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RENEW – Renewable fuels for advanced powertrains

Integrated Project
Sustainable energy systems

Deliverable D 5.3.6
BIOMASS PROVISION COSTS – FINAL REPORT

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CONTENT

ABBREVIATIONS

a	annum
50	50 MW biomass feedstock – direct provision
500	500 MW biomass feedstock – direct provision
500P	500 MW biomass feedstock – pyrolysis (P)
app.	approximately
BtL	biomass to liquid
CHP	combined heat and power
DH	district heating
DM	dry matter
EUC	eucalythus (only relevant for SOUTH)
FBS	first biomass site
GP	gathering point
HGV	heavy good vehicle
LHV	lower heating value
LR	logging residues
MIS	miscanthus bales
O&M	operation and maintenance
S1	Scenario 1: Maximized bio-fuel production ‘2020
S2	Scenario 2: Self-sufficient bio-fuel production ‘2020
SRC	short rotation coppice chips
Starting Point (SP)	situation for 2000-2004 (base case)
STR	straw bales
SWG	switch grass (only relevant for SOUTH)
t	tonne
w.b.	wet basis
WB	wood bundles
WC	wood chips
WCC	whole cereal crop bales

GLOSSARY

biomass freight	biomass assortment (e.g. straw, forest residues, energy crops)
block train	freight line, usually based on one wagon type for uninterrupted transport of biomass freight from start to destination station
cargo handling	loading and discharging of a biomass freight between different means of transport or delivery of a container
combined transport	special form of multimodal transport involving the cargo handling of biomass freight in a container, swap body or tank (i.e. the biomass freight itself is not handled)
detour factor	Ratio of air-line and actual distance of road, train line and inland waterway (based on average sample)
forerun	transport of biomass freight by lorry e.g. between first gathering point to harbour or goods station, basic part of multimodal transport
frequency of cargo handling	amount of biomass freight handled per time unit (e.g. t/h); differences between slow-moving and fast-moving items
front end loader	a type of tractor that uses a wide square tilting bucket on the end of movable arms to lift and move material/loads; loaders used for handling straw bales or wood logs are equipped with specialized fork or claw respectively
full-container-load	container completely loaded during harvesting / at storage and discharged at conversion (BtL) plant gate
lift-on/lift-off system	vertical cargo handling by crane
loading platform	at-grade loading and discharging of a biomass freight of mean of transport
main run	transport of biomass freight between forerun and off-carriage
multimodal transport	combination of different two (i.e. bimodal) or more transport options for the provision of one biomass freight within the provision chain
multiple sourcing	multi-supplier principle, i.e. procurement strategy for the provision of similar biomass freight (or auxiliaries) from several suppliers

off-carriage	transport of biomass freight by lorry between e.g. inner harbour/dock side or goods station to the conversion plant; depending on BtL plant site infrastructure part of multimodal transport
roll-on/roll-off system	horizontal cargo handling by means of ascending
semitrailer	also tractor trailer or heavy goods vehicle (HGV), lorry combined with different types of trailer (e.g. open truck body with crane)
storage logistics	totality of logistic issues and measures of scheduling and operation of a storage
swap body	transport attachment for combined transport (e.g. container)
toll	paying of a fee for the use of buildings, like roads, bridges, motorways and tunnels etc.
TEU	Twenty Feet Equivalent Unit, measure of capacity based on the number of transportable 20` (inch) container

1 INTRODUCTION

1.1 Objectives within the RENEW project

This deliverable D 5.3.6 "Biomass provision costs" is prepared by EC BREC and IEE within the WP 5.3 Micro-economics and socio-economic assessment in the European project Renewable Fuels for Advanced Powertrains (RENEW). The project is supported by European Commission within the 6th Framework Programme and coordinated by Volkswagen. This report includes a review of provision costs of agricultural and forest residues reported in some existing studies as well as definitions of biomass provision chains. Moreover, the general methodical approach for the cost calculation of biomass provision costs is presented.

For the production of liquid biofuels (BtL) several steps are necessary. The liquid biofuel production and provision chain is shown in Figure 1-1. The chain starts with biomass production and provision, which are the scope of this report and attached cost calculation matrixes.

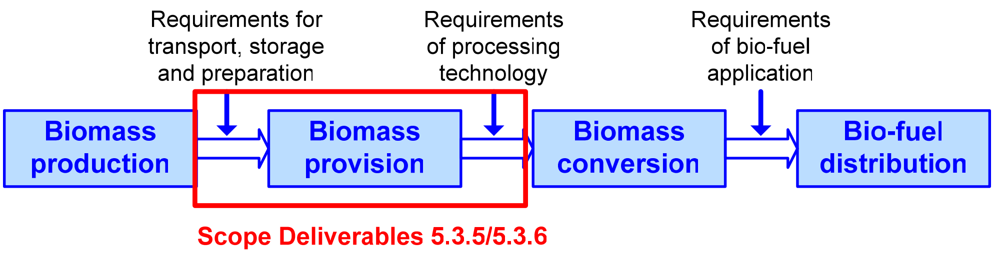

Figure 1-1 Elements of BtL supply chain and scope of the report

For the needs of this report and further works within WP 5.3 biomass provision chains are divided into two main stages: (i) from production site up to the 1st gathering point (performed by EC BREC) and (ii) from the 1st gathering point to the processing plant (performed by IEE).

The provision of the following biomass assortments will be investigated:

- energy crops (willow, poplar, eucalyptus, miscanthus, switch grass, and triticale),

* agricultural residues (straw),
* forestry wood (logging residues, thinning wood, root and stump wood).

For residue biomass (forestry and agricultural residues) both stages of the provision chain (up to the 1st gathering point and from the 1st gathering point to the BtL plant gate) are analysed in this report[1]. On the contrary, energy crop provision chains up to the 1st gathering point were analysed in deliverable D 5.3.4 “Energy crop production cost in the EU”.

1.2 General assumptions

Many concepts for biomass conversion are subject system-inherent trade-off between preferably large-scale plants with regard to “economy of scale” – and thus a high biomass demand – and a relatively small catchment area for the supply of this feedstock demand. This is particularly true for so far not matured concepts that are designed for large-scale conversion of biomass (e.g. energy crops, straw and forestry wood). Within the RENEW project different scales of BtL production (i.e. biomass demand of 50 MW_{th} and 500 MW_{th}) are investigated. Depending on regional conditions, the overall biomass supply chain (i.e. starting from biomass production over biomass provision and biomass conversion) is coupled to different aspects on “biomass side” and “demand side” (Figure 1-2). As shown, the chain of biomass provision is divided into two stages: (i) up to the 1st gathering point and (ii) from the 1st gathering point to the BtL plant. No defined chain (e.g. transport distance of biomass production and biomass demand is about 150 km) is conferrable to different regions, because of e.g. (i) different distribution and size of biomass growing areas as well as their ratio to land area and (ii) different infrastructure in terms of transport and ownership structure of growing areas. Thus, for the analysis of biomass logistics following specific criteria are of importance such as:

* area or region specific potential (i.e. the technical biomass potential per ha total area

[1] Some aspects of cereal straw provision costs were also included in D 5.3.4. The reason to include straw in the calculations was to make the calculations between energy crops and straw comparable. However, exact values for straw provision at all European regions were not included in D 5.3.4 and due to this fact are analysed within this report.

land of a region or country such as the reference countries per EU region)

* biomass assortment
* biomass treatment
* means of transport
* transport distance
* storage technology
* storage demand
* biomass demand
* plant site and local infrastructure

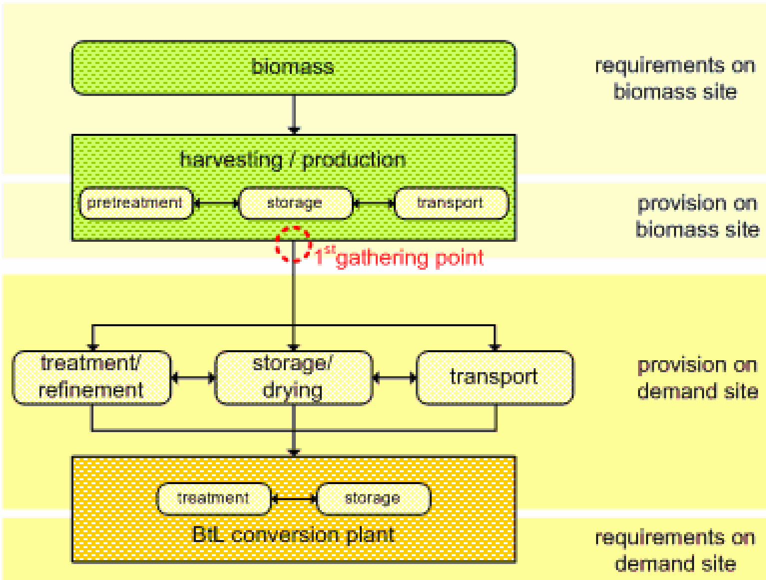

Figure 1-2 Overall biomass supply chain

While considering the types of biomass indicated above, the analysis of biomass production (i.e. cultivation) is only relevant for energy crops. Agricultural and forestry residues belong to the category of residues/by-products, thus the production chains can be neglected here since they belong to the main product (i.e. grain, timber, wood industry goods) (D 5.3.1). Thereby, the responsibilities of the WP 5.3 partners are the following (Figure 1-3).

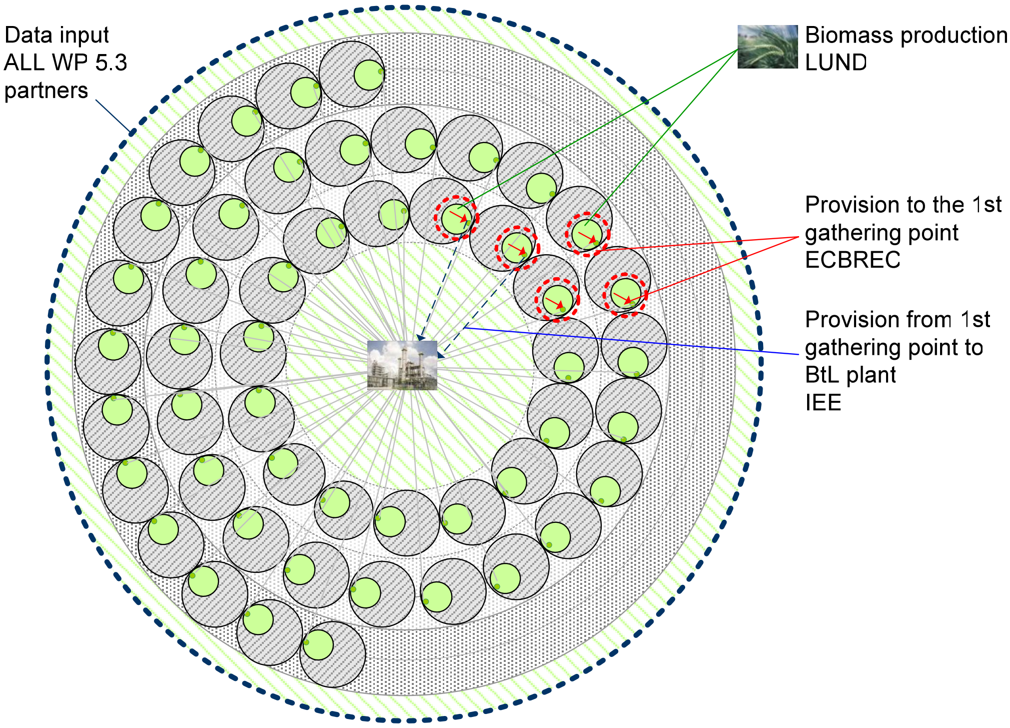

Figure 1-3 Responsibilities of WP 5.3 partners in terms of biomass production and provision

The definitions of provision chains provided are the background for the calculation of biomass provision costs. The structure of provision chain as well as the costs may be different for the six European regions (NORTH, WEST, ALPINE, the UK and Ireland, EAST and SOUTH) based on diversified resources, climatic, economic as well as agricultural conditions. Thus, the WP 5.3 partners responsible for the European regions (Table 1-1) contributed to the inventory of data base (e.g. regarding means of transport, costs) typical for a particular region.

Table 1-1 WP 5.3 partners' responsibility for European regions and cost data provision

WP5.3 partner	Country	European region
EC BREC – EC Baltic Renewable Energy Center	Poland	EAST
IEE - Institute for Energy and Environment	Germany	WEST
LU – Environmental and Energy Sys. Studies Department, Lund University	Sweden	NORTH
CRES – Center for Renewable Energy Sources	Greece	SOUTH
ESU – services	Switzerland	ALPINE
UCD – National University of Ireland	Ireland	UK+IR

2 BIOMASS PROVISION UP TO THE FIRST GATHERING POINT (ECBREC)

2.1 Methodical approach

2.1.1 General approach

Biomass provision up to the 1st gathering point (GP) includes all operations, which have to be performed to supply biomass from production site to a local gathering/storage place (called the 1st GP), e.g. biomass production (relevant only for energy crops), harvesting, handling, field transport/ forest terrain haulage, road transport and storage.

The provision costs are estimated for energy crops, agricultural residues (i.e. straw) and forestry biomass (i.e. logging residues and thinning wood). The costs for energy crops have been presented in Deliverable D 5.3.4 “Energy crops production costs in the EU” prepared by Lund University, Sweden. The costs figures for energy crops include production as well as provision to the 1st GP. For residue biomass, namely straw and forestry residues only provision costs are analysed (production costs are included in the main product procurement).

The structure of biomass provision chains as common frame conditions is presented in Figure 2-1. More detailed remarks on the chains are provided in Section 2.2.

