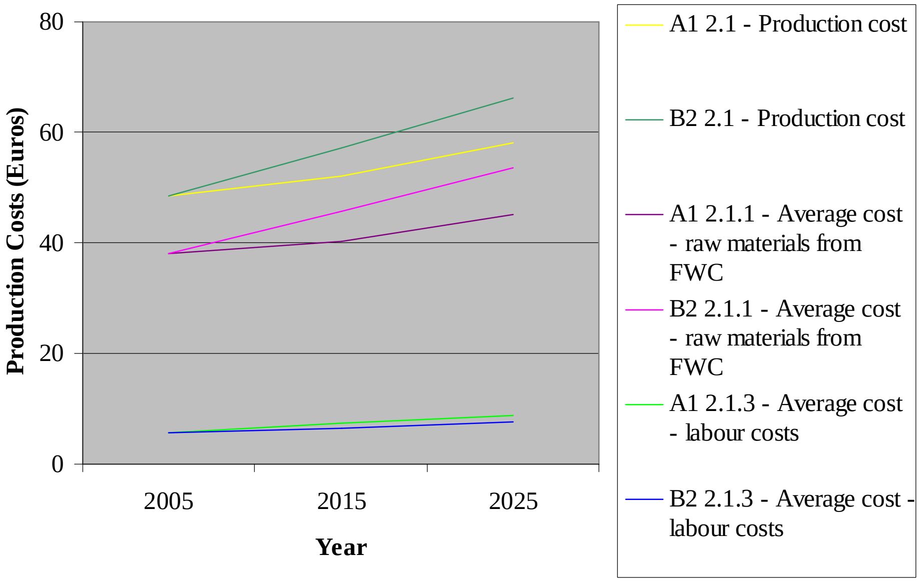

Figure 31 – The increasing production costs in futures A1 and B2.

On site heat generation from renewables – residues from process – will remain on the same level in all reference futures, and there will also be less energy in total used in the future compared to the year 2005 as shown in Figure 32.

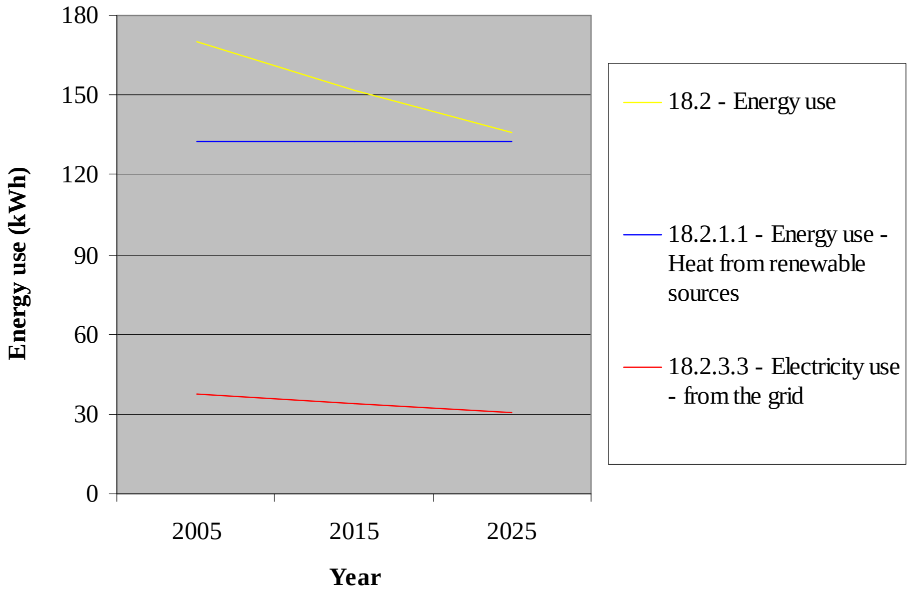

Figure 32 – The decreasing amount of energy consumed during production in future years.

Greenhouse gas emissions are expected to be reduced by 12 % in A1 2015 and B2 2015 compared to the year 2005, due to decreasing emissions from machinery. The corresponding value for A1 2025 and B2 2025 is 23 %, illustrated in Figure 33.

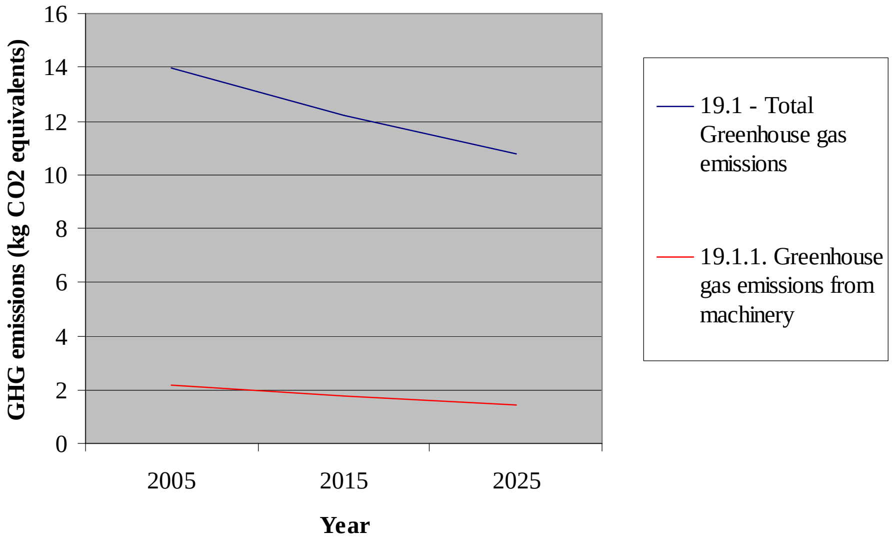

Figure 33 – The decreasing GHG emissions in future years.

4.8.1 X-Ray scanning for internal characterisation of round wood and sawn timber products

Scanners are based on x-ray technology combined with true shape data through laser applications. Depending on the systems configuration, scanners provide different levels of detailed information about knottiness, individual knots, density, annual ring orientation, and moisture content etc. Scanners can be implemented at log sorting stations, 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. Descriptions 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.
This technology in Western Central Europe is currently at the stage where it has been adopted by some SME's. It is expected to be generally adopted in this region by 2010 as shown in Figure 34.

Region	Expected Time	2005	2010	2015	2020	2025
Western / Central Europe	Research & Development phase					
	Industrial Trials					
	Adopted In some SME's	▨				
	Generally Adopted		▨	▨	▨	▨

Figure 34 - X-Ray scanning of internal properties of stems and logs future uptake

Practical consequences of implications:

- X-ray technology provides the possibility to see inside the log and stem just before sawing operation. Sawing set-ups and procedures can be established on prior sawing data, information and knowledge.
- Manufacturing processes will be more flexible and efficient. It will be possible to simultaneously produce value added components and standard products.
- Utilisation of wood raw material will be dramatically improved in terms of value of the final products. X-ray technology is also a data generator providing relevant data and information for planning of harvesting, production, production control and marketing.
- Properties of sawn timber products will be improved as sawing patterns can be optimised in order to produce more homogenous standard products and component products, with very specific quality characteristics. The volume of "falling products" will decrease considerable.
- Customer satisfaction will be improved dramatically as products can be ordered with specific properties. The variations of wood properties between wood species within a product class will decrease resulting in an increase in

homogenous classes. Values of sawn timber products will increase and thus also the prices.

- Less waste is produced due to new manufacturing processes. This will decrease wood flow from sawmills to pulp mills.
- Social acceptance of wood products will be improved with this technology due to the higher quality of the products.

5 Conclusions

The case studies presented in Chapter 4 outlined how and to what degree response factors impact sustainability indicators in the reference futures. Response factors for environmental indicators were based on industrial trends, statements from the industry and the descriptions of the reference futures (Chapter 2.3.2). This approach carries with it a number of generalisations and assumptions that have been introduced into the data and are being manipulated within ToSIA. However, whichever method partners used, uncertainties cannot be avoided due to the nature of predictions and forecasting.