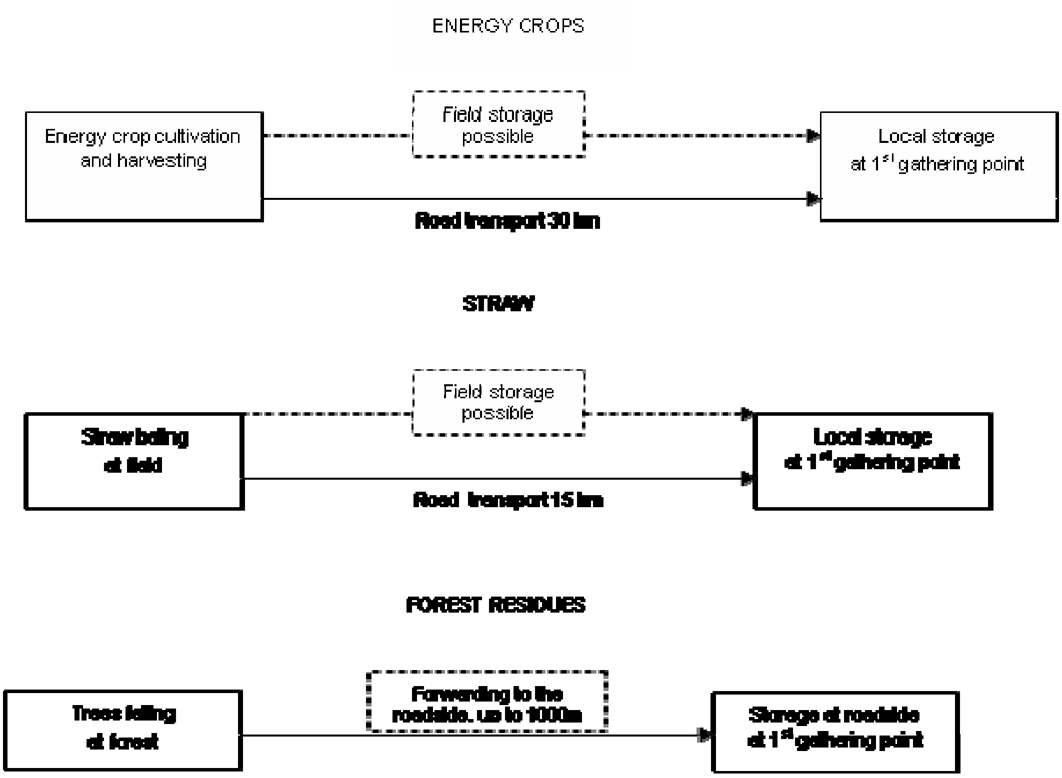

Figure 2-1 Structure of biomass provision chains up to the 1st GP

The structure of biomass chains are defined as most typical supply systems used currently for large-scale energy (DH or CHP) plants in Europe (cf. D 5.3.5). Considering the RENEW project assumption on BtL plants sizes of 50 MW_{th} and 500 MW_{th}, large amounts of biomass will be required as a raw material. Due to this fact only land areas of significant biomass potential are regarded as biomass supply areas for BtL production. In such regions effective provision options with high-capacity machineries can be performed. This is consistent with the fact that biomass provision for energy is typically done by contractors, who operate high capacity machinery to ensure cost efficiency of biomass provision.

2.1.2 Cost calculation approach

The objective is to calculate indicative values of biomass provision costs at 1st GP for three RENEW scenarios. One important purpose is also to identify and analyze the structure of provision costs as well as the main cost-drivers. The calculations contain two main elements:

* Calculation of the base case (Starting Point) economics of straw and forestry biomass provision for the analyzed countries.
* Making cost assumptions for 2020 and transforming the calculations from Starting Point to 2020 (Scenarios S1 and S2)[2].

Provision costs at 1st GP are given as €/GJ for the defined frame conditions. The cost structure of provision chains is analysed as costs of separate operations in the chain, e.g. baling, collecting, transportation, etc. In the process of performing the calculations main cost components are estimated, such as investment related costs, labour costs, fuel costs and other O&M costs. This enables to perform sensitivity analysis in order to estimate provision costs for future scenarios S1 and S2. The base methodology structure is presented in Figure 2-2.

[2] Scenario S1 and S2 represents year 2020 when the BtL industrial production plants will be under operation in Europe. Scenario S1 represents intensive biomass production based on high level of inputs and high harvesting rates. Scenario S2 represents biomass production with low level of inputs and considerably low harvesting rates

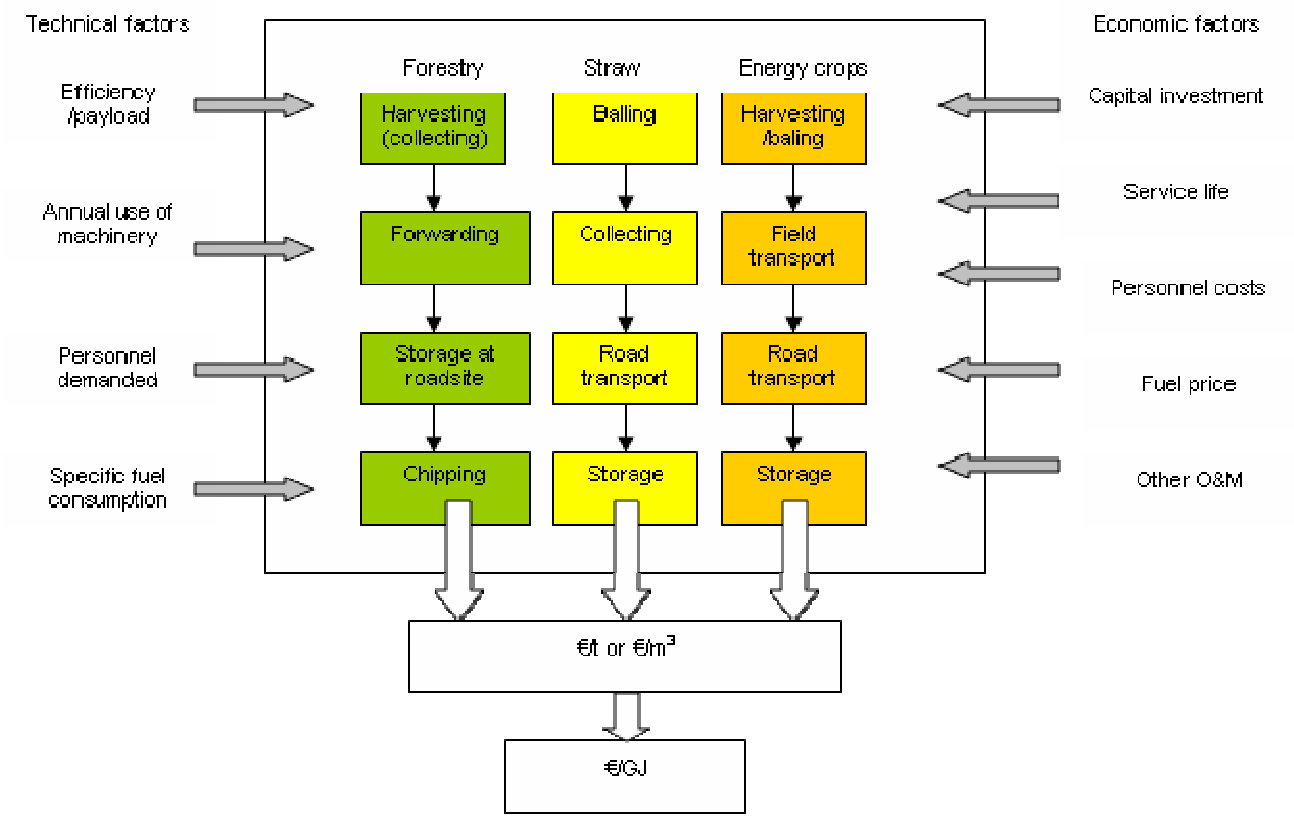

Figure 2-2 Cost calculation approach of the residue biomass provision up to the 1st GP

Straw provision costs were estimated with usual accounting method adapted for agriculture (Muzalewski, 2005). Forestry machine costs were calculated with the method described by Miyata (Miyata, 1980). These methods enable to calculate the machinery costs based on ownership costs, operating costs and labour. This is a classical approach in agriculture and forestry. The economic and technical factors presented in Figure 2-2 were used to calculate hourly operating costs, which then were recalculated into cost as €/GJ.

To perform the calculatations of provision costs at 1st GP the partners of WP5.3 were asked to supply regional specific data on the biomass provision operations. They were asked both, for technical and economic parameters on the various operations in the provision chains (see Annex D.5.3.5 ‘Data cost inventory’). However, the data provided were commonly affected by taking the parameters for a single operation from different data sources. This made the data incoherent. To overcome this inconsistency data calibration was justified before performing the calculations.

Due to large difficulties with data availability on provision costs in forestry (little data delivered by WP.5.3 partners), it was impossible to estimate the wood provision costs based on the most commonly used technologies in the analyzed countries. The only feasible option was to estimate the wood provision costs with a unified method, in which costs were calculated for a given set of professional wood harvesting machineries. The same set of machineries was applied for the analysed countries, but regional specifications such as machinery efficiency, labour cost, fuel costs and annual use of machineries were taken into account. This was done for Timberjack energy harvester (feller-buncher) model 720, forwarder Timberjack 1110 and truck mounted chipper Jenz HEM 560 D. Some main cost input data used for the calculations are presented in Annex 1.

2.1.3 Basic assumptions

Energy crops

Energy crops production and provision costs, including 30 km transportation to the 1st GP are presented in D 5.3.4. Cost figures for willow, miscanthus and triticale presented in this report in Section 2.2 are derived from D 5.3.4. They include production, provision costs as well as costs for land and costs for risk compensation (for details see D 5.3.4).

Straw

Straw provision includes baling, bales collecting, loading in, transport, loading out and storage. Additionally, straw fertilizer (NPK) value, administration and brokerage are included.

Provision chains with large rectangular bales (1.2×1.3×2.4 m), which are proved to be the most efficient straw handling technology, were assumed for the whole Europe (D5.3.5). However, the data collection by WP5.3 regional partners revealed that a departure from this assumption has to be done for Starting Point. Details are discussed in Section 2.2.1.

Bales' collecting is performed in the field by a tractor equipped with a front loader. Field transport costs are included in this category. Road transport distance is on average 15 km up to the 1st GP. Bales are delivered typically by tractors and trailers. At the storage bales are loaded out with a telescopic loader. Storage is organized in a stack on a hard ground and under a portable roof construction. The assumed storage period is on average 6 months.

Straw NPK value was included in the straw provision costs to compensate the fertilizer value of the residue material removed from the field. Straw NPK value is estimated based on fertilization value of straw. The NPK components for one tonne of straw are: 4 kg of N, 2 kg of P_2O_5 and 12 kg of K_2O (Sourie, 2005).

Brokerage is included for all biomass assortments. A broker is a company that acts between a farmer and biomass end user organizing the contract and the biomass provision (here up to the 1st GP). This company looks after the supply and storage logistics and coordination requirements, ensuring and maintaining a steady, reliable and suitable supply of biomass.

Forestry biomass

A short characteristic of energy wood harvesting technologies across European regions is presented in Annex 1. This is to understand the base conditions for logging residues and thinning wood calculations presented in Section 2.2

Fuel wood provision chains analyzed in this report are as following:

* Logging residues: Forwarding → Storage → Roadside chipping
* Thinning wood: Trees thinning → Forwarding → Storage → Roadside chipping

Logging residues are residues which are created during harvest of merchantable timber (e.g.contains of trees tops and branches including leaves and needles). Thinning wood originates from thinning operations (usually young trees with low diameter of stems <10-15 cm). Early pre-commercial and commercial thinning operations are performed in young stands in order to improve species structure of stands and to improve the quality of trees.

Roadside chipping is the most efficient and most common energy wood provision option (see D 5.3.5). Wood is forwarded (short-distance wood transport from the felling site to a roadside) ususllay at the distance of 300 to 700 m to roadside, where is stored and then chipped with a mobile chipper directly to a container on a truck. The alternatives would be transporting loose uncomminuted residue or bundles. For the loose uncomminuted residue the very low bulk density results in difficulty of fully exploiting the vehicle payload. The profitability drops very quickly with transportation distance and the system is only suitable to short hauls (Spinelli et al., 2006b). Provision chain with residues bundling represents an additional processing pace with considerably high costs and runs at much slower pace compared to provision chain with chipping. Additionally, it can be only perform on clear cuts, which are common only in Scandinavia, but not in the rest of Europe.

Provision option with roadside chipping and woodchips transportation has the highest cost efficiency under current conditions. For this reason it was chosen for the calculations of biomass provision costs in this report, both for logging residues and thinning wood.

Root and stump wood extraction was excluded from the analysis as it is only performed in Finland on a commercial scale. As reported by WP5.3 regional partners, root and stump wood extraction is not assumed to be developed in the next 10 to 20 years on a wide scale in other European countries.

Logging residues are left in piles by the roundwood harvester; the costs of logging residues collecting are included into forwarding.

Storage of wood takes place at forest roadside. These costs are not reported as a separate category as they are assumed to be insignificant, in practice often limited to the cost of the cover (paper) for the wood piles.

Administration and brokerage are included as separate cost categories.

<u>Wood industry by-products</u>

Wood industry by-products prices are excluded from the analysis. It is mainly due the fact that availability of wood by-products on the market is very limited. Great amounts of them are utilized in place of their production for material and energy purposes. No significant surplus is available for other uses such as BtL (see D 5.1.3).

2.1.4 Cost assumptions for future scenarios

The provision cost will change in the future. This will result from many different conditions:

* Labour costs. Currently large differences in labour costs in Europe are reported. It is assumed that for future scenarios cost leveling will happen across Europe as a result of further integration process within the European Union. Especially in the countries of Eastern and Southern Europe, which aim to catch up with – to converge upon – the developed economics of western Europe, it is assumed that the labour costs will significantly increase, see Table 2-5. This assumption is in line with D5.3.4.
* Annual use of machinery. This parameter is expected to increase, especially for agricultural operations, which is due to the development of energy crops plantations. Straw harvesting and handling machinery will be also used for harvesting certain energy crops (Reed Canary Grass, Miscanthus, Switch grass, Hemp), which will mean better utilization of machinery and reduced operation costs. The annual use of machinery will be slightly lower in S2 compared to S1, see Table 2-5.
* Brokerage. Cost reductions in the future would be possible due to better organization and more competition.
* Storage keeping. If there will be energy crops production developed on a wide scale, the storage infrastructure may be utilized by many, which will reduce the costs.
* Over the next 15 years a wide-scale mechanization of forest operations will develop in Europe. Manual wood harvesting, which is now very common in the EAST and SOUTH, will become costly as the labour costs will increase. However, in some remote regions and in stands of sensitive conditions manual harvesting still will be performed[3], but this is not considered as raw material supply for large scale BtL

[3] Manual felling will still be performed in some countries of Eastern and Southern Europe. It is assumed that about 50% of energy wood still will be harvested manually in such countries: Poland, Hungary, Latvia, Lithuania and even higher level for Romania, Bulgaria, Ukraine, etc. (IBL, 2006) The main barrier will be very high

systems.

* Logging residues bundling technology is investigated for S1 only for the NORTH. This technology is performed on clear cuts, which are not common apart from Scandinavia. Moreover, in the future the share of wood felling with clear cuts is expected to decrease due to sustainable forest management programmes in Europe (Resolution H1, 1993). For this reason spreading of bundling technology across Europe is expected only to very little extend. The cost will be analyzed only for Sweden for S1.
* In S1 an intensive forestry biomass harvesting will be performed. This will occur both in good quality stands as well as in stands of more difficult harvesting conditions. This will influence the costs much in NORTH and ALPINE region. In other European regions the share of hardly accessible stands is low and will not have such a great impact on average fuel wood costs.
* In S2 it is assumed that some sensitive stands will be excluded from harvesting operations. This will result in lower overall provision chain capacity and lower rate of machinery utilization.

investment costs of harvesting and forwarding machineries, such as a harvester or truck-mounted chipper, which may cost between 300,000 and 400,000 €.

Table 2-1 Projected changes of some costs and cost related parameters over time, in reference to SP

	WEST (Germany)	EAST (Poland)	NORTH (Sweden)	ALPINE (Switzerland)	SOUTH (Greece)	UK+IR (Ireland)
Agriculture						
Labour cost: S1, S2	-	+160% (12 €/h in 2020)	-	-	+75% (14 €/h in 2020)	-
Number of hours of machinery annual use, S1	+20%	+20%	+20%	+10% [a]	+20%	+20%
Number of hours of machinery annual use, S2	+10%	+10%	+10%	+5% [a]	+10%	+10%
Transport: S1, S2	-5%	+20% [b]	-5%	- 5%	+10% [b]	-5%
Storage costs: S1, S2	-5%	+20% [b]	-5%	- 5%	+10% [b]	-5%
Brokerage: S1, S2	-25%	-10% [c]	-25%	-25%	-10% [c]	-25%
Forestry						
Labour cost: S1, S2	-	+100% (12 €/h)	-	-	+75% (14 €/h)	-
Number of hours of machineries Annual use, S1	+10%	-	+10%	+10%	-	+10%
Number of hours of machineries Annual use, S2	-10%	-	-10%	-10%	-	-10%

[a] lower increase in annual utilization due to considerable low amount of land available for energy crops
[b] increase of costs due to average increase in cost of production means in these countries till 2020
[c] lower level of costs reduction due to expected increase in labour costs

2.1.5 Costs for different area or region specific potentials at 1st GP

Area or region specific potentials may significantly influence the costs of biomass provisions. In areas, where biomass potential is large and biomass sites are concentrated, the opportunities for significant cost reductions exist. The cost can be reduced due to more efficient utilization of machineries (large number of hours of annual usage) and lower distances for machineries movement from site to site. Large biomass feedstock availability in a specific area creates the opportunity of using the machineries of the highest capacities, this results with high cost efficiency. There is also the advantage of efficient provision chain organization and administration (the volume of transportation and storage means can be used up to its full capacities).

If the area or region specific potentials are low, the machineries of lower capacity are used. Often they require more labour force. In such areas large-scale and highly efficient machineries can not be used to its full capacity and the exploitation potential, otherwise it would result with extremely high operation costs. The average distances from provision site to the gathering point would be longer and result in cost increase. The organization and administration cost are also higher.

2.2 Provision costs at the 1st GP

2.2.1 Starting point (base case)

The Table 2-2 presents the biomass provision costs at 1st GP for the base case. For energy crops a detailed cost analysis is provided in D 5.3.4. Below, the cost interpretation is focused only on straw and forestry biomass.

Table 2-2 Biomass provision costs at 1st GP for SP

Cost, €/GJ	WEST (Germany)	EAST (Poland)	NORTH (Sweden)	ALPINE (Switzerland)	SOUTH (Greece)	UK+IR (Ireland)
Willow	5.80	5.30	5.50	5.20	4.30*	5.70
Miscanthus	7.40	5.90	8.40	7.40	4.70**	7.80
Triticale whole crop	6.80	5.30	7.10	6.60	6.40	6.60
Straw	3.43	2.15	3.88	3.65	2.90	3.48
Logging residues	2.63	1.32***	2.54	2.74	Not harvested	2.64
Thinning wood	5.80	2.37***	5.07	5.93	2.88	5.62

* for southern Europe these are costs for Eucalyptus
** for southern Europe these are costs for Switch grass
*** manual harvesting

Straw

Large rectangular bale (1.2×1.3×2.4m) harvesting technology is investigated for NORTH, UK&IE, WEST and EAST. As reported by the WP5.3 regional partners in some countries such technologies are not commonly available for farmers. Namely, in Switzerland and Greece straw harvesting with round bales (1.2×1.3m) is investigated for Starting Point. With relatively very low straw yields and scattered fields, the usage of large rectangular balers would be inefficient and very costly.

The costs of straw provision are the highest in Sweden, the lowest in Poland. Figure 2-3presents straw provision cost structure to understand the contribution of each cost component to the total (see also Annex 1 for cost figures). Straw baling cost contributes much to the total. Baling cost with large rectangular bales are more or less at a similar level for Sweden, Ireland, Germany, while in Poland they are much lower. The difference comes from large gap between labour cost as well lower machinery investment and O&M costs in Poland, having the other parameters at similar levels. In Greece the NPK value of straw is the highest among countries, due to high fertilizers costs (see Annex 1). In Switzerland and Greece straw is baled with round balers. Lower labour cost in Greece makes the provision cheaper than in Switzerland, even though the machinery investment costs were reported lower for Switzerland.

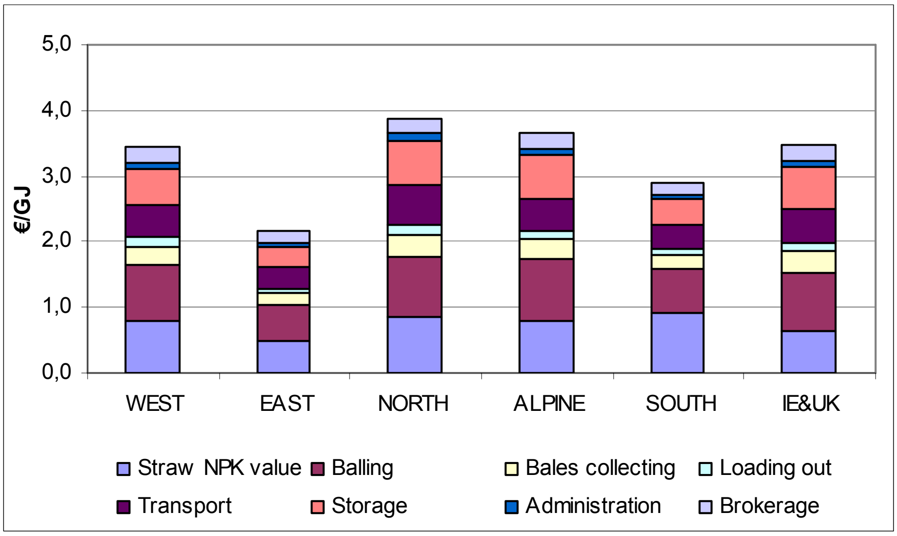

Figure 2-3 Straw provision costs structure for selected European regions for SP

<u>Forestry</u>

Provision costs for logging residues and thinning wood are presented in Table 2-2. These are cost for the roadside chipping option. Cost for logging residues in Greece were not reported as this biomass fraction is not harvested there. This is due to specific type of forest (weak structure), difficult harvesting conditions and the risk of erosion. In Poland logging residues are harvested manually. In the rest of countries a mechanical provision chain is the most common. For Sweden the costs are slightly lower than for Germany, Ireland and Switzerland, which is due to much higher utilization of machineries in the NORTH, where intensive fuel wood procurement takes place. The logistics is there well organized with minimal machinery delays and waitings time. The cost in the ALPINE region are the highest, which is related to higher labour and fuel costs compared to other countries, while the utilization of machineries is at the similar level as in Germany and Ireland. Higher costs result also from difficult terrain conditions (mountain), which influence the overall chain efficiency. Logging residues cost structure is presented in Figure 2-4. See Annex 1 for cost figures.

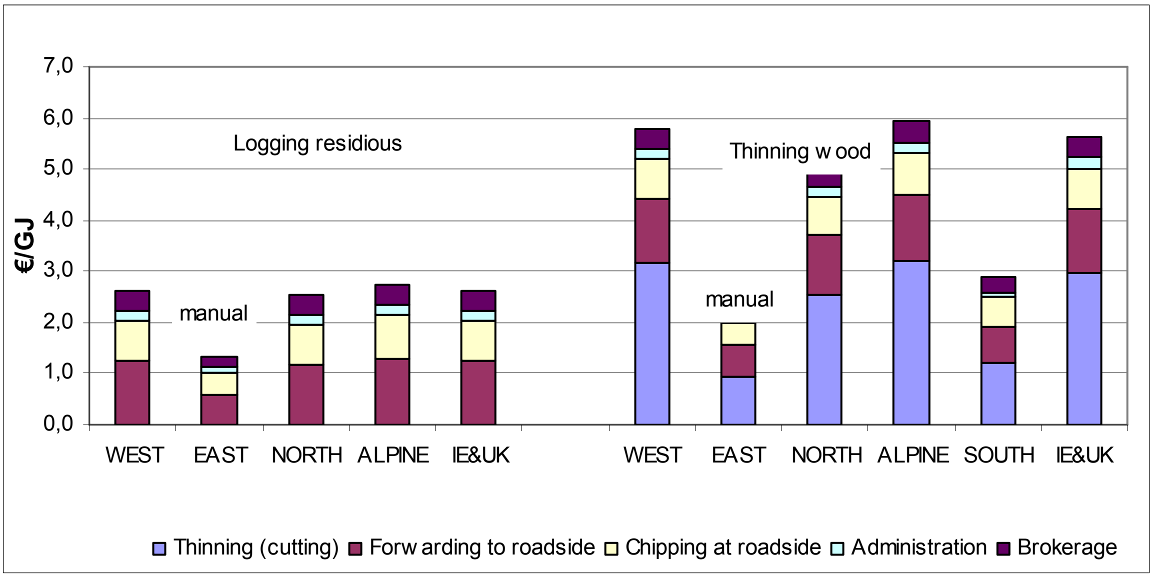

Figure 2-4 Cost structure of logging residues and thinning wood provision for SP

Thinning wood provision costs are also based on the provision chain with roadside chipping option. The costs are higher compared to logging residues, which is mainly because of relatively high cost of thinning operations. In the WEST, NORTH, UK+IR and ALPINE thinning is done with energy harvester. In Poland and Greece thinning is typically performed by workers using chainsaws.

Thinning cost structure is presented in Figure 2-4 (see Annex 1 for cost figures). For mechanized chain the lower cost are in Sweden, which is due to much higher annual utilization of machineries compared to other countries. The difference between Germany and Ireland is mainly due to higher harvester efficiency in UK+IR, where stands are in common age and have similar species structure. For mechanized chains the largest contribution in total cost has thinning, which constitute more than 50% of total. In Greece and Poland the thinning wood costs are much lower. This is due to low cost of manual harvesting. In Greece the costs are higher, which is due to higher labour cost than in Poland.

Wood industry by-products

Wood industry-by products market values in the representative countries are presented in Table 2-3. The data were delivered by WP5.3 regional partners with a comment that commonly the by-products are utilized at the place of origin for material or energy purposes in wood industry.

Table 2-3 Wood industry by-product market values at the place of origin

	WEST (Germany)	EAST (Poland)	NORTH (Sweden)	ALPINE (Switzerland)	SOUTH (Greece)	UK+IR (Ireland)
Woodchips	3.0	3.5	3.9	9.5	-	10.3
Sawdust	-	2.0	2.8	-	1.5	1.2-2.2

2.2.2 Future scenario S1

The costs estimated for Scenario S1 are presented in Table 2-4. General tendency is that cost will decrease in 2020 due to higher biomass yields and more efficient provision. However, for NORTH and ALPINE forestry biomass provision costs will increase.

Table 2-4 Biomass provision costs at 1st GP for S1

Cost, €/GJ	WEST (Germany)	EAST (Poland)	NORTH (Sweden)	ALPINE (Switzerland)	SOUTH (Greece)	UK+IR (Ireland)
Willow	3.80	3.40	3.60	3.50	3.30*	3.70
Miscanthus	6.10	6.20	6.40	6.20	4.70**	6.20
Triticale whole crop	6.60	7.00	6.60	6.50	7.20	6.30
Straw	3.23	2.61	3.56	3.41	2.97	3.26
Logging residues	2.40	2.21	2.61 (3.14)***	2.88	-	2.45
Thinning wood	5.42	5.26	4.99	5.86	5.83	5.30

* for southern Europe these are costs for Eucalyptus
** for southern Europe these are costs for Switch grass
*** logging residues bundling

<u>Straw</u>

For all countries large rectangular bales technology is assumed. Due to labour cost leveling, the costs of straw provision are on similar level across Europe. Poland is the only country where increase of costs is expected compared to the Starting Point (increase in labour costs). In the other countries straw provision costs will drop significantly due to better utilization of machinery and storage capacity, which will be used both for straw and energy crops harvesting. Also cost of brokerage will fall down due to higher competition among brokerage companies. In Greece, labour cost will increase, but this will be compensated with exchanging the round bales with large bales and better machinery annual utilization.

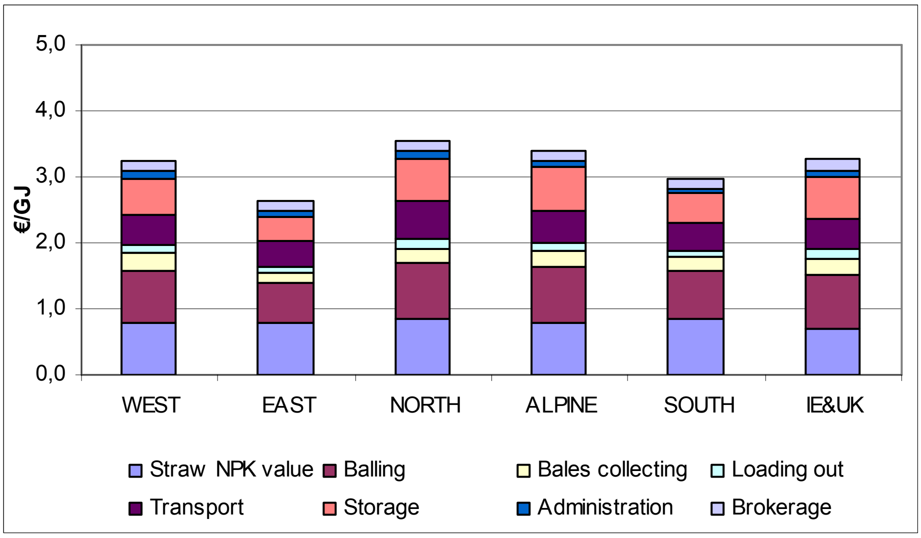

Figure 2-5 Cost structure of straw provision for S1

Figure 2-6 presents the straw provision cost structure for Sweden and Poland for SP and S1. For Sweden all the cost components decrease between SP and S1 (no change for fertilizer value) and the cost structure is very similar for both scenarios. The change in costs between SP and S1 amounts at 8%. On the contrary, in Poland there is a significant change in cost figures between SP and S1. The cost of field operations will increase due to higher labour cost and higher investment costs and this will not be compensated with the cost reduction due to more efficient usage of machineries. The fertilizer value of straw, storage and transportation costs will approach much the cost levels of the rest of Europe.