The representativeness of the response factors is directly related to the level of their accuracy. It is important to note that within the scope of EFORWOOD no margins of error were introduced and collected as the aim of the project was not to provide statistically robust dataset, but to provide tools for sustainability assessment. To achieve this goal it was, however, essential to have the best available data in order to develop these tools in ‘real time’.

Table 9 highlights that even a 0.5% change in a response factor can lead to significant differences in reference future data. The first row shows a 2% increase per year, the second row an increase of 2.5% and the third row an increase of 3% per year. By the year 2025 indicator values generated differ by more than 15% due to a 0.5% change in the response factor. It is clear that inaccuracies can have a major influence on the results.

Table 9 - Example of how inaccuracies of response factors lead to large errors

Response Factor	**2005**	**2010**	**2015**	**2020**	**2025**
2.0 %	1000.000	1104.081	1218.994	1345.868	1485.947
2.5 %	1000.000	1131.408	1280.085	1448.298	1638.616
3.0 %	1000.000	1159.274	1343.916	1557.967	1806.111

Realistically, it can be assumed that there will be an increase in energy efficiency for all processes. The pace of these changes (i.e. response factors) has been estimated using trends in historic data sets and the initial descriptions of the two reference futures. Nevertheless, partners were very cautious in estimating the response factors as representativeness of these can not be taken for granted. In reality, greater changes could take place resulting in increased positive effects, more so than the EFORWOOD results might suggest; especially, if environmental issues continue to gain attention as suggested in the B2 reference future.

At the same time, changes in consumer behaviour and policies of national governments or EU representatives may not always include considerations for forest and forestry wood chain industries. If fossil fuels are to be replaced with biofuels, total greenhouse gases could potentially increase as the heat content of biofuels is lower than that of fossil fuels. Emissions from biofuels are often considered "neutral" as the carbon released during burning has been sequestrated to biomass. However, carbon sequestration in forestry can take up to 75 years and scientists are continuously working on mutual agreements on forestry sink methodology measurements. Deep seas, permafrost taiga and similar environments could have a major role to play in the carbon release or storage in the near future.

Definitions of 'biofuel' and biomass are also yet to be finalised on EU and member state level to cover certain national or international elements (e.g. black liquor). Furthermore, biomass may only include a short rotation crop, therefore, limiting the contribution from the forestry sector, or even a shift focus from wood biofuels to non-wood biofuels. This is a detail which was not clearly modelled in the indicators as it felt out of the scope of EFORWOOD project.

Water consumption and the rate of renewal and volumes stored in different types of aquifers are another topic which will increasingly receive greater attention in the near future. The global water footprint is already being calculated and the trade of water in products from one country to another discussed in the media. It is difficult to estimate the impact of water use and re-use on any industry given every day news on global warming events (e.g. increase incidents of extreme weather patterns). It will no doubt lead to all industries increasingly incorporating water reduction technologies. These two points illustrate some of the difficulties with achieving acceptable levels of accuracies with the response factors due to the myriad of uncertainties.

A consistent and high quality base-year data-set is important in estimating true, and therefore representative, predictions for the future. In Table 10 all three rows have the same response factors with a difference of 5% in the base-year data. It is evident that by the year 2025 the errors, although not as great as those in Table 9, as well as their associated conclusions or assumptions, are significant.

In conclusion, it is not possible to validate response factors as an accurate and reliable tool overall. Nonetheless, within the scope of EFORWOOD these are an appropriate element of work. As the purpose of developing, testing and providing tools for sustainability assessment require limited levels of data-sets.

Table 10 – Example of how an inaccuracy in base-year data leads to errors

Response Factor	**2005**	**2010**	**2015**	**2020**	**2025**
2.0 %	950.000	1048.877	1158.045	1278.575	1411.650
2.0 %	1000.000	1104.081	1218.994	1345.868	1485.947
2.0 %	1050.000	1159.285	1279.944	1413.162	1560.245

These factors are but a few which demonstrate the complexities involved in constructing and studying sub-processes within a research tool such as ToSIA. Despite the limitations outlined above, response factors are essential within the development of tools such as ToSIA, although their relevance for predicting indicator values for reference futures is problematic, and this should be represented in all results provided to users of the tool. The user then can make appropriate choices in relation to their objectives and needs.

APPENDIX A

RESPONSE FACTOR INDICATOR TABLES

Table 11 - Response Factors for environmental indicators

ENERGY	A1	B2
18.1 - On-site energy generation from renewables	same as 2005	same as 2005
18.1.1.1 - On-site heat generation from renewables - residues from process inputs	same as 2005	same as 2005
18.1.1.2 - On-site heat generation from renewables - other wood biomass	same as 2005	same as 2005
18.1.1.3 - On-site heat generation from renewables - non-wood based renewable heat	same as 2005	same as 2005
18.1.2.1 - On-site electricity generation from renewables - residues from process	+ 1% / year	+ 1% / year
18.1.2.2 - On-site electricity generation from renewables - other wood biomass	+ 1% / year	+ 1% / year
18.1.2.3 - On-site electricity generation from renewables - non-wood based renewable electricity	+ 1% / year	+ 1% / year
18.1.3.1 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - residues from process	same as 2005	same as 2005
18.1.3.2 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - other wood biomass	same as 2005	same as 2005
18.1.3.3 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - Non-wood based renewable fuel production	same as 2005	same as 2005
18.2 - Energy use		
18.2.1.1 - Energy use - Heat from renewable sources	same as 2005	same as 2005
18.2.1.2 - Energy use - Heat from fossil sources	- 2% / year	- 2% / year
18.2.2.1 - Energy use - Direct fuel use - renewable fuel	same as 2005	same as 2005
18.2.2.2 - Energy use - Direct fuel use - fossil fuel	- 2% / year	- 2% / year
18.2.3.1 - Electricity use - from 100% renewable sources	+ 1% / year	+ 1% / year
18.2.3.2 - Electricity use - from 100% fossil sources	- 2% / year	- 2% / year
18.2.3.3 - Electricity use - from the grid	- 1% / year	- 1% / year
GHG	**A1**	**B2**
19.1 - Greenhouse gas emissions	Increases, based on fuels used on-site	Increases, based on fuels used on-site
19.1.1. Greenhouse gas emissions from machinery	Calculated based on energy generation and fuels used	Calculated based on energy generation and fuels used

19.1.2. Greenhouse gas emissions from wood combustion	Calculated based on energy generation and fuels used	Calculated based on energy generation and fuels used
WATER	**A1**	**B2**
21.1 - Water use (freshwater intake by industry) [relevant for industry]	- 1% / year	- 1% / year
POLLUTION	**A1**	**B2**
24.1.1 - Water pollution - organic substances (biochemical oxygen demand)	same as 2005	- 1% / year
24.1.2 - Water pollution - nutrients (nitrogen, phosphorus) as Nitrogen or TKN (Total KJELDAHL Nitrogen)	same as 2005	- 1% / year
24.2.1 - Non-greenhouse gas emissions into air - CO	Calculated based on energy generation and fuels used	Calculated based on energy generation and fuels used
24.2.2 - Non-greenhouse gas emissions into air - NOx	Calculated based on energy generation and fuels used	Calculated based on energy generation and fuels used
24.2.3 - Non-greenhouse gas emissions into air - SO2	Calculated based on energy generation and fuels used	Calculated based on energy generation and fuels used
24.2.4 - Non-greenhouse gas emissions into air - NMVOC	Calculated based on energy generation and fuels used	Calculated based on energy generation and fuels used
WASTE	**A1**	**B2**
27.1 - Generation of waste in total	same as 2005	same as 2005
27.1.1 - Not classified as hazardous waste	same as 2005	same as 2005
27.1.2 - Hazardous waste	same as 2005	same as 2005
27.2.1 - Waste to material recycling	same as 2005	+ 1% / year
27.2.2 - Waste to incineration	same as 2005	same as 2005
27.2.3 - Waste to landfill	same as 2005	- 1% / year