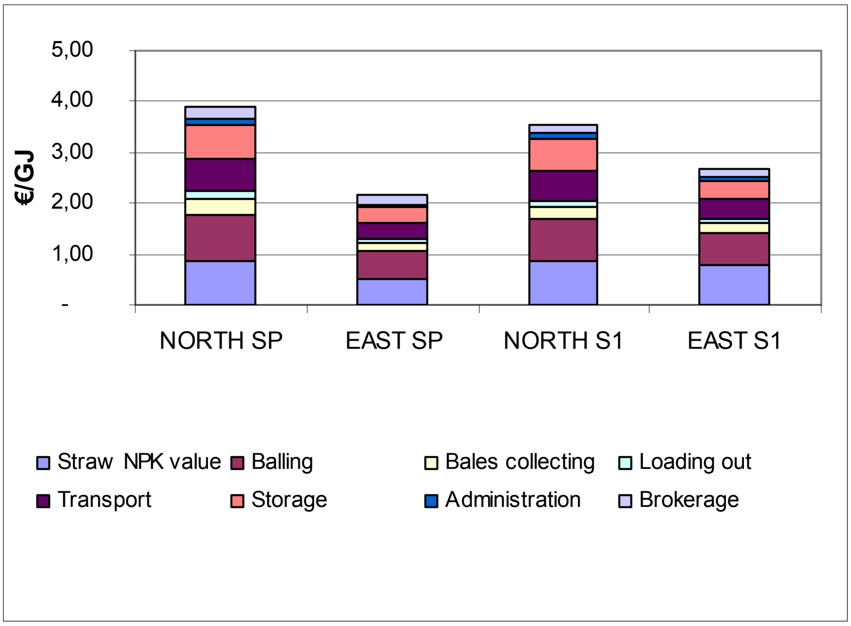

Figure 2-6 Straw provision costs structure for EAST (Poland) and NORTH (Sweden) and for SP and S1

<u>Forestry</u>

High level of mechanization of forest operations in Europe is expected in 2020, especially when large-scale and cost efficient provision chains are analysed.

For logging residues cost increase is expected for NORTH, ALPINE and EAST. In the NORTH and ALPINE regions more intensive biomass procurement in S1 will result from the exploitation of remote and/or not easily accessible stands, which are currently not exploited. High cost of machinery movement and lower overall efficiency of the chain if working in difficult conditions (steep slopes, bad road conditions for heavy machinery transportation to the working place, etc.) will make the total cost higher. This will not be compensated by better annual utilisation of machineries. In Poland there will be a shift from manual harvesting to provision chain mechanisation. This will significantly increase the costs, even though the machineries will be utilised with high annual rate, due to expected increase in wood felling rate (see D 5.1.3). High machinery investment costs are the main reason for large cost increase compared with manual chain. Cost structure is presented in Figure 2-7 (see also Annex 1 for cost figures).

In the WEST and UK&IR the energy wood provision cost will fall down, which will be the effect of more intensive machinery utilisation. In these countries most of the exploited stands are of a good structure and accessibility. The share of hardly available and remote stands is marginal, and will not influence the average logging residues provision costs.

For Sweden the cost of logging residues bundling were calculated at 120% of the costs of roadside chipping option. The reason for higher costs is the process of bundling, which still has relatively high costs.

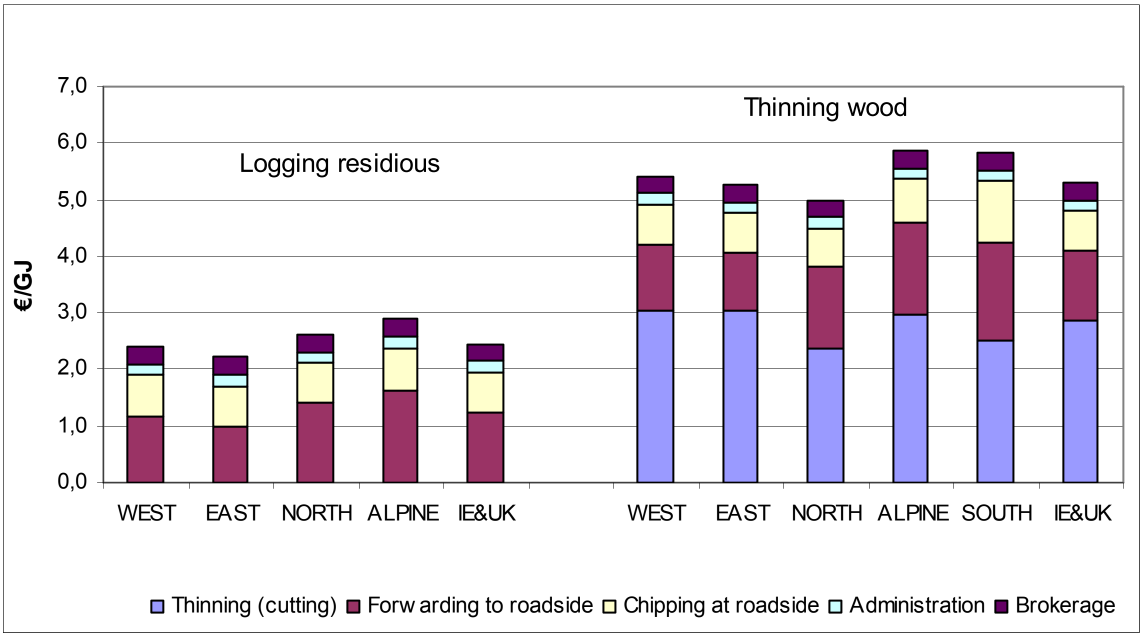

Figure 2-7 Cost structure of logging residues and thinning wood provision for S1

For thinning wood cost decrease is expected for all countries except from Greece and Poland, where the shift from manual to mechanized system will result in higher costs. Increase in annual use of machineries is the main reason for cost drop in NORTH, WEST, UK+IR and ALPINE. For cost structure see Figure 2-7.

2.2.3 Future scenario S2

In scenario S2 the costs of biomass provision are generally higher than for SP and S1, which is due to lower biomass yields, see Table 2-5. The provision operations are less efficient compared with S1 and even SP (for forestry).

Table 2-5 Biomass provision costs at 1st GP for S2

Cost, €/GJ	WEST (Germany)	EAST (Poland)	NORTH (Sweden)	ALPINE (Switzerland)	SOUTH (Greece)	UK+IR (Ireland)
Willow	4.40	3.80	4.10	3.80	3.80*	4.40
Miscanthus	6.00	6.10	6.30	6.10	6.30**	6.10
Triticale whole crop	7.10	7.60	7.10	6.90	7.70	6.70
Straw	3.34	2.74	3.67	3.52	3.06	3.37
Logging residues	2.76	2.65	2.77	3.24	-	2.79
Thinning wood	6.78	6.38	6.12	7.46	6.79	6.68

* for southern Europe these are costs for Eucalyptus
** for southern Europe these are costs for Switch grass

Straw

The decrease in straw yields in S2 will result with higher costs of operations performed in the field namely balling, bales collecting and loading in (see Annex 1). The machinery will be less efficiently used than in S1, however there will be a higher number of hours of annual utilization than in SP. Labour cost and are at the same level as for S1.

Figure 2-8 presents cost figures and percentage cost breakdown for Poland and Sweden for SP and both future scenarios. In Poland significant cost increase results mainly from labour cost increase. For Sweden the highest costs are for SP, in the future scenarios higher utilization of machineries and lower brokerage costs will reduce the total costs.

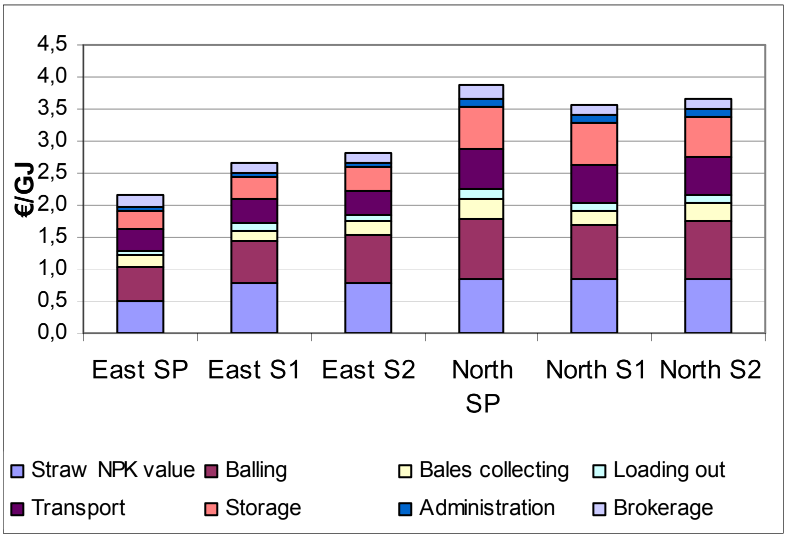

Figure 2-8 Cost structure of straw provision for EAST (Poland) and NORTH (Sweden) for SP, S1 and S2

Forestry

Increase in logging residues and thinning wood provision costs is expected in S2. For S2 the environmental restrictions are prioritized, this will require less intensive rate of biomass removal from forestry. Additionally, it is assumed that the some stands will not be excluded from wood removal, e.g. soil or water protecting stands, etc. For this reason the annual use of machineries will be even lower than for SP, which will increase the costs of provision. Thinning operations will be performed with lower rate. This will have a considerable impact on the average cost increase.

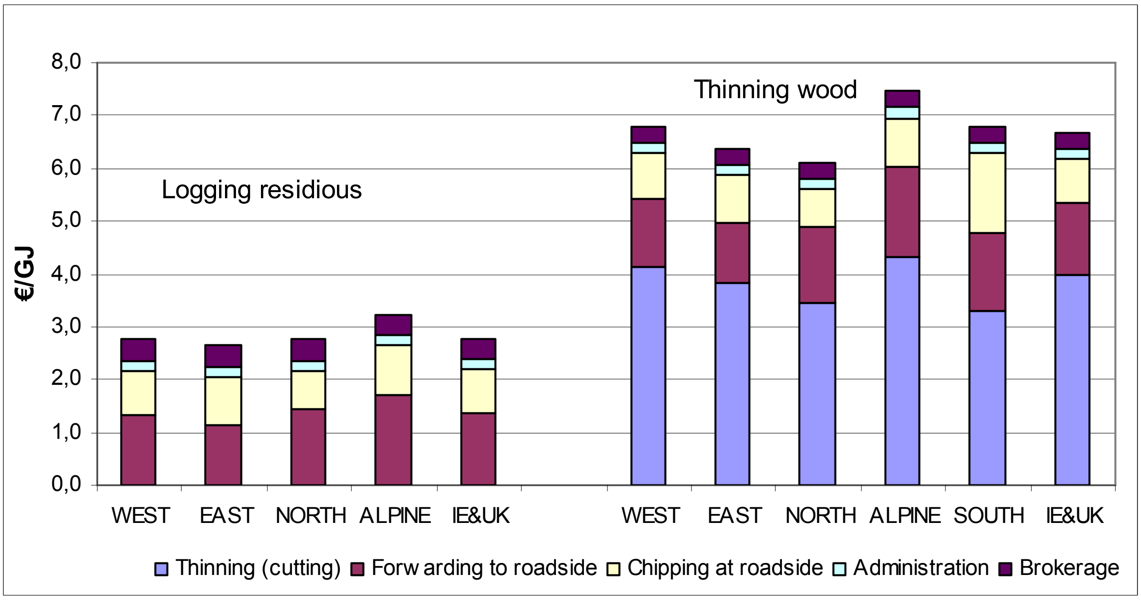

Figure 2-9 Cost structure of logging residues and thinning wood provision for S2

Figure 2-10 presents the change in cost structure for Poland and Sweden for SP, S1 and S2.

Lower costs are expected in S1 compared to S2 scenario for both countries. It is due to fact that higher stands exploitation and intensive annual machinery use in S1 will result with costs decrease. A great change occurs in Poland. The shift from manual chain into fully mechanized chain between SP and S1 results in cost increase with 122%. It is due to high investment costs connected with system change. Such large changes do not occur for Sweden, where the mechanical system is typical for all scenarios. The thinning cost for Poland will be higher than for Sweden as the machinery will not be used so efficiently as in densely forested Scandinavian conditions.

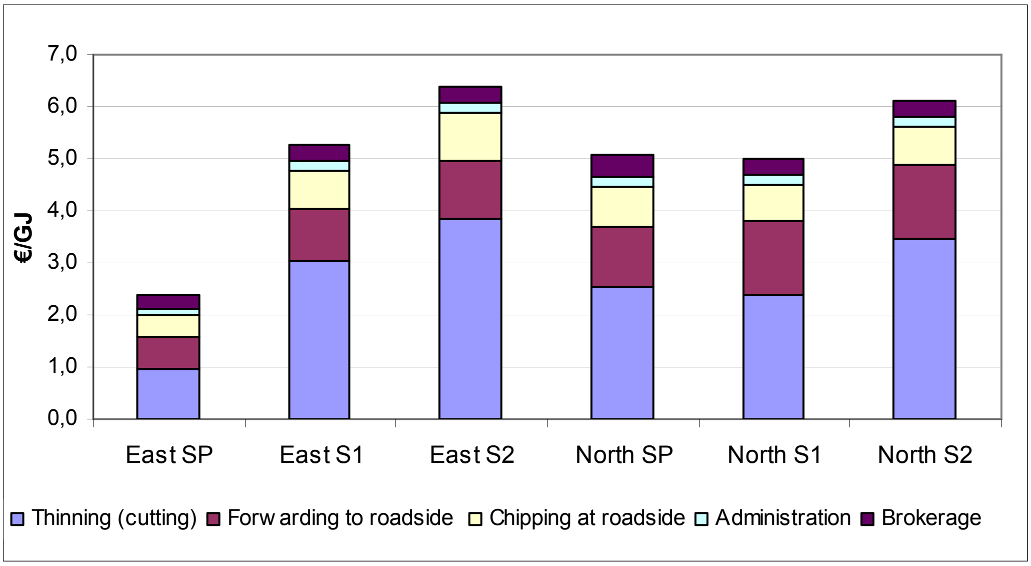

Figure 2-10 Cost structure of thinning wood provision for EAST (Poland) and NORTH (Sweden) for SP, S1 and S2

2.2.4 Comparison with other studies

Here is a comparison of biomass costs at 1st gathering point for the SP and future scenarios S1 and S2. See Figure 2-11, Figure 2-12 and Figure 2-13.

For SP residue biomass can be supplied at the lowest costs. Energy crops have relatively high costs. Miscanthus is the most costly biomass source, while logging residues (at roadside) is the cheapest. In scenario S1 costs levels for almost all biomass assortments are lower compared to SP. Economies of scale of energy crops development will have significant effect on costs reductions. Willow has the highest cost reduction potential. Miscanthus and triticale production will be also characterized by significant cost reduction, while straw and forestry residues has very little change in costs, expect from Eastern and Southern Europe. The residue biomass harvesting technology is well developed already in most of the European regions and vary little cost reductions are possible over time. The exceptions are Eastern and Southern Europe, where labour cost increase and shift from manual to mechanized harvesting technologies in forestry will result is higher provision costs in 2020.

In scenario S2 costs are higher than for S1 for all biomass assortments. This is the effect of lower biomass yields in agriculture production and less intensive forestry biomass removal.

Higher costs will result mainly from less intensive machinery usage than in S1.