Table 12 - Main drivers for each economic indicator selected for ToSIA demonstration for calculating the reference future

	Process group			
Indicators	**Pulp and paper processes**	**Primary conversion solid wood processes**	**Secondary conversion solid wood processes**	**Bioenergy**
1.1 - Gross value added (at factory cost)	Product price development (EFI-GTM), production cost development (indicator 2.1)	Product price development (EFI-GTM), production cost development (indicator 2.1)	Product price development (EFI-GTM), production cost development (indicator 2.1)	Assumed to be same as in 2005
2.1 - Production cost	Sum of indicators 2.1.1 - 2.1.6	Sum of indicators 2.1.1 - 2.1.6	Sum of indicators 2.1.1 - 2.1.6	Sum of indicators 2.1.1 - 2.1.6
2.1.1 - Average cost - raw materials from FWC	Material cost (EFI-GTM) increase weighted by the share of different input products	Material cost (EFI-GTM) increase weighted by the share of different input products	Material cost (EFI-GTM) increase weighted by the share of different input products (possible relationship with non-wood materials in composites, e.g. walls & furniture)	Material cost (EFI-GTM) increase weighted by the share of different input products
2.1.2 - Average cost - raw materials from outside FWC	Crude oil price development, Labour costs development and productivity increase (EFI-GTM)	Crude oil price development, Labour costs development and productivity increase (EFI-GTM)	Crude oil price development, Labour costs development and productivity increase (EFI-GTM)	Crude oil price development, Labour costs development and productivity increase (EFI-GTM)
2.1.3 - Average cost - labour costs	Wage increase (EFI-GTM), productivity increase (EFI-GTM)	Wage increase (EFI-GTM), productivity increase (EFI-GTM)	Wage increase (EFI-GTM), productivity increase (EFI-GTM)	Wage increase (EFI-GTM), productivity increase (EFI-GTM)
2.1.4 - Average cost - energy costs	energy costs increase (source: EFI-GTM data)	energy costs increase (source: EFI-GTM data)	energy costs increase (source: EFI-GTM data)	energy costs increase (source: EFI-GTM data)
2.1.5 - Other productive costs	Assumed to be same as in 2005	Assumed to be same as in 2005	Assumed to be same as in 2005	Assumed to be same as in 2005
2.1.6 - Non-productive costs	Assumed to be same as in 2005	Assumed to be same as in 2005	Assumed to be same as in 2005	Assumed to be same as in 2005

APPENDIX B

REFERENCE FUTURE DESCRIPTIONS

A1 Storyline

Forestry Sector developments

Forest functions are clearly spatially separated. The free trade of goods leads to cheap wood raw material (and commodities) being imported from outside Europe, and thus to less harvesting from European forests. The rate of gain in market share by the wood based construction industry has slowed to almost 0% per annum. Since there is less focus on environmental issues and less pressure on wood prices, the recycling rate of paper products is not increasing above today's values.

The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in midcentury and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. In general public awareness concerning environmental issues is low. (IPCC SRES)

Forest resource and forestry to industry

The forest owners remain in a difficult financial position with reduced supply potential and markets dominated by imports. Where the forestry industry survives, it invests a lot in technological innovation, mainly with the aim to increase cost efficiency. The cheap woody raw material is being imported from plantations in tropical countries, Russia etc. This leads to little investment in forest management and low harvesting levels in Europe. However, the hardwood sector (and forest owners) is doing relatively well because specific high quality assortments are very expensive and because high quality tropical hardwood resources are getting depleted.

Processing and manufacturing

Most of the heavy industries will move to Eastern Europe and the developing world where wages are still lower. However, in Western-Europe there are high levels of technical development, innovation and education with high rates of investment. Production will focus on a wider range of products and more on high-tech value added niche markets.

Industry to consumer

The paper industry has seen mergers into fewer and larger global multinationals and profits from the availability of a cheap woody fibre resource. The bulk of the paper, however, will be produced further away outside Europe, but transport costs are relatively low. The European paper industry focuses on innovative value added products. Industries meet consumers' needs regarding type and quality of paper and size of product. The basis weight of the paper used in printing, publishing as well packaging sectors is half of that of today. The performance requirements of the printing technology have increased. Increasing education standards in the South will cause a growth in paper consumption of approximately 70% as a result of the necessary production of educational material. There is an increase in packaging demand associated with this increase in smaller households and increased transportation of goods.

B2 Storyline

Forestry Sector developments

The slower economic growth leads to low overall consumption levels and a relatively large demand for lower quality furniture and finishing.

At the same time the emphasis on bio-energy, leads to a high rise in the use of woody biomass.

The high sustainability credentials of the forest industry attract high levels of political interest and support. Forestry is viewed globally as having a key role to play in this programme which leads to increased planting programmes for carbon sequestration (but in competition with demand for agricultural land). There is strong support for low carbon footprint homes, which benefits the forest industry.

The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population, intermediate levels of economic development, and less rapid and more diverse technological change than in A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels. (IPCC SRES)

Forest resource and forestry to industry

Reduced wood imports in combination with the high demand for wood products for building and biomass increases the demand for European wood (e.g. increase in fellings of 1.5% a^{-1}). This is favourable for the forest owner who makes high profits from harvesting and who invests in his estate. Increased investment in IT infrastructure by forest industry companies has resulted in enhanced interaction in the value chain and in reduced costs and increased efficiency.

The forest industry takes advantage of new multi-modal forms of transport to optimise its costs within this framework.

Processing and manufacturing

The demand for biomass for bioenergy has pushed raw material prices up. Because of the high environmental awareness and high raw material prices the recycling and recovery rates are higher than today and recycled material supply chains are very sophisticated. But there is also strong competition from the energy sector for supplies.

The panel industry is strong but also sees increased competition from wood plastic composites as more plastics are recycled into environmentally friendly products.

Because of high raw material prices together with the high energy costs the paper industry is faced with high production costs.

Industry to consumer

The overall per capita consumption levels decreases and there is more demand for cheaper and lower quality goods. There is more emphasis on the full chain and re-use, recyclability and/or biodegradability are important trends. Products are locally produced and transport distances are limited.

Lower wealth combined with high material costs will lead to lower consumption of paper for printing and publishing and paper for packaging.

In the packaging sector, there is a trend for material reduction (lighter packaging) and the avoidance of redundant packaging.

APPENDIX C

CASE STUDY INDICATOR TABLES

Table 13 – Full table of sustainability indicators for coated woodcontaining paper in Western Central Europe for the reference futures A1 and B2 for 2015 and 2025 provided by KCL[28]

	2005	A1 2015	A1 2025	B2 2015	B2 2025
1.1 - Gross value added	86	146	153	133	139
2.1 - Production cost	497	451	450	458	454
2.1.1 - Average cost - raw materials from FWC	175	201	219	209	227
2.1.2 - Average cost - raw materials from outside FWC	113	119	114	120	115
2.1.3 - Average cost - labour costs	64	70	74	70	70
2.1.4 - Average cost - energy costs	101	85	66	84	67
2.1.5 - Other productive costs	23	23	23	23	23
2.1.6 - Non-productive costs	20	20	20	20	20
10.1 - Employment - absolute number	0.0008352	0.0008268	0.0007918	0.0008277	0.0008001
11.1 - Wages and salaries - total	31.6	42	54.3	38.5	46.1
12.1 - Occupational accidents - total	0.23	0.01	0.12	1.46	1.26
12.1.1 - Occupational accidents (non-fatal) - absolute numbers	0.23	1.46	1.25	1.46	1.26
12.1.2 - Occupational accidents (fatal) - absolute numbers	7.94E-05	7.94E-05	7.94E-05	7.94E-05	7.94E-05
18.1 - On-site energy generation from renewables	539.4	539.4	539.4	539.4	539.4
18.1.1.1 - On-site heat generation from renewables - residues from process - inputs	1292	1292	1292	1292	1292
18.1.1.2 - On-site heat generation from renewables - other wood biomass	653	653	653	653	653
18.1.1.3 - On-site heat generation from renewables - non-wood based renewable heat	0	0	0	0	0
18.1.2.1 - On-site electricity generation from renewables - residues from process	0	0	0	0	0
18.1.2.2 - On-site electricity generation from renewables - other wood biomass	0	0	0	0	0
18.1.2.3 - On-site electricity generation from renewables - non-wood based renewable electricity	0	0	0	0	0
18.1.3.1 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - residues from process	0	0	0	0	0
18.1.3.2 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - other wood biomass	0	0	0	0	0
18.1.3.3 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - Non-wood based renewable fuel production	0	0	0	0	0