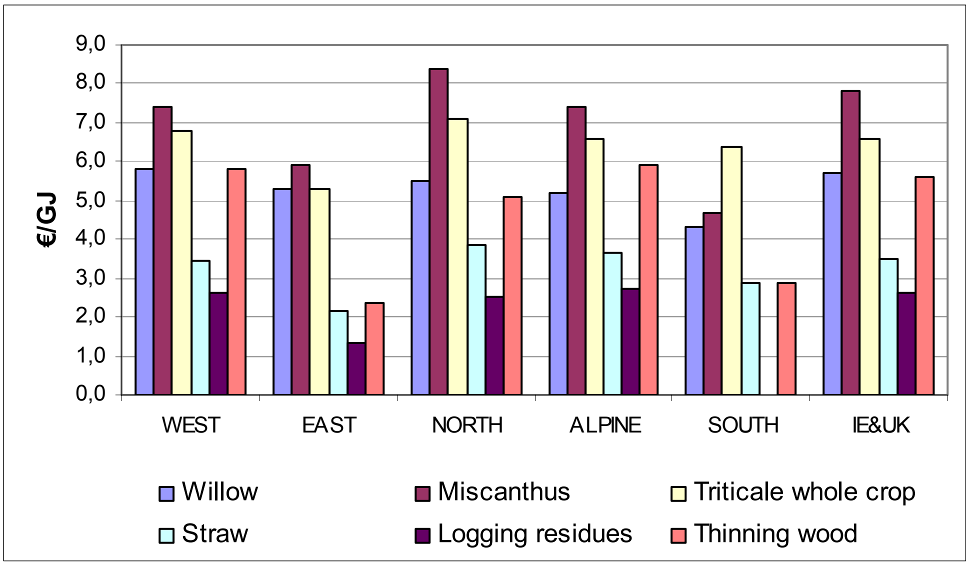

Figure 2-11 Cost of energy crops, straw and forestry residues for SP

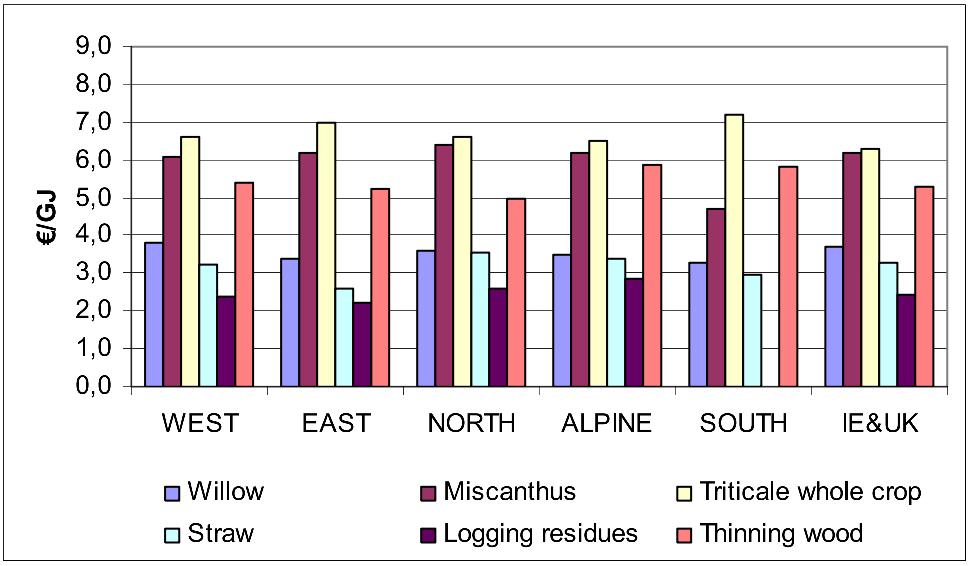

Figure 2-12 Cost of energy crops, straw and forestry residues for S1

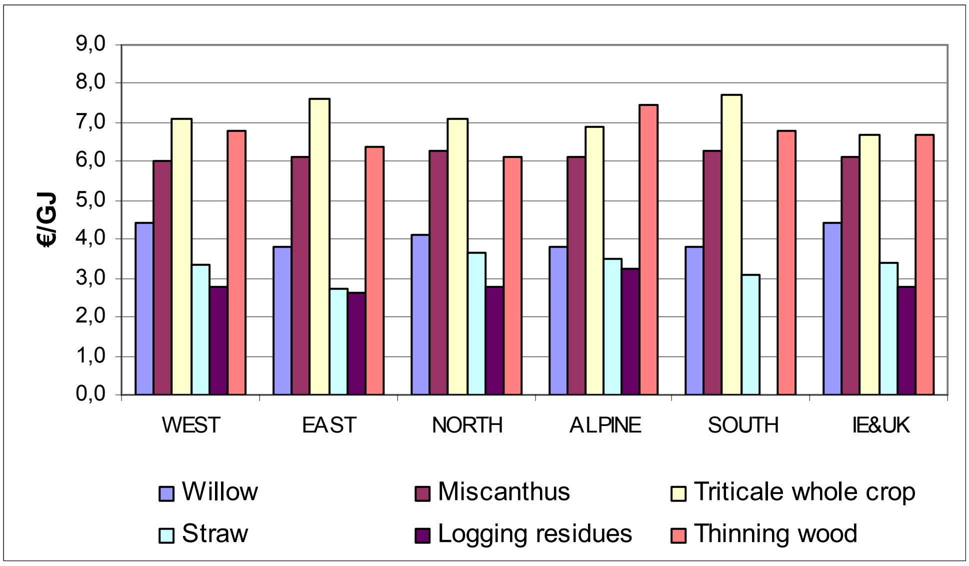

Figure 2-13 Cost of energy crops, straw and forestry residues for S2

Here is a comparison of the calculated biomass provision costs with costs in other existing studies. A review of energy crops production costs were presented in D5.3.3 *"Review on existing production cost studies. Energy crops in Europe"*. In the 22 previous studies most of the energy crops production costs ranged from 1.3 to 5.0 €/GJ. The studies differ in terms of yield assumptions, cost items included, cost levels, subsidies and discount rates. Under this deliverable energy crops costs are at the level of 5.2 to 8.4 €/GJ for the Starting Point. These figures apart from cultivation and harvesting costs include also provision costs, as well as storage, brokerage and land and risk costs, which were commonly excluded from the cost figures in the other studies.

Concerning forestry biomass provision costs comparison of costs with other studies may be unjustified due to very different forest types and felling systems across Europe. One reference for our calculation results can be the Finish study on forestry woodchips procurement by Hakkila (2004). Hakkila calculated the thinning wood costs at 3.2 to 10.8 €/GJ (thinning, forwarding, roadside chipping) in coniferous Scandinavian forests, dependant on stem volume. Under this deliverable thinning wood costs are calculated at 5.1 to 5.9 €/GJ for mechanized provision chain for the base case different regions in the EU. Logging residue costs have been estimated at 1.7 €/GJ by Hakkila. Under this deliverable logging residues costs are calculated at 2.5 to 2.7 €/GJ for the Starting Point (mechanized chain). The later figures are higher as they refer to different forest types than in Finland. A potential explanation of higher costs are lower logging residues yields per hectare in the rest of Europe compared to Scandinavia, where spruce stands are the most common and clear felling are performed. This factors make the logging residues procurement very efficient compared with mixed or broadleaved stands in the rest of Europe and selected felling technology.

3 BIOMASS PROVISION FROM THE FIRST GATHERING POINT (IEE)

In addition to the given results for the biomass provision to the 1st gathering point, the costs for the provision of selected biomass assortment from that gathering point to the BtL production plant will be analysed and calculated for the different European regions in the following. Therefore, starting with a brief refresh of the methodical approach (given in D 5.3.5) reference concepts and the basic assumptions will be introduced (chapter 3.1). Based on that, the biomass provision costs at the BtL plant will be calculated and the results will be discussed for the relevant present and future scenario (chapter 3.2).

3.1 Methodical approach

In the following only the most relevant aspects of the definition and methodical approach will be considered since additional information can be gathered from D 5.3.5.

3.1.1 Reference concepts

The definition of relevant reference concepts is made by integrating the provision criteria in an application-oriented calculation model. Figure 3-1 shows the general structure of reference concepts to be considered. The relevant provision criteria (i.e. biomass assortment, biomass demand and BtL plant site) are integrated as input data. In addition, criteria such as biomass treatment, means of transport and storage technology are coupled within the reference pathways. The parameter transport distance and storage volume are represented as output data.

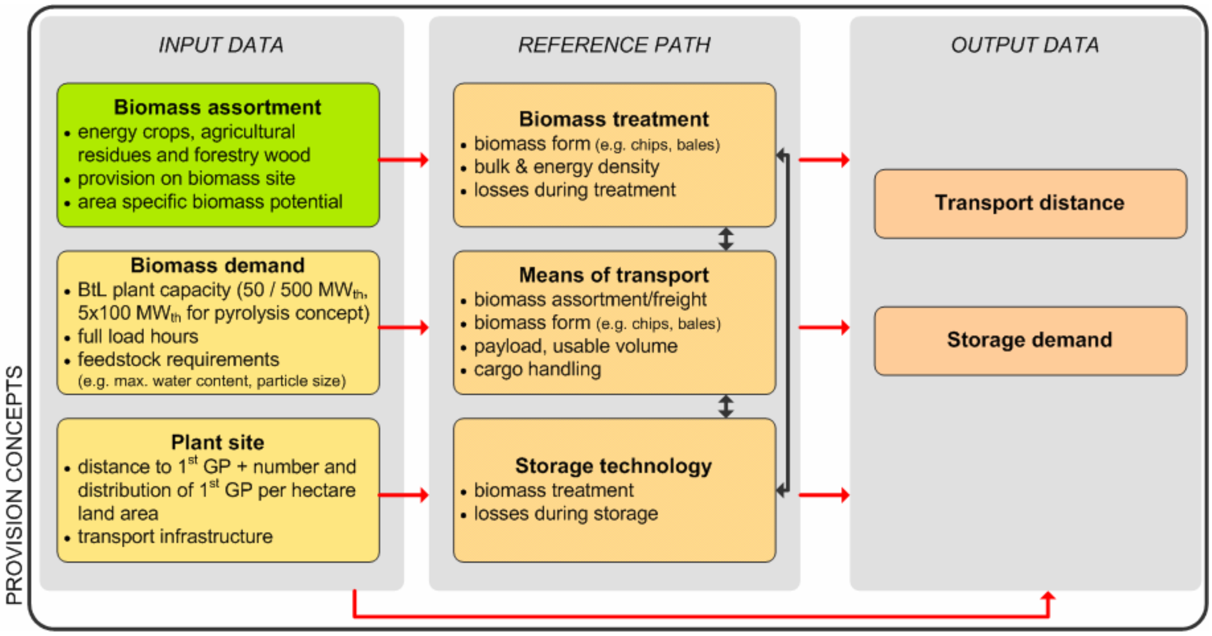

Figure 3-1 General structure of reference concepts

Based on the important provision criteria (i.e. area or region specific potential, biomass assortment, biomass treatment, means of transport, transport distance, storage technology and demand, biomass demand and plant site), there are a multitude of conceivable routes for biomass provision from 1st gathering point. With regard to the different BtL concepts in terms of the reference pathways two approaches will be investigated: (i) direct biomass provision and (ii) provision including decentral pyrolysis. The direct transportation (i.e. using a lorry or semitrailer respectively) from 1st gathering point to the BtL plant is the simplest way of biomass provision. Though to include decentralised provision steps increase the complexity of the biomass provision chain, it offers, however, to uncouple the respective requirements on biomass and demand site (see Figure 1-2). Thus, preliminary and downstream provision steps can be targeted to these requirements. In particular the pyrolysis step can be targeted to the requirements on biomass demand site. Local storages and pyrolysis plants are coupled by appropriate transport steps.

Figure 3-2 gives a survey of optional reference pathways. These pathways are structured into sections (alphabetical) and routes per section (numerical). Gathering points, such as for decentral or central storage, cargo handling (e.g. at a harbour or rail station) or decentral pyrolysis plant for biomass pre-conversion to pyrolysis slurry (see also Figure 3-2) are indicated as white rectangle; means of transportation are indicated orange.

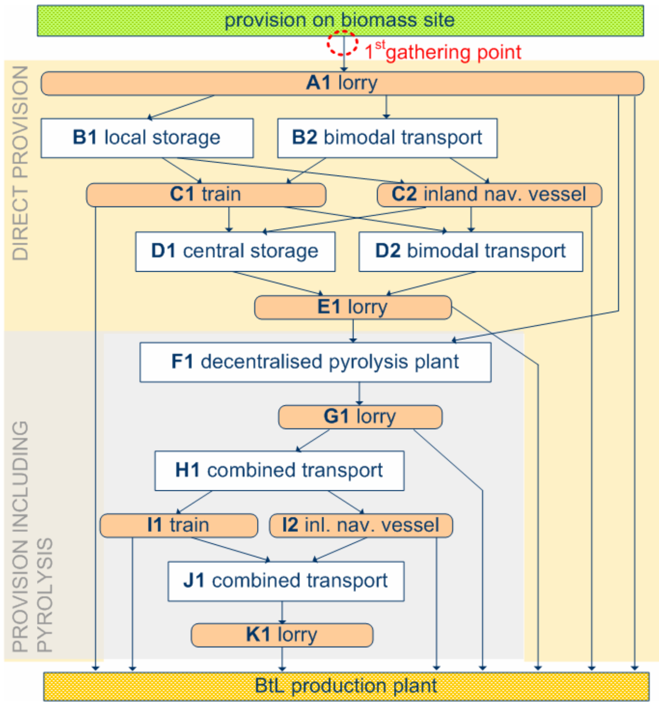

Figure 3-2 General reference pathways within the reference concepts

With regard to this, the reference concepts that are investigated in terms of biomass provision costs are summarised in Table 3-1 with practical relevance for the different European regions.

Table 3-1 Investigated reference concepts

European region	WEST	EAST	NORTH	ALPINE	SOUTH	UK+IR
Reference country	Germany[a]	Poland	Sweden[b]	Switzer- land[c]	Greece[d]	Ireland
DIRECT PROVISION PATHS						
Biomass assortments: wood chips (LR), wood chips (TW), wood bundles (LR + TW)[b], SRC chips (willow), miscanthus bales, triticale bales						
road direct (A1)	x	x	x	x	x	x
road-rail (A1-B2-C1)	x	x	x	x	x	x
road-rail-road (A1-B2-C1-D1-E1)	x	x	x	x	x	x
road-water (A1-B2-C2)	x					
road-water-road (A1-B2-C2-D1-E1)	x					
Biomass assortment: straw bales[c]						
road direct (A1)	x	x	x		x	x
road-rail (A1-B2-C1)	x	x	x		x	x
road-rail-road (A1-B2-C1-D1-E1)	x	x	x		x	x
PROVISION INCLUDING PYROLYSIS						
Biomass assortments: wood chips (LR), wood chips (TW), wood bundles (LR + TW)[c], SRC chips (willow), miscanthus bales, triticale bales, straw bales						
road-pyrolysis-road (A1-F1-G1)	x	x	x	x	x	x
road-pyrolysis-road-train (A1-F1-G1-H1-I1)	x	x	x	x	x	x

[a] The use of inland waterways is only relevant for Germany.
[b] The provision and use of wood bundles (LR+TW) is only relevant for Sweden.
[c] The provision and use of straw bales is not relevant for Switzerland.
[d] The provision and use of wood chips (LR) is not relevant for Greece.
[e] The provision of straw via inland waterway seems to be not meaningful.