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[28] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

	2005	**A1 2015**	**A1 2025**	**B2 2015**	**B2 2025**
18.2 - Energy use	2741	2441	2186	2441	2186
18.2.1.1 - Energy use - Heat from renewable sources	1944	1944	1944	1944	1944
18.2.1.2 - Energy use - Heat from fossil sources	3698	3022	2469	3022	2469
18.2.2.1 - Energy use - Direct fuel use - renewable fuel	0	0	0	0	0
18.2.2.2 - Energy use - Direct fuel use - fossil fuel	0	0	0	0	0
18.2.3.1 - Electricity use - from 100% renewable sources	0	0	0	0	0
18.2.3.2 - Electricity use - from 100% fossil sources	0	0	0	0	0
18.2.3.3 - Electricity use - from the grid	1175	1061	960	1061	960
19.1 - Greenhouse gas emissions	570	499	441	499	441
19.1.1. Greenhouse gas emissions from machinery	386	315	257	315	257
19.1.2. Greenhouse gas emissions from wood combustion	184	184	184	184	184
21.1 - Water use (freshwater intake by industry) [relevant for industry]	17.4	15.7	14.2	15.7	14.2
21.2 - Water use (of the forest ecosystem)	N. A.	N. A	N. A	N. A	N. A
21.2.1 - Water use (of the forest ecosystem) - Evapotranspiration from the system	N. A	N. A	N. A	N. A	N. A
21.2.2 - Water use (of the forest ecosystem) - Groundwater recharge	N. A	N. A	N. A	N. A	N. A
24.1.1 - Water pollution - organic substances (biochemical oxygen demand)	0.3	0.3	0.3	0.28	0.25
24.1.2 - Water pollution - nutrients (nitrogen. phosphorus) as Nitrogen or TKN (Total KJELDAHL Nitrogen)	0.15	0.15	0.15	0.13	0.12
24.2.1 - Non-greenhouse gas emissions into air - CO	0.09	0	0	0	0
24.2.2 - Non-greenhouse gas emissions into air - NOx	0.78	0.67	0.58	0.67	0.58
24.2.3 - Non-greenhouse gas emissions into air - SO2	0.26	0.23	0.19	0.23	0.19
24.2.4 - Non-greenhouse gas emissions into air - NMVOC	0	0	0	0	0
27.1 - Generation of waste in total	18.3	18.3	18.3	18.3	18.3
27.1.1 - Not classified as hazardous waste	18.3	18.3	18.3	18.3	18.3
27.1.2 - Hazardous waste	0	0	0	0	0
27.2.1 - Waste to material recycling	14.8	14.8	14.8	16.4	18
27.2.2 - Waste to incineration	0	0	0	0	0
27.2.3 - Waste to landfill	3.5	3.5	3.5	1.9	0.2

Table 14 – Full table of sustainability indicators for a Cartonboard mill in Western Central Europe for the reference futures A1 and B2 for 2015 and 2025 provided by KCPK[29]

	2005	A1 2015	A1 2025	B2 2015	B2 2025
1.1 - Gross value added	82.72	262.24	223.22	259.27	213.92914
2.1 - Production cost	411.84	403.53	413.46	398.88	395.28898
2.1.1 - Average cost - raw materials from FWC	176.88	230.09	256.67	224.55	234.22764
2.1.2 - Average cost - raw materials from outside FWC	84.48	88.76	85.5	89.39	86.146676
2.1.3 - Average cost - labour costs	26.4	28.97	30.73	28.98	31.0524
2.1.4 - Average cost - energy costs	66.88	53.55	39.74	53.15	40.565305
2.1.5 - Other productive costs	27.28	27.28	27.28	27.28	27.28
2.1.6 - Non-productive costs	29.92	29.92	29.92	29.92	29.92
10.1 - Employment - absolute number	0.0004189	0.0004147	0.0003971	0.0004151	0.0004013
11.1 - Wages and salaries - total	15.8	21.2	27.2	19.3	23.1
12.1 - Occupational accidents - total	1.162E-05	7.39E-06	6.32E-06	7.40E-06	6.38E-06
12.1.1 - Occupational accidents (non-fatal) - absolute numbers	1.162E-05	7.39E-06	6.32E-06	7.40E-06	6.38E-06
12.1.2 - Occupational accidents (fatal) - absolute numbers	3.99E-09	3.99E-09	3.99E-09	3.99E-09	3.99E-09
18.1 - On-site energy generation from renewables	4151.4	4151	4151	4151	4151
18.1.1.1 - On-site heat generation from renewables - residues from process - inputs	0	0	0	0	0
18.1.1.2 - On-site heat generation from renewables - other wood biomass	0	0	0	0	0
18.1.1.3 - On-site heat generation from renewables - non-wood based renewable heat	0	0	0	0	0
18.1.2.1 - On-site electricity generation from renewables - residues from process	0	0	0	0	0
18.1.2.2 - On-site electricity generation from renewables - other wood biomass	0	0	0	0	0
18.1.2.3 - On-site electricity generation from renewables - non-wood based renewable electricity	0	0	0	0	0
18.1.3.1 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - residues from process	0	0	0	0	0
18.1.3.2 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - other wood biomass	0	0	0	0	0
18.1.3.3 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - Non-wood based renewable fuel production	0	0	0	0	0

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[29] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

	2005	A1 2015	A1 2025	B2 2015	B2 2025
18.2 - Energy use	6142.7422	5974	5847	5974	5847
18.2.1.1 - Energy use - Heat from renewable sources	14945.04	14945	14945	14945	14945
18.2.1.2 - Energy use - Heat from fossil sources	3417.92	2793	2282	2793	2282
18.2.2.1 - Energy use - Direct fuel use - renewable fuel	0	0	0	0	0
18.2.2.2 - Energy use - Direct fuel use - fossil fuel	0	0	0	0	0
18.2.3.1 - Electricity use - from 100% renewable sources	520.96	575	636	575	636
18.2.3.2 - Electricity use - from 100% fossil sources	0	0	0	0	0
18.2.3.3 - Electricity use - from the grid	520.96	471	426	471	426
19.1 - Greenhouse gas emissions	2082.08	1751	1480	1751	1480
19.1.1. Greenhouse gas emissions from machinery	1812	1481	1210	1481	1210
19.1.2. Greenhouse gas emissions from wood combustion	270	270	270	270	270
21.1 - Water use (freshwater intake by industry) [relevant for industry]	89	80	73	80	73
21.2 - Water use (of the forest ecosystem)	N.A.	N.A.	N.A.	N.A.	N.A.
21.2.1 - Water use (of the forest ecosystem) - Evapotranspiration from the system	N.A.	N.A.	N.A.	N.A.	N.A.
21.2.2 - Water use (of the forest ecosystem) - Groundwater recharge	N.A.	N.A.	N.A.	N.A.	N.A.
24.1.1 - Water pollution - organic substances (biochemical oxygen demand)	10	10	10	9	8
24.1.2 - Water pollution - nutrients (nitrogen. phosphorus) as Nitrogen or TKN (Total KJELDAHL Nitrogen)	0.0352	0	0	0	0
24.2.1 - Non-greenhouse gas emissions into air - CO	0.0176	0	0	0	0
24.2.2 - Non-greenhouse gas emissions into air - NOx	0.02112	0	0	0	0
24.2.3 - Non-greenhouse gas emissions into air - SO2	0	0	0	0	0
24.2.4 - Non-greenhouse gas emissions into air - NMVOC	0	0	0	0	0
27.1 - Generation of waste in total	132.704	133	133	133	133
27.1.1 - Not classified as hazardous waste	132.352	132	132	132	132
27.1.2 - Hazardous waste	0.352	0	0	0	0
27.2.1 - Waste to material recycling	73.04	73	73	81	89
27.2.2 - Waste to incineration	0	0	0	0	0
27.2.3 - Waste to landfill	59.84	60	60	52	44