The cost analysis for these reference concepts will be based on an elaborated calculation tool which is briefly described in the following section.

3.1.2 Calculation model

Biomass availability at the 1st gathering points

Based on the general approach (cf. Figure 3-1), the IEE has developed an approach for the calculation of the available amounts of the different biomass assortments at the 1st gathering points (i.e. number of 1st gathering points per total area land and biomass availability at one 1st gathering point) using a simplified circle model. Therefore, the biomass availability is a function of the catchment area of one 1st GP, the biomass production and single provision area as well as the number of them and the area specific potential (see Figure 3-3). In the next step, the regional specific availability of the different assortments at the 1st gathering points (cf. Figure 1-3) is incorporated into the calculation of the average transport distances and storage demand (cf. Figure 3-1).

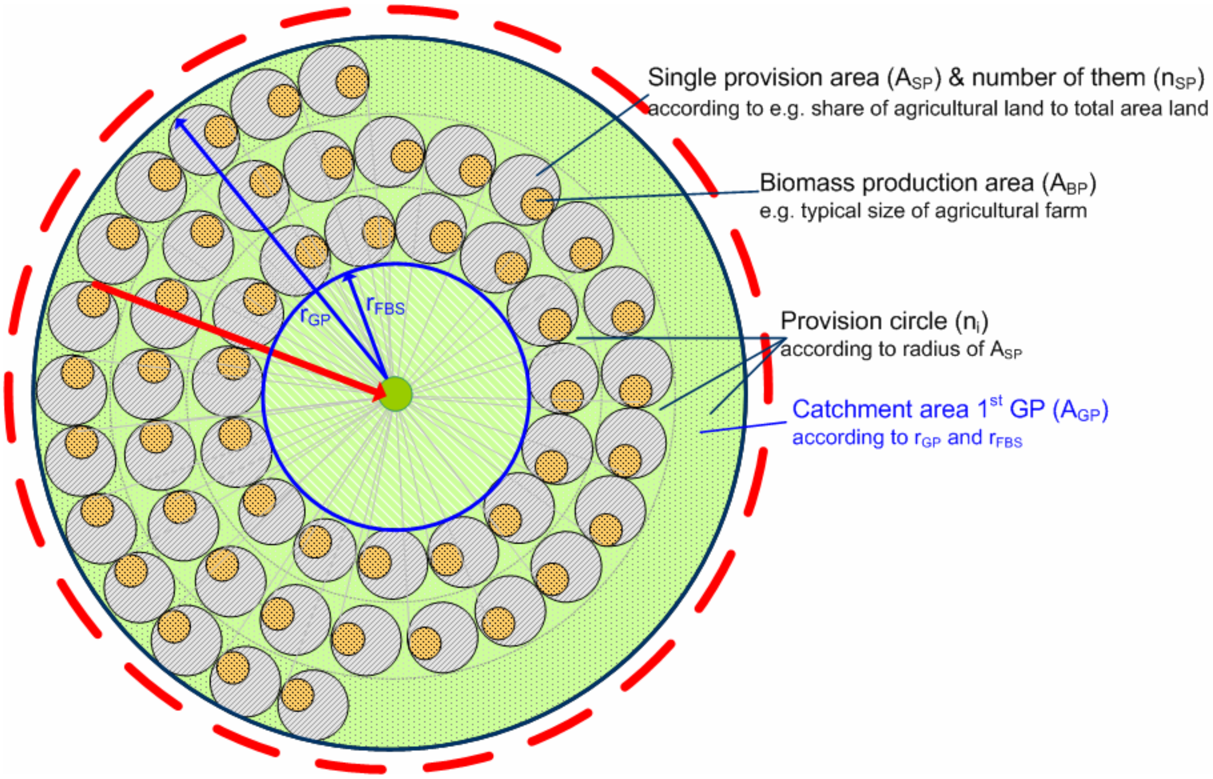

Figure 3-3 Provision model for biomass availability at the 1st GP (cf. also Figure 1-3)

<u>Provision cost calculation</u>

In the cost calculation model plant specific level are included for the different steps of the biomass provision to BtL production. The main principle of this model is shown in Figure 3-4. Relevant costs of each level are added or summarised respectively to total biomass provision costs (given in €/GJ_{LHV}). The comparison of these total costs of the different reference concepts will be categorised in (i) biomass production and provision to the 1st gathering point (see chapter 2), (ii) storage, (iii) transport, (iv) cargo handling, (v) pyrolysis, (vi) swap body for bimodal transportation as well as (vii) storage and pre-treatment of the biomass freight at the BtL plant site.

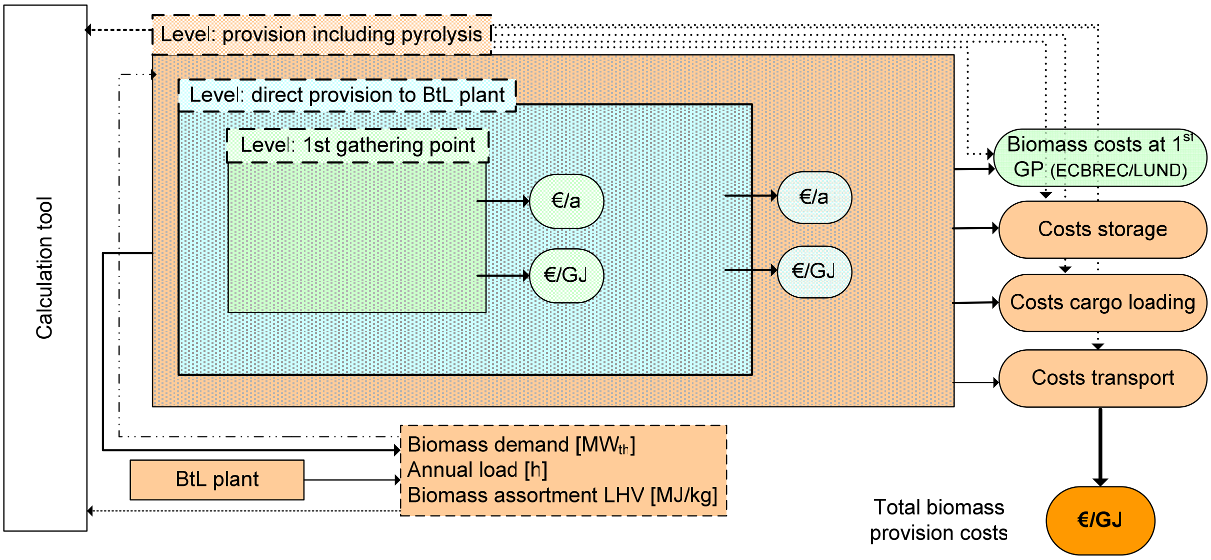

Figure 3-4 Calculation model – biomass provision cost at BtL plant

3.1.3 Basic assumptions and data base

For the calculation of the biomass availability as well as the provision costs from the 1st gathering point to BtL plant, the following assumptions were made:

* As the storage of agricultural residues, forestry wood and energy crops is among to the analysis of the 1st gathering point (cf. chapter 2.1), the biomass assortments are dehydrated during storage to the moisture content which will be received at BtL plant[4]. The average storage time is assumed to be about 6 month. For this time –depending on the type of storage (cf. chapter 2.1) – typical storage losses of dry matter are assumed (i.e. about 10 % for forestry wood and 15 % SRC chips, 3 % for miscanthus and triticale bales as well as 2 % for straw) and considered for the calculation of the biomass availability at the 1st gathering points.

[4] For woody biomass the moisture as received can be higher (i.e. 40 to 45 %) than the fixed moisture given in the RENEW scenario paper (30 %). However, it can be assumed that this will have no significant influence on plant performance since enough heat is available and simply the conveyer drier need to be adapted.

* The catchment area of the 1st GP (see Figure 3-3) depends on the distance between the place of harvesting and the place of storage (i.e. r_{GP}), which is assumed to be 30 km for energy crops, 15 km for agricultural residues and up to 1 km for forestry wood (cf. Figure 2-1). The radius to the first biomass site (r_{FBS}) is assumed to be 0 km; i.e. the area of available biomass starts nearby the storages.
* Logging residues and thinning wood are provided together in form mixed wood chips in containers (swap bodies), i.e. forestry wood is chipped at road site (relevant to costs at 1st gathering point) and loaded to the container (i.e. interface of cost calculations by ECBREC and IEE). SRC is provided as wood chips, miscanthus, triticale and straw in form of bales.
* Considering the provision paths including pyrolysis, only the costs provision of biomass to the pyrolysis plant and thence the provision of pyrolysis slurry are taken into account. The specific capital investment and O&M costs for the pyrolysis plant are counted among the calculation of the total biomass conversion costs (part of deliverable D 5.3.7). Thus, it is assured that only the provision-related costs are taken into consideration for all investigated reference concepts that enables the comparison of the these concept under equal frame conditions.
* The final biomass treatment is done at the BtL plants with regard to the different requirements of the specific concepts (e.g. UET, TUV/BKG, CUTEC, CHEMREC, FZK),
* The biomass input to be considered at BtL plant is about 50 MW_{th} biomass input for the TUV/BKG concept, about five pyrolysis plant of 100 MW_{th} biomass input each for pyrolysis (i.e. approx. 432 MW_{th} of pyrolysis slurry at the BtL plant) as well as 500 MW_{th} biomass input for the other BtL plants.

Assumptions for the analysis of the future scenarios S1 and S2 can be summarised as follows (cf. D 5.3.5):

* Different to biomass production (particularly of energy crops), for biomass provision from the 1st gathering point only effects (e.g. through technical development, prospected price evolution) will be considered that will cause a reasonable change of provision cost parameters.
* For the scenario S1 an overall state of the art is expected in all Member States; a significant modification of that biomass provision chains are not expected (e.g. a doubling of transportation fuel costs is only of minor influence to the total provision costs and thus to the BtL production costs). For the scenario S2 it is assumed that BtL is used as transportation fuel.

The used data base comprehends the

* technical biomass potentials for selected biomass assortments from ECBREC (cf. Annex 2 (to chapter 3) – Data base),
* country specific data on infrastructure (e.g. detour factors, connection points, available

land), technical and cost data e.g. for means of transport, storage, cargo handling from the WP 5.3 partners and – if adaptations and completions were required – from IEE (cf. Annex 2 (to chapter 3) – Data base),

* biomass provision costs of agricultural and forestry residues from ECBREC (cf. Annex 1 (to chapter 2) – Provision costs at 1st GP) as well as
* biomass production and provision costs of energy crops from LUND (cf. D 5.3.4, Table 2-2 et seqq.); thereof the best cost alternatives per European regions are applied, since it can be assumed that biomass assortments available at these costs will primarily be used.

3.2 Biomass availability at 1st gathering points

One of the most important criteria for biomass provision is the regional specific biomass availability expressed by means of the area or region specific potential (i.e. the technical biomass potential provided by WP 5.1, ECBREC per region specific area land, cf. Table A2-0-1) that is given for the different European regions and scenarios (Figure 3-5). Due to the defined frame conditions within the cost assessment average values at country level (as reference of the respective EU regions) are given; i.e. at a higher regional level (e.g. territorial units such as federal states or provinces) a higher region specific potential can be available (e.g. up to approx. 1.45 t_d/(ha a) for agricultural and forestry residues and up to approx. 3.3 t_d/(ha a) see D 5.1.7, D 5.1.8)

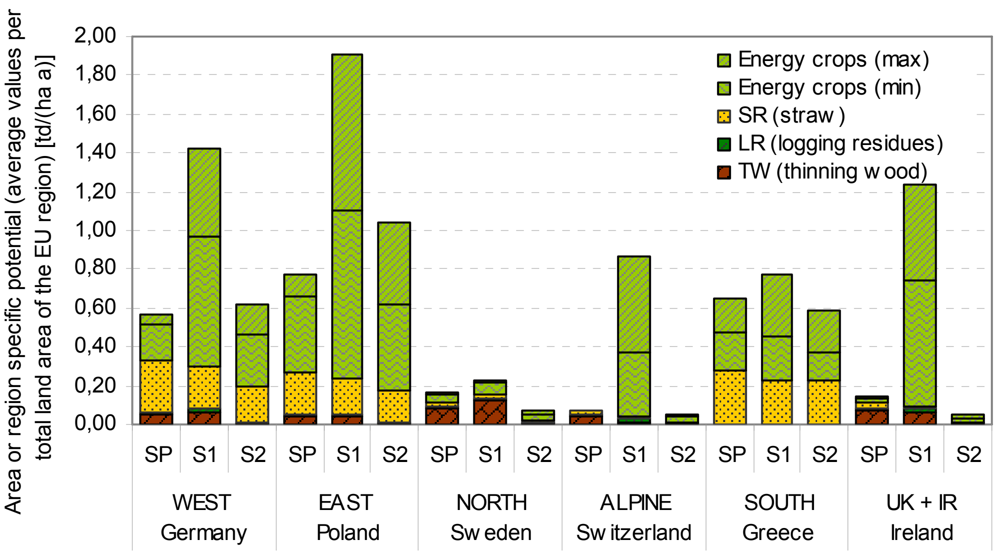

Figure 3-5 Area or region specific biomass potentials per EU region

From the SP to the S1 there will be a significant increase of technical biomass potentials in all regions. However, the biomass potential is – partly dramatically – lower if comparing S1 and S2. The regions WEST and EAST show the highest potentials. The major proportion of the potential is provided by the energy crops (i.e. willow, triticale, miscanthus, except for SOUTH, where switch grass and eucalyptus are used) which are shown in minimum and maximum values. This is due to technical potentials for the energy crops to be considered for the calculation of biomass provision costs are alternative options and cannot be accumulated, since they use the same agricultural land.

Based on that potentials and basic assumptions regarding typical distances from biomass site to the 1st gathering point (cf. chapter 3.1.3), the results of the biomass availability at the 1st gathering points are given as follows for the different biomass assortments and scenarios (Figure 3-6, Table A2-0-4 et seqq.).