Table 15 – Full table of sustainability indicators for a Cartonboard mill in Baden-Württemberg for the reference futures A1 and B2 for 2015 and 2025 provided by Pöyry[30]

	2005	A1 2015	A1 2025	B2 2015	B2 2025
1.1 - Gross value added	83	123	91	122	87
2.1 - Production cost	412	404	414	399	395
2.1.1 - Average cost - raw materials from FWC	177	230	257	225	234
2.1.2 - Average cost - raw materials from outside FWC	85	89	86	89	86
2.1.3 - Average cost - labour costs	26	29	31	30	31
2.1.4 - Average cost - energy costs	67	54	40	53	41
2.1.5 - Other productive costs	28	27	27	27	27
2.1.6 - Non-productive costs	30	30	30	30	30
10.1 - Employment - absolute number	0.0004	0.0004	0.0004	0.0004	0.0004
11.1 - Wages and salaries – total	16	21	27	19	23
12.1 - Occupational accidents – total	1.20E-05	7.40E-06	6.20E-06	7.40E-06	6.40E-06
12.1.1 - Occupational accidents (non-fatal) - absolute numbers	1.20E-05	7.40E-06	6.30E-06	7.40E-06	6.40E-06
12.1.2 - Occupational accidents (fatal) - absolute numbers	4.00E-09	4.00E-09	4.00E-09	4.00E-09	4.00E-09
18.1 - On-site energy generation from renewables	4151	4151	4151	4151	4151
18.1.1.1 - On-site heat generation from renewables - residues from process - inputs	0	0	0	0	0
18.1.1.2 - On-site heat generation from renewables - other wood biomass	0	0	0	0	0
18.1.1.3 - On-site heat generation from renewables - non-wood based renewable heat	0	0	0	0	0
18.1.2.1 - On-site electricity generation from renewables - residues from process	0	0	0	0	0
18.1.2.2 - On-site electricity generation from renewables - other wood biomass	0	0	0	0	0
18.1.2.3 - On-site electricity generation from renewables - non-wood based renewable electricity	0	0	0	0	0
18.1.3.1 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - residues from process	0	0	0	0	0
18.1.3.2 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - other wood biomass	0	0	0	0	0
18.1.3.3 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - Non-wood based renewable fuel production	0	0	0	0	0

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[30] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

	2005	**A1 2015**	**A1 2025**	**B2 2015**	**B2 2025**
18.2 - Energy use	6143	5974	5847	5974	5847
18.2.1.1 - Energy use - Heat from renewable sources	14945	14945	14945	14945	14945
18.2.1.2 - Energy use - Heat from fossil sources	3418	2793	2282	2793	2282
18.2.2.1 - Energy use - Direct fuel use - renewable fuel	0	0	0	0	0
18.2.2.2 - Energy use - Direct fuel use - fossil fuel	0	0	0	0	0
18.2.3.1 - Electricity use - from 100% renewable sources	521	575	636	575	636
18.2.3.2 - Electricity use - from 100% fossil sources	0	0	0	0	0
18.2.3.3 - Electricity use - from the grid	521	471	426	471	426
19.1 - Greenhouse gas emissions	2082	1751	1480	1751	1480
19.1.1. Greenhouse gas emissions from machinery	1812	1481	1210	1481	1210
19.1.2. Greenhouse gas emissions from wood combustion	270	270	270	270	270
21.1 - Water use (freshwater intake by industry) [relevant for industry]	89	80	73	80	73
21.2 - Water use (of the forest ecosystem)	0	0	0	0	0
21.2.1 - Water use (of the forest ecosystem) - Evapotranspiration from the system	0	0	0	0	0
21.2.2 - Water use (of the forest ecosystem) - Groundwater recharge	0	0	0	0	0
24.1.1 - Water pollution - organic substances (biochemical oxygen demand)	9.9	9.9	9.9	9	8.1
24.1.2 - Water pollution - nutrients (nitrogen. phosphorus) as Nitrogen or TKN (Total KJELDAHL Nitrogen)	0.035	0.04	0.04	0.03	0.03
24.2.1 - Non-greenhouse gas emissions into air – CO	0.018	0.014	0.012	0.014	0.012
24.2.2 - Non-greenhouse gas emissions into air – Nox	0.021	0.017	0.014	0.017	0.014
24.2.3 - Non-greenhouse gas emissions into air - SO2	0	0	0	0	0
24.2.4 - Non-greenhouse gas emissions into air – NMVOC	0	0	0	0	0
27.1 - Generation of waste in total	133	133	133	133	133
27.1.1 - Not classified as hazardous waste	132	132	132	132	132
27.1.2 - Hazardous waste	0.4	0.4	0.4	0.4	0.4
27.2.1 - Waste to material recycling	73	73	73	81	89
27.2.2 - Waste to incineration	0	0	0	0	0
27.2.3 - Waste to landfill	60	60	60	52	44

Table 16 – Full table of sustainability indicators for a Container Board (Kraft Liner) mill in Nordic Countries for the reference futures A1 and B2 for 2015 and 2025 provided by INNVENTIA AB[31]

	2005	A1 2015	A1 2025	B2 2015	B2 2025
1.1 - Gross value added	45	87	84	88	77
2.1 - Production cost	158	66	69	71	80
2.1.1 - Average cost - raw materials from FWC	90	97	106	109	132
2.1.2 - Average cost - raw materials from outside FWC	11	11	10	11	11
2.1.3 - Average cost - labour costs	23	24	22	24	24
2.1.4 - Average cost - energy costs	15	16	17	16	17
2.1.5 - Other productive costs	10	10	10	10	10
2.1.6 - Non-productive costs	8	8	8	8	8
10.1 - Employment - absolute number	0.000376	0.000346	0.000296	0.000347	0.000312
11.1 - Wages and salaries - total	13.88	18.47	23.9	16.94	20.27
12.1 - Occupational accidents - total	6.04E-06	3.65E-06	3.05E-06	3.67 E-6	3.22E-06
12.1.1 - Occupational accidents (non-fatal) - absolute numbers	6.02E-06	3.64E-06	3.03E-06	3.65E-06	3.20E-06
12.1.2 - Occupational accidents (fatal) - absolute numbers	1.98E-08	1.98E-08	1.98E-08	1.98E-08	1.98E-08
18.1 - On-site energy generation from renewables	122	122	122	122	122
18.1.1.1 - On-site heat generation from renewables - residues from process - inputs	0	0	0	0	0
18.1.1.2 - On-site heat generation from renewables - other wood biomass	220	220	220	220	220
18.1.1.3 - On-site heat generation from renewables - non-wood based renewable heat	0	0	0	0	0
18.1.2.1 - On-site electricity generation from renewables - residues from process	0	0	0	0	0
18.1.2.2 - On-site electricity generation from renewables - other wood biomass	61	68	75	68	75
18.1.2.3 - On-site electricity generation from renewables - non-wood based renewable electricity	0	0	0	0	0
18.1.3.1 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - residues from process	0	0	0	0	0
18.1.3.2 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - other wood biomass	0	0	0	0	0
18.1.3.3 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - Non-wood based renewable fuel production	0	0	0	0	0

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[31] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

	2005	A1 2015	A1 2025	B2 2015	B2 2025
18.2 - Energy use	1448	1381	1325	1381	1325
18.2.1.1 - Energy use - Heat from renewable sources	3462	3462	3462	3462	3462
18.2.1.2 - Energy use - Heat from fossil sources	831	679	555	679	555
18.2.2.1 - Energy use - Direct fuel use - renewable fuel	0	0	0	0	0
18.2.2.2 - Energy use - Direct fuel use - fossil fuel	0	0	0	0	0
18.2.3.1 - Electricity use - from 100% renewable sources	0	0	0	0	0
18.2.3.2 - Electricity use - from 100% fossil sources	0	0	0	0	0
18.2.3.3 - Electricity use - from the grid	255	231	209	231	209
19.1 - Greenhouse gas emissions	493	481	472	481	472
19.1.1. Greenhouse gas emissions from machinery	63	51	42	54	42
19.1.2. Greenhouse gas emissions from wood combustion	430	430	430	430	430
21.1 - Water use (freshwater intake by industry) [relevant for industry]	17	15	14	15	14
21.2 - Water use (of the forest ecosystem)	N.A	N.A	N.A	N.A	N.A
21.2.1 - Water use (of the forest ecosystem) - Evapotranspiration from the system	N.A	N.A	N.A	N.A	N.A
21.2.2 - Water use (of the forest ecosystem) - Groundwater recharge	N.A	N.A	N.A	N.A	N.A
24.1.1 - Water pollution - organic substances (biochemical oxygen demand)	1.4	1.4	1.4	1.4	1.2
24.1.2 - Water pollution - nutrients (nitrogen. phosphorus) as Nitrogen or TKN (Total KJELDAHL Nitrogen)	0.12	0.12	0.12	0.12	0.1
24.2.1 - Non-greenhouse gas emissions into air - CO	0	0	0	0	0
24.2.2 - Non-greenhouse gas emissions into air - NOx	0.36	0.29	0.24	0.29	0.24
24.2.3 - Non-greenhouse gas emissions into air - SO2	0.18	0.15	0.12	0.15	0.12
24.2.4 - Non-greenhouse gas emissions into air - NMVOC	0	0	0	0	0
27.1 - Generation of waste in total	22.4	22.4	22.4	22.4	22.4
27.1.1 - Not classified as hazardous waste	22.3	22.3	22.3	22.3	22
27.1.2 - Hazardous waste	0.1	0.1	0.1	0.1	0.1
27.2.1 - Waste to material recycling	14.6	14.6	14.6	16.1	17.8
27.2.2 - Waste to incineration	0.8	0.8	0.8	0.8	0.8
27.2.3 - Waste to landfill	7	7	7	5.5	3.8

Table 17 – Full table of sustainability indicators for a Pellet mill in Scandinavia for the reference futures A1 and B2 for 2015 and 2025 provided by VTT[32]

	2005	A1 2015	A1 2025	B2 2015	B2 2025
1.1 - Gross value added	202	157	93	169	112
2.1 - Production cost	241	423	559	384	471
2.1.1 - Average cost - raw materials from FWC	120	238	340	208	279
2.1.2 - Average cost - raw materials from outside FWC	0	0	0	0	0
2.1.3 - Average cost - labour costs	17	20	23	18	19
2.1.4 - Average cost - energy costs	31	78	93	75	80
2.1.5 - Other productive costs	51	49	53	48	50
2.1.6 - Non-productive costs	22	38	51	35	43
10.1 - Employment - absolute number	0.0005291	0.000463	0.0004115	0.000463	0.0004115
11.1 - Wages and salaries - total	8.5	10	11.5	9	9.5
12.1 - Occupational accidents - total	1.47E-05	8.16E-06	6.48E-06	8.16E-06	6.48E-06
12.1.1 - Occupational accidents (non-fatal) - absolute numbers	1.47E-05	8.16E-06	6.47E-06	8.16E-06	6.47E-06
12.1.2 - Occupational accidents (fatal) - absolute numbers	5.03E-09	4.45E-09	4.13E-09	4.44E-09	4.09E-09
18.1 - On-site energy generation from renewables	0	0	0	0	0
18.1.1.1 - On-site heat generation from renewables - residues from process - inputs	0	0	0	0	0
18.1.1.2 - On-site heat generation from renewables - other wood biomass	0	0	0	0	0
18.1.1.3 - On-site heat generation from renewables - non-wood based renewable heat	0	0	0	0	0
18.1.2.1 - On-site electricity generation from renewables - residues from process	0	0	0	0	0
18.1.2.2 - On-site electricity generation from renewables - other wood biomass	0	0	0	0	0
18.1.2.3 - On-site electricity generation from renewables - non-wood based renewable electricity	0	0	0	0	0
18.1.3.1 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - residues from process	0	0	0	0	0
18.1.3.2 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - other wood biomass	0	0	0	0	0
18.1.3.3 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - Non-wood based renewable fuel production	0	0	0	0	0

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[32] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

	2005	A1 2015	A1 2025	B2 2015	B2 2025
18.2 - Energy use	788	1728	1846	1728	1846
18.2.1.1 - Energy use - Heat from renewable sources	1880	5080	5400	5080	5400
18.2.1.2 - Energy use - Heat from fossil sources	3698	3022	2469	3022	2469
18.2.2.1 - Energy use - Direct fuel use - renewable fuel	0	0	0	0	0
18.2.2.2 - Energy use - Direct fuel use - fossil fuel	78	78	78	78	78
18.2.3.1 - Electricity use - from 100% renewable sources	0	0	0	0	0
18.2.3.2 - Electricity use - from 100% fossil sources	0	0	0	0	0
18.2.3.3 - Electricity use - from the grid	244	296	324	296	324
19.1 - Greenhouse gas emissions	6	6	6	6	6
19.1.1. Greenhouse gas emissions from machinery	0	0	0	0	0
19.1.2. Greenhouse gas emissions from wood combustion	0	0	0	0	0
21.1 - Water use (freshwater intake by industry) [relevant for industry]	0	0	0	0	0
21.2 - Water use (of the forest ecosystem)	N. A.	N. A	N. A	N. A	N. A
21.2.1 - Water use (of the forest ecosystem) - Evapotranspiration from the system	N. A	N. A	N. A	N. A	N. A
21.2.2 - Water use (of the forest ecosystem) - Groundwater recharge	N. A	N. A	N. A	N. A	N. A
24.1.1 - Water pollution - organic substances (biochemical oxygen demand)	0	0	0	0	0
24.1.2 - Water pollution - nutrients (nitrogen. phosphorus) as Nitrogen or TKN (Total KJELDAHL Nitrogen)	0	0	0	0	0
24.2.1 - Non-greenhouse gas emissions into air - CO	0	0	0	0	0
24.2.2 - Non-greenhouse gas emissions into air - NOx	0	0	0	0	0
24.2.3 - Non-greenhouse gas emissions into air - SO2	0	0	0	0	0
24.2.4 - Non-greenhouse gas emissions into air - NMVOC	0	0	0	0	0
27.1 - Generation of waste in total	0	0	0	0	0
27.1.1 - Not classified as hazardous waste	0	0	0	0	0
27.1.2 - Hazardous waste	0	0	0	0	0
27.2.1 - Waste to material recycling	0	0	0	0	0
27.2.2 - Waste to incineration	0	0	0	0	0
27.2.3 - Waste to landfill	0	0	0	0	0

Table 18 – Full table of sustainability indicators for the production of parquet and glued boards in Eastern Europe for the reference futures A1 and B2 for 2015 and 2025 provided by TUZVO[33]