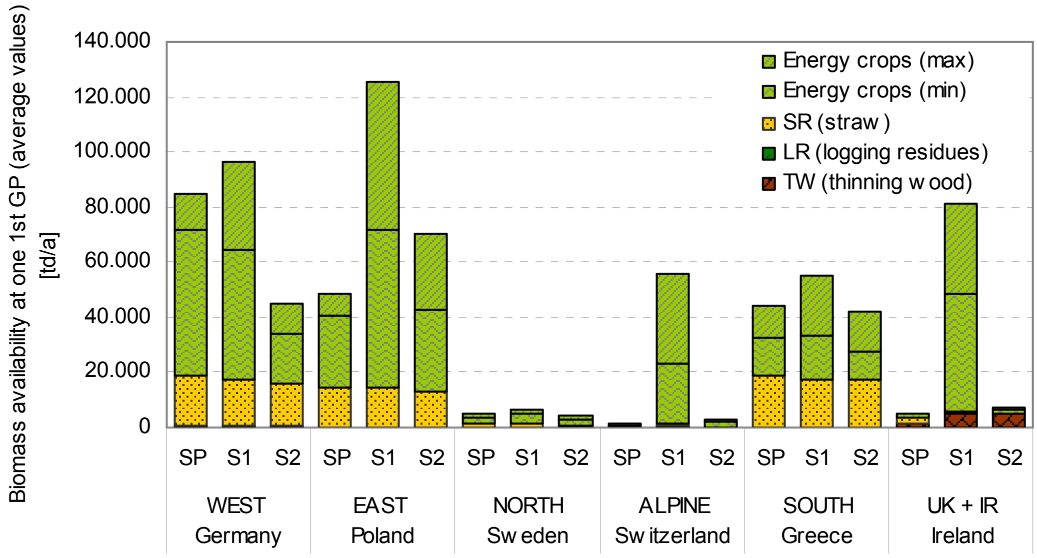

Figure 3-6 Biomass availability at one 1st gathering point

3.3 Provision costs at the BtL plant

With regard to the comprehensive results coming from costs for six different regions, six different biomass assortments, direct and indirect biomass provision pathways with two to five different logistic concepts exemplarily results of the cost calculation are given as follows. The whole results can be gathered from Annex 2 (to chapter 162H3), Results.

When comparing the results for the different European region the biomass provision costs from 1st GP to BtL plant are primarily influenced by the following parameters/aspects:

* The area or region specific biomass potentials (cf. Figure 3-5) and infrastructure aspects (e.g. detour factors, connection point/distribution of freight depots for cargo handling from e.g. road to rail or road to harbor) per European region are relevant, that have a strong impact to regional specific transport distance and thus to the transport costs (e.g. comparibly very small area or region specific straw potentials in the SOUTH and accordingly higher transport distances).
* The biomass provision costs at the 1st gathering point are one of the main total cost impacts that differ for the investigated scenarios (SP, S1, S2) based on the assumptions and regional frame conditions (cf. chapter 2). For the consideration of the share of these costs to the total provision costs at the BtL plant it should be noted, that these costs can be vary from logistic concept to concept since in addition to the storage

losses at the 1st gathering point also losses during transportation (e.g. as bulk or in containers) are taken into account.

* The data base given by the WP 5.3. partners for the different EU regions (such as regarding transportation means, cargo handling, storage) and therefore e.g. strong impact to the load and costs of transportation means (i.e. semi trailer with container for chips, pallet for bales or swap body for slurry) and thus the frequency of movements and finally the resulting transport costs.

3.3.1 Starting point (base case)

The direct biomass provision via direct road transport is one of the most often applications in practice, which is shown as follows for the different biomass assortment groups „residues" as well as „energy crops" for the investigated regions as well as the different relevant BtL plant capacities (cf. chapter 3.1.3).

Agricultural and forestry residues

The variation of total provision costs for agricultural (straw) and forestry residues (wood chips and bundles) is between 3.04 and 21.01 €/GJ_{LHV} (Figure 3-7). They increase with BtL plants capacity. Depending on the region (area or region specific potentials and infrastructure aspects) the total provision costs are typically dominated by the biomass costs at the 1st gathering point. These cost parameter increases when pyrolysis is applied and thus – in addition to the storage losses – also losses due to the pyrolysis conversion efficiency have been taken into account. Moreover, primarily due to the increased energy density of pyrolysis slurry (when compared to the direct provision), overall transport costs can be slightly reduced (although the bulk of the costs incur for straw provision free pyrolysis plant) while cargo handling costs increase. As already mentioned, the transport costs are basically caused by the following parameters: (i) means of transport, their load and associated costs and thus the frequency of movements, (ii) area or region specific potentials of the different biomass assortments and thus the average transport distance between the 1st GP and the BtL plant.

If focus is set on road transport, for the European regions the following can be revealed (see Figure 3-7):

* For direct road transport from the 1st gathering point to the BtL plant no additional storage costs accumulate.
* In EAST, followed by WEST, agricultural and forestry residues can be provided at favourable costs (approx. 3 to 10 €/GJ_{LHV}). Transport costs are comparatively low primarily due to higher area or region specific potentials (cf. Figure 3-5) and thus lower transport distances.
* This is partly true for NORTH (approx. 6 to 11 €/GJ_{LHV}). Only there wood bundles are provided. Due to lower area or region specific potentials for straw transport distances and therefore transport costs are significantly higher.

* Higher costs are also shown for the ALPINE, SOUTH and UK+IR regions (approx. 7 to 21 €/GJ_{LHV}). Whereas higher provision costs – especially for straw – are caused by unfavourable straw potentials in ALPINE and UK+IR, the reason for the high costs in SOUTH is the below average transport load of the semi trailer (cf. Table A2-0-3).

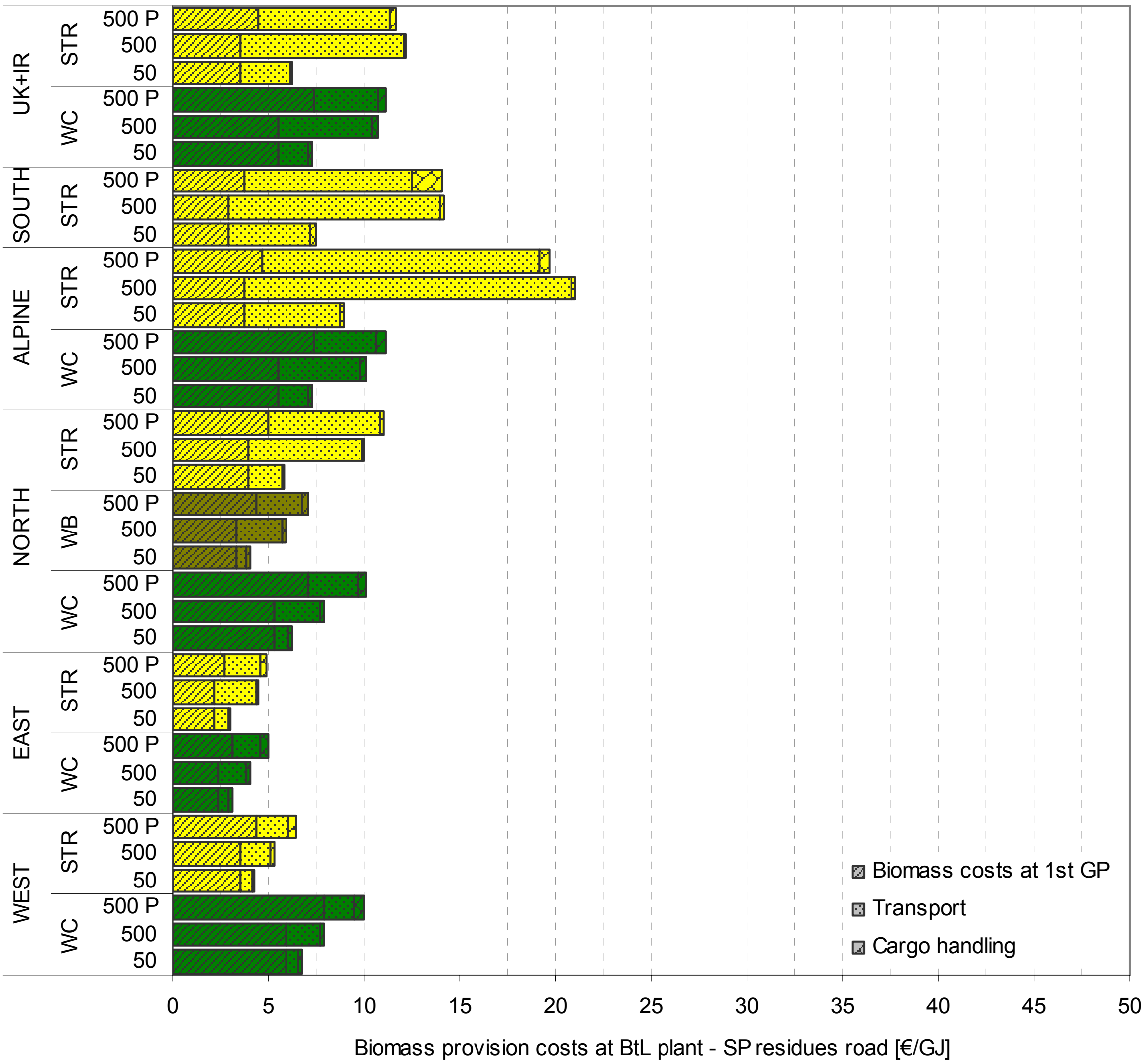

Figure 3-7 Total provision costs at BtL plant (SP) – road transport of residues (WC/WB, STR)

In order to identify the main differences regarding the means of transportations, results are shown in the following for a 500 MW_{th}-plant for straw via direct provision and using pyrolysis (Figure 3-8). For the investigated regions one can conclude:

* At WEST and EAST frame conditions the total provision costs at BtL plant slightly increase with the rising complexity of the logistic concepts (e.g. from direct road to road-rail-road). While transport costs can be reduced due to a higher load of trains compared to semi trailers (especially in case of EAST), cargo handling costs increase. This is also true for the provision chain including pyrolysis. Due to the higher bulk density of pyrolysis slurry (cf. Table A2-0-2) and more favourable conditions for train use, in the EAST total provision costs for pyrolysis slurry are similar to direct

provision costs. These effects cannot be seen for WEST as the biomass provision costs at the 1st GP are higher.

* In the other European regions the total provision costs fall with increasing complexity of the logistic concept as the rail transport is more favourable compared to the road transport. Reasons for that are e.g. unfavourable straw potentials, worse load of semi trailers at partly higher investment and O+M costs. This effect cannot be seen for UK+IR for pyrolysis slurry provision costs via rail since the load of the train is worse so that the cost reduction in transport is only limited when compared to road transport.
* In NORTH and ALPINE that are characterised by only low straw potentials (cf. Figure 3-5) significantly higher storage costs incur due to a worse load of storage capacities as well as 1st gathering points per ha.

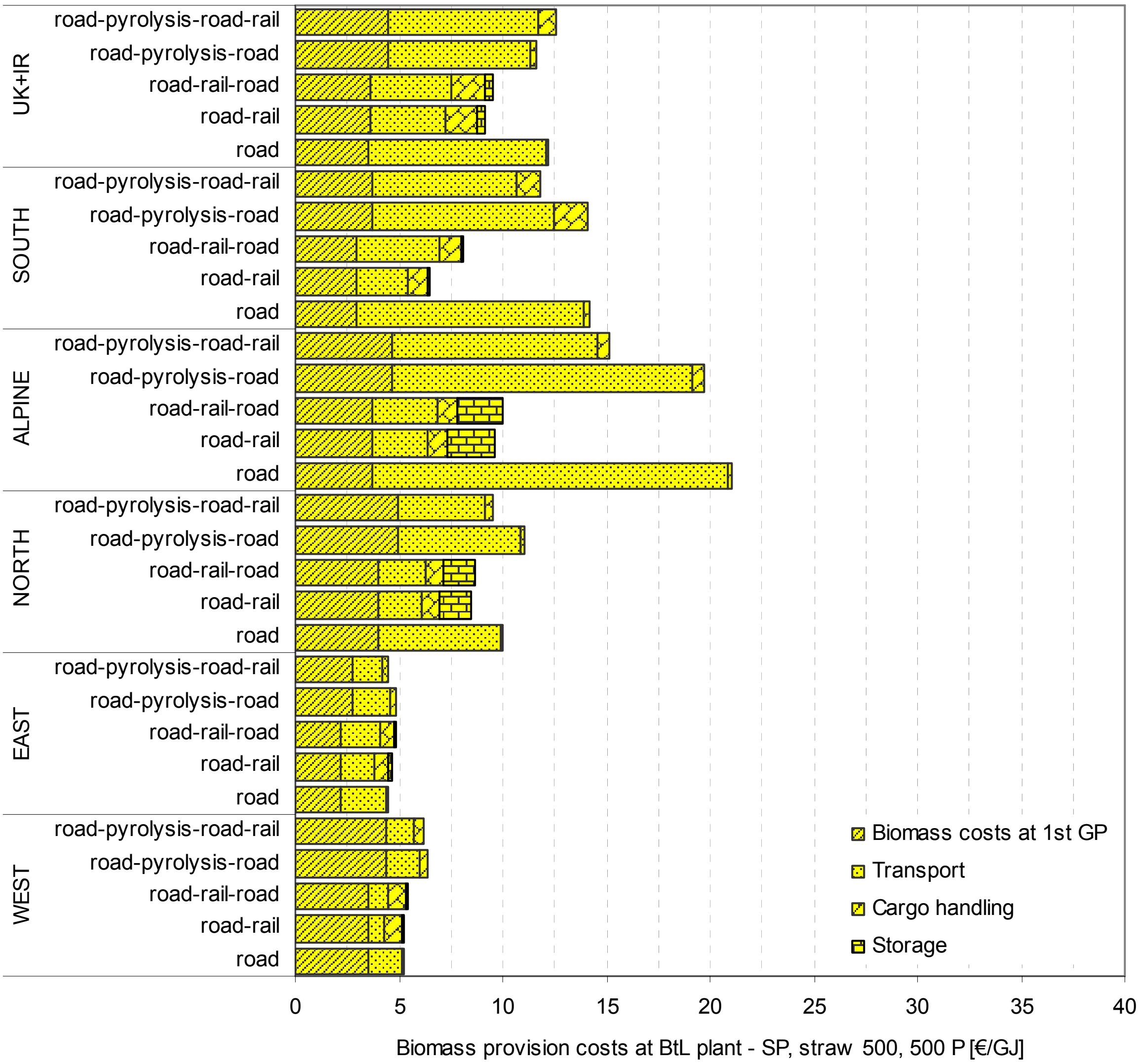

Figure 3-8 Total provision costs at BtL plant (SP) – straw, 500 MW_{th} (500, 500 P)

Energy crops

Compared to the costs for residues, the total provision costs of energy crops (focus road transport) are significantly higher (6.65 to 46.22 €/GJ$_{LHV}$), this is especially true for the ALPINE region, where the costs are in the range of 17 to 46 €/GJ$_{LHV}$ (Figure 3-9). Basically the same parameter and tendencies are valid for the different regions as already discussed above for the residues. Favourable costs are shown for WEST, EAST and NORTH (approx. 7 to 18 €/GJ$_{LHV}$). For SOUTH the relevant energy crops are eucalyptus (EUC) and switch grass (SWG) instead of short rotation coppice and miscanthus, provision costs range between 8 to 32 €/GJ$_{LHV}$. The total provision costs for energy crops in UK+IR are about 12 to 36 €/GJ$_{LHV}$.