	2005	A1 2015	A1 2025	B2 2015	B2 2025
1.1 - Gross value added	17.4	18.2	19.3	17.4	17.8
2.1 - Production cost	64.5	64.2	66	67.9	71.6
2.1.1 - Average cost - raw materials from FWC	35.8	35.8	37	37	39
2.1.2 - Average cost - raw materials from outside FWC	15.4	15.4	16.5	16.5	17.3
2.1.3 - Average cost - labour costs	2.5	2.5	2.7	2.8	3.1
2.1.4 - Average cost - energy costs	3.3	3.3	3.4	3.6	3.8
2.1.5 - Other productive costs	4.3	4.3	3.9	4.6	4.8
2.1.6 - Non-productive costs	3.2	2.9	2.5	3.4	3.6
10.1 - Employment - absolute number	124	121	120	128	142
11.1 - Wages and salaries - total	2.5	2.5	2.7	2.8	3.1
12.1 - Occupational accidents - total	3.21E-05	3.30E-05	1.70E-05	3.95E-05	4.20E-05
12.1.1 - Occupational accidents (non-fatal) - absolute numbers	2.40E-05	1.65E-05	1.70E-05	2.30E-05	2.80E-05
12.1.2 - Occupational accidents (fatal) - absolute numbers	8.10E-06	1.65E-05	0	1.65E-05	1.40E-05
18.1 - On-site energy generation from renewables	0	0	0	0	0
18.1.1.1 - On-site heat generation from renewables - residues from process - inputs	0	0	0	0	0
18.1.1.2 - On-site heat generation from renewables - other wood biomass	0	0	0	0	0
18.1.1.3 - On-site heat generation from renewables - non-wood based renewable heat	0	0	0	0	0
18.1.2.1 - On-site electricity generation from renewables - residues from process	0	0	0	0	0
18.1.2.2 - On-site electricity generation from renewables - other wood biomass	0	0	0	0	0
18.1.2.3 - On-site electricity generation from renewables - non-wood based renewable electricity	0	0	0	0	0
18.1.3.1 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - residues from process	0	0	0	0	0
18.1.3.2 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - other wood biomass	0	0	0	0	0
18.1.3.3 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - Non-wood based renewable fuel production	0	0	0	0	0

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[33] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

	2005	A1 2015	A1 2025	B2 2015	B2 2025
18.2 - Energy use	110.5	110.5	110.5	110.5	110.5
18.2.1.1 - Energy use - Heat from renewable sources GWh	0	33.4	33.4	26.2	27.8
18.2.1.2 - Energy use - Heat from fossil sources GWh	82.3	48.6	49.5	56.1	56.4
18.2.2.1 - Energy use - Direct fuel use - renewable fuel	0	0	0	0	0
18.2.2.2 - Energy use - Direct fuel use - fossil fuel	0	0	0	0	0
18.2.3.1 - Electricity use - from 100% renewable sources	0	0	0	0	0
18.2.3.2 - Electricity use - from 100% fossil sources	0	0	0	0	0
18.2.3.3 - Electricity use - from the grid mil kWh	28.2	28.5	27.6	28.2	26.3
19.1 - Greenhouse gas emissions	0	120	120	120	120
19.1.1. Greenhouse gas emissions from machinery	0	0	0	0	0
19.1.2. Greenhouse gas emissions from wood combustion	0	120	120	120	120
21.1 - Water use (freshwater intake by industry) [relevant for industry]	0	0	0	0	0
21.2 - Water use (of the forest ecosystem)	N.A.	N.A.	N.A.	N.A.	N.A.
21.2.1 - Water use (of the forest ecosystem) - Evapotranspiration from the system	N.A.	N.A.	N.A.	N.A.	N.A.
21.2.2 - Water use (of the forest ecosystem) - Groundwater recharge	N.A.	N.A.	N.A.	N.A.	N.A.
24.1.1 - Water pollution - organic substances (biochemical oxygen demand)	0	0	0	0	0
24.1.2 - Water pollution - nutrients (nitrogen, phosphorus) as Nitrogen or TKN (Total KJELDAHL Nitrogen)	0	0	0	0	0
24.2.1 - Non-greenhouse gas emissions into air - CO	0	0	0	0	0
24.2.2 - Non-greenhouse gas emissions into air - NOx	0	0	0	0	0
24.2.3 - Non-greenhouse gas emissions into air - SO2	0	0	0	0	0
24.2.4 - Non-greenhouse gas emissions into air - NMVOC	0	0	0	0	0
27.1 - Generation of waste in total	0	0	0	0	0
27.1.1 - Not classified as hazardous waste	0	0	0	0	0
27.1.2 - Hazardous waste	0	0	0	0	0
27.2.1 - Waste to material recycling	0	0	0	0	0
27.2.2 - Waste to incineration	0	0	0	0	0
27.2.3 - Waste to landfill	0	0	0	0	0

Table 19 – Full table of sustainability indicators for a large softwood sawmill in Baden-Württemberg for the reference futures A1 and B2 for 2015 and 2025 provided by BRE[34]

	2005	A1 2015	A1 2025	B2 2015	B2 2025
1.1 - Gross value added	9	164.69656	168.50380	187.73817	202.08864
2.1 - Production cost	77.5	38.14899	39.70974	42.28862	47.06687
2.1.1 - Average cost - raw materials from FWC	63	62.01768	65.15209	70.34607	79.77135
2.1.2 - Average cost - raw materials from outside FWC	0	0	0	0	0
2.1.3 - Average cost - labour costs	7	7.38460	7.61004	7.36413	7.70766
2.1.4 - Average cost - energy costs	1.5	1.39570	1.15735	1.36705	1.15473
2.1.5 - Other productive costs	5.5	5.5	5.5	5.5	5.5
2.1.6 - Non-productive costs	0	0	0	0	0
10.1 - Employment - absolute number	0.0004	0.0003808	0.000354	0.00038	0.00036
11.1 - Wages and salaries – total	12.0384	15.971325	20.64603	14.6931	17.6347
12.1 - Occupational accidents – total	3.05E-05	3.05E-05	3.05E-05	3.05E-05	3.05E-05
12.1.1 - Occupational accidents (non-fatal) - absolute numbers	3.05E-05	3.05E-05	3.05E-05	3.05E-05	3.05E-05
12.1.2 - Occupational accidents (fatal) - absolute numbers	2.58E-08	2.58E-08	2.58E-08	2.58E-08	2.58E-08
18.1 - On-site energy generation from renewables	3676.67222	3676.672	3676.672	3676.672	3676.672
18.1.1.1 - On-site heat generation from renewables - residues from process – inputs	0	0	0	0	0
18.1.1.2 - On-site heat generation from renewables - other wood biomass	0	0	0	0	0
18.1.1.3 - On-site heat generation from renewables - non-wood based renewable heat	13236.02	13236.02	13236.02	13236.02	13236.02
18.1.2.1 - On-site electricity generation from renewables - residues from process	0	0	0	0	0
18.1.2.2 - On-site electricity generation from renewables - other wood biomass	0	0	0	0	0
18.1.2.3 - On-site electricity generation from renewables - non-wood based renewable electricity	0	0	0	0	0
18.1.3.1 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - residues from process	0	0	0	0	0
18.1.3.2 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - other wood biomass	0	0	0	0	0
18.1.3.3 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - Non-wood based renewable fuel production	0	0	0	0	0

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[34] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

	2005	A1 2015	A1 2025	B2 2015	B2 2025
18.2 - Energy use	4878.65	4671.99711	4501.882	4671.997	4501.88244
18.2.1.1 - Energy use - Heat from renewable sources	13236.02	13236.02	13236.02	13236.02	13236.02
18.2.1.2 - Energy use - Heat from fossil sources	720.72	588.880713	481.1584	588.8807	481.158417
18.2.2.1 - Energy use - Direct fuel use - renewable fuel	0	0	0	0	0
18.2.2.2 - Energy use - Direct fuel use - fossil fuel	3061.24	2501.25596	2043.708	2501.256	2043.70823
18.2.3.1 - Electricity use - from 100% renewable sources	0	0	0	0	0
18.2.3.2 - Electricity use - from 100% fossil sources	0	0	0	0	0
18.2.3.3 - Electricity use - from the grid	151.433333	136.9536	123.8584	136.9536	123.8584
19.1 - Greenhouse gas emissions	128.039632	104.6177	85.4803	104.6177	85.4803
19.1.1. Greenhouse gas emissions from machinery	NF	NF	NF	NF	NF
19.1.2. Greenhouse gas emissions from wood combustion	NF	NF	NF	NF	NF
21.1 - Water use (freshwater intake by industry) [relevant for industry]	5.04	4.56	4.12	4.56	4.12
21.2 - Water use (of the forest ecosystem)	NF	NF	NF	NF	NF
21.2.1 - Water use (of the forest ecosystem) - Evapotranspiration from the system	NF	NF	NF	NF	NF
21.2.2 - Water use (of the forest ecosystem) - Groundwater recharge	NF	NF	NF	NF	NF
24.1.1 - Water pollution - organic substances (biochemical oxygen demand)	0.08658877	0.08658877	0.086589	0.078309	0.07082155
24.1.2 - Water pollution - nutrients (nitrogen, phosphorus) as Nitrogen or TKN (Total KJELDAHL Nitrogen)	0.00057551	0.00057551	0.000576	0.00052	0.00047072
24.2.1 - Non-greenhouse gas emissions into air - CO	0.1498	0.1224	0.1000	0.1224	0.1000
24.2.2 - Non-greenhouse gas emissions into air - NOx	0.3598	0.2940	0.2402	0.2940	0.2402
24.2.3 - Non-greenhouse gas emissions into air - SO2	0.1596	0.1304	0.10655	0.1304	0.10655
24.2.4 - Non-greenhouse gas emissions into air - NMVOC	0.02702	0.02208	0.01804	0.02208	0.01804
27.1 - Generation of waste in total	380.24	343.88	311.00	343.88	311.00
27.1.1 - Not classified as hazardous waste	349.8208	316.3717	286.1209	316.3717	286.1209
27.1.2 - Hazardous waste	30.4192	27.5106	24.8801	27.5106	24.8801
27.2.1 - Waste to material recycling	6.91345455	287.610601	260.109872	287.610601	260.109872
27.2.2 - Waste to incineration	311.105455	0	0	0	0
27.2.3 - Waste to landfill	345.672727	312.620218	282.728122	312.620218	282.728122

Table 20 – Full table of sustainability indicators for a the production of value added wooden components in Western Central Europe for the reference futures A1 and B2 for 2015 and 2025 provided by VTT[35]

	2005	A1 2015	A1 2025	B2 2015	B2 2025
1.1 - Gross value added	18.877	17.563	13.202	21.340	18.324
2.1 - Production cost	48.545	52.015	58.147	57.043	66.193
2.1.1 - Average cost - raw materials from FWC	38.110	40.352	45.164	45.509	53.615
2.1.2 - Average cost - raw materials from outside FWC	0	0	0	0	0
2.1.3 - Average cost - labour costs	5.699	7.210	8.669	6.594	7.478
2.1.4 - Average cost - energy costs	0.819	0.842	0.771	0.825	0.769
2.1.5 - Other productive costs	3.918	3.612	3.543	4.115	4.331
2.1.6 - Non-productive costs	0	0	0	0	0
10.1 - Employment - absolute number	0.0002142	0.000212	0.000203	0.0002122	0.0002052
11.1 - Wages and salaries - total	6.56	8.72	11.27	7.99	9.57
12.1 - Occupational accidents - total	4.21E-05	2.64E-05	2.26E-05	2.64E-05	2.28E-05
12.1.1 - Occupational accidents (non-fatal) - absolute numbers	4.20E-05	2.64E-05	2.25E-05	2.64E-05	2.28E-05
12.1.2 - Occupational accidents (fatal) - absolute numbers	3.88E-08	3.88E-08	3.88E-08	3.88E-08	3.88E-08
18.1 - On-site energy generation from renewables	36.82	36.82	36.82	36.82	36.82
18.1.1.1 - On-site heat generation from renewables - residues from process - inputs	132.56	132.56	132.56	132.56	132.56
18.1.1.2 - On-site heat generation from renewables - other wood biomass	0	0	0	0	0
18.1.1.3 - On-site heat generation from renewables - non-wood based renewable heat	0	0	0	0	0
18.1.2.1 - On-site electricity generation from renewables - residues from process	0	0	0	0	0
18.1.2.2 - On-site electricity generation from renewables - other wood biomass	0	0	0	0	0
18.1.2.3 - On-site electricity generation from renewables - non-wood based renewable electricity	0	0	0	0	0
18.1.3.1 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - residues from process	0	0	0	0	0
18.1.3.2 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - other wood biomass	0	0	0	0	0
18.1.3.3 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - Non-wood based renewable fuel production	0	0	0	0	0

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[35] All the economic values for years 2015 and 2025 are based on EFI-GTM values and are not official Pöyry forecasts – communication from Pöyry 25/06/09

	2005	A1 2015	A1 2025	B2 2015	B2 2025
18.2 - Energy use	170.23	151.6	135.76	151.6	135.76
18.2.1.1 - Energy use - Heat from renewable sources	477.21	477.21	477.21	477.21	477.21
18.2.1.2 - Energy use - Heat from fossil sources	0	0	0	0	0
18.2.2.1 - Energy use - Direct fuel use - renewable fuel	0	0	0	0	0
18.2.2.2 - Energy use - Direct fuel use - fossil fuel	0	0	0	0	0
18.2.3.1 - Electricity use - from 100% renewable sources	0	0	0	0	0
18.2.3.2 - Electricity use - from 100% fossil sources	0	0	0	0	0
18.2.3.3 - Electricity use - from the grid	37.67	34.02	30.78	34.02	30.78
19.1 - Greenhouse gas emissions	13.93	12.19	10.78	12.19	10.78
19.1.1. Greenhouse gas emissions from machinery	2.13	1.74	1.42	1.74	1.42
19.1.2. Greenhouse gas emissions from wood combustion	11.8	11.8	11.8	11.8	11.8
21.1 - Water use (freshwater intake by industry) [relevant for industry]	0.038	0.03429	0.03101	0.03429	0.03101
21.2 - Water use (of the forest ecosystem)	0	0	0	0	0
21.2.1 - Water use (of the forest ecosystem) - Evapotranspiration from the system	0	0	0	0	0
21.2.2 - Water use (of the forest ecosystem) - Groundwater recharge	0	0	0	0	0
24.1.1 - Water pollution - organic substances (biochemical oxygen demand)	0.00139	0.00139	0.00139	0.0013	0.00116
24.1.2 - Water pollution - nutrients (nitrogen. phosphorus) as Nitrogen or TKN (Total KJELDAHL Nitrogen)	6.95E-02	6.95E-02	6.95E-02	6.02E-02	5.56E-02
24.2.1 - Non-greenhouse gas emissions into air - CO	0.264	0.264	0.264	0.264	0.264
24.2.2 - Non-greenhouse gas emissions into air - NOx	0.156	0.134	0.116	0.134	0.116
24.2.3 - Non-greenhouse gas emissions into air - SO2	0.02	0.018	0.015	0.018	0.015
24.2.4 - Non-greenhouse gas emissions into air - NMVOC	0.035	0.035	0.035	0.035	0.035
27.1 - Generation of waste in total					
27.1.1 - Not classified as hazardous waste					
27.1.2 - Hazardous waste	0.386	0.386	0.386	0.386	0.386
27.2.1 - Waste to material recycling					
27.2.2 - Waste to incineration					
27.2.3 - Waste to landfill	0.328	0.328	0.328	0.178	0.019