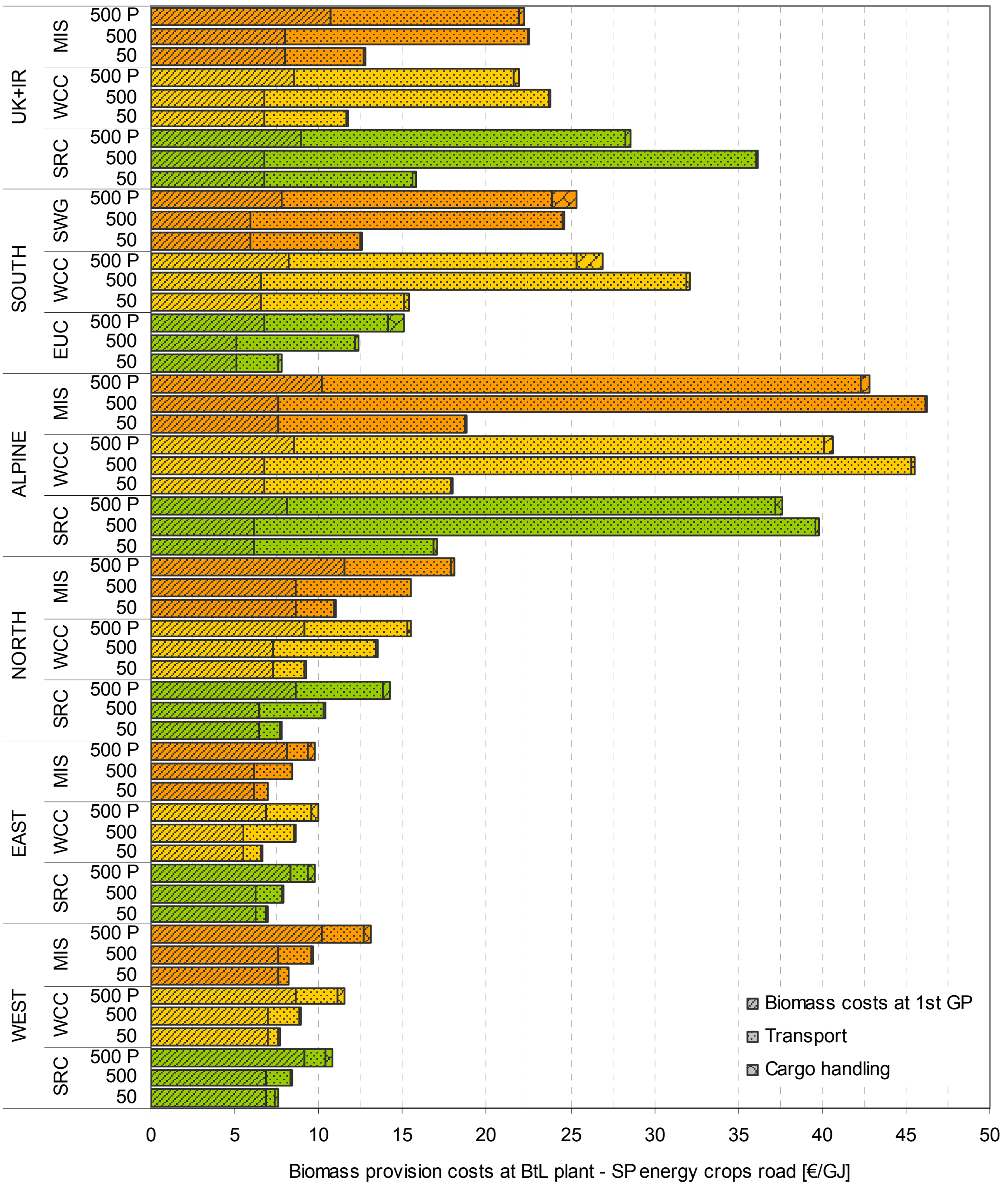

Figure 3-9 Total provision costs at BtL plant (SP) – road transport of energy crops (SRC, MIS, WCC)

Main differences concerning the means of transportations are shown in the following for a 500 MW_{th}-plant for SRC (willow salix) via direct provision and using pyrolysis for the considered regions (Figure 3-10).

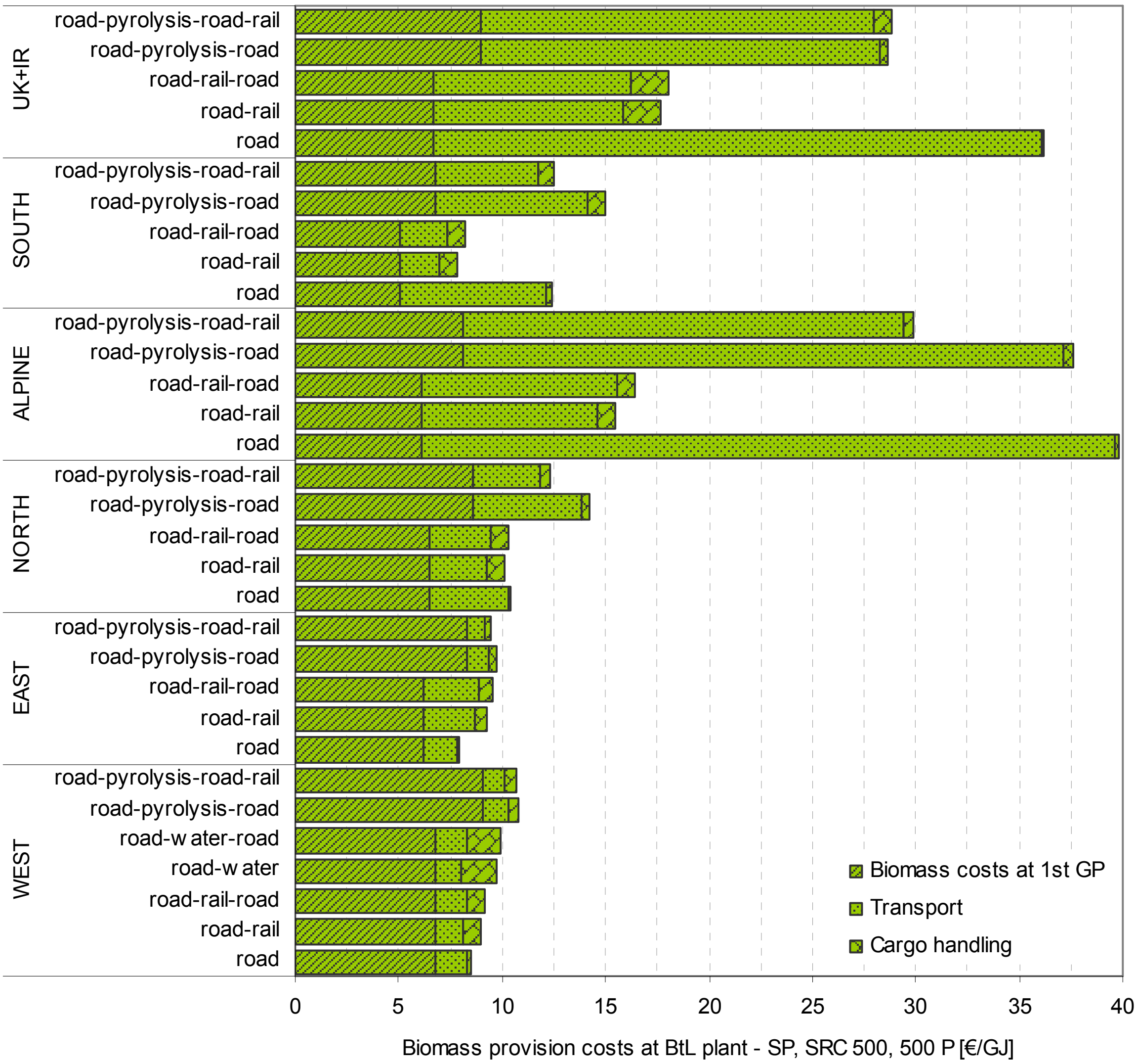

Figure 3-10 Total provision costs at BtL plant (SP) – SRC, 500 MW_{th} (500, 500 P)

Due to the fact that swap bodies (container) are applied for the provision of SRC chips, it is assumed that no additional storage costs incur. For the investigated regions the results can be discussed as follows.

* At WEST and EAST conditions (cf. Table A2-0-3) total provision costs increase with the rising complexity of the logistic concepts (e.g. from direct road to road-pyrolysis-road). This is basically due to increasing costs for cargo handling. However, whereas the transport costs in WEST fall due to a better load of trains and inland water vessels compared to semi trailers, the transport costs in EAST also increase due to a comparatively lower siding tracks for cargo handling from road to rail (and therefore larger distances of more transport cost intensive road transport).

* For NORTH, ALPINE, SOUTH and UK+IR the rail transport is more favourable as road transport. Reasons for that are e.g. unfavourable SRC potentials, bad load of semi trailers at partly higher investment and O+M costs.

3.3.2 Future scenarios (S1, S2) in comparison

Future biomass provision costs at the BtL plant are basically influenced by the differences in the provision costs at the 1st GP as well as the differences regarding the biomass potentials and thus the area or region specific potentials. The results are exemplarily summarised as follows for different biomass assortments[5] of the scenario paper (Figure 3-11 et seq.), as the main diversity between the EU regions as well as the considered BtL plant capacities persist. The complete results can be gathered from Annex 2 (to chapter 162H3), Results.

<u>Agricultural residues</u>

According to the assumed frame conditions (e.g. increasing biomass potentials, differences in biomass provision costs at the 1st gathering point, cf. Annex 1 (to chapter 2) et seq.) for straw provision the following can be concluded:

* For both scenarios (S1, S2) an increase of the total straw provision costs can be expected in EAST (11 to 27% compared to SP), SOUTH (1 to 3%) and UK+IR (39 to 53%). However, there is no straw available in the UK+IR within the S2.
* This is only partly true for WEST and NORTH; here the costs decrease slightly from SP to S1 about 4 to 5% or 3 to 6% respectively and rise from SP to S2 about 1 to 7% or 3 to 7% respectively.
* For the ALPINE, where no straw is available at S2, the total provision costs also decreases about 2 to 6%.
* In total the cheapest straw provision can be expected for the EAST region

[5] In addition to miscanthus, straw and willow (SRC) are fixed as reference feedstocks within the scenario paper of SP5.

(3.00 to 6.70 €/GJ_{LHV}).

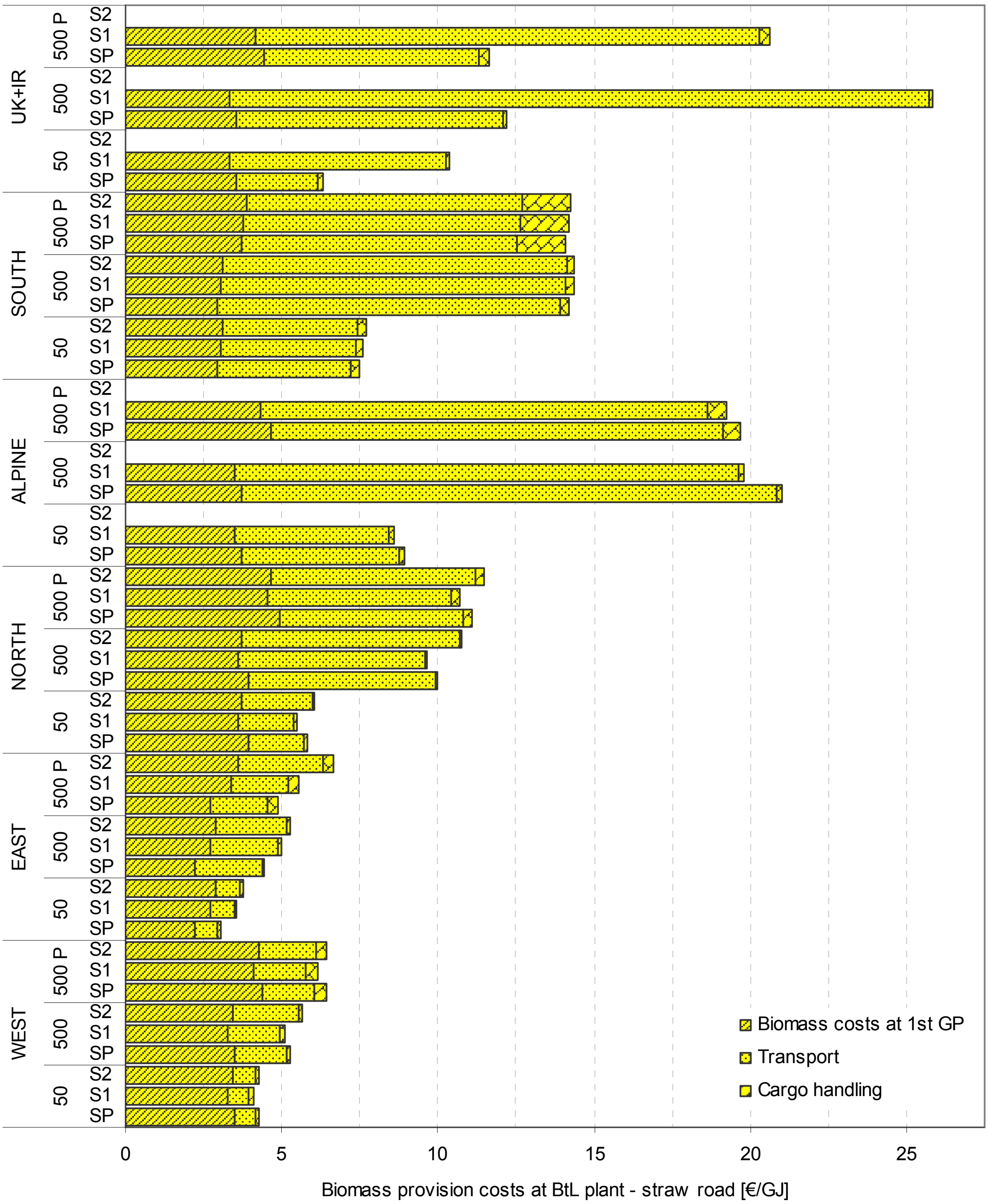

Figure 3-11 Total provision costs at BtL plant – scenario comparison, straw road transport

Energy crops

Regarding the development of costs in the different scenarios the results for SRC (in SOUTH EUC) show the following aspects (cf. Figure 3-12):

* The total provision costs are significantly higher compared to straw. In total, the cheapest SRC provision can be expected for the EAST (4.50 to 9.70 €/GJ_{LHV}).
* Different to straw, the total provision costs will be reduced for both scenarios (S1, S2). However, the cost reduction potential from SP to S2 will be higher when compared to that from SP to S1: WEST (38 to 45% and 1 to 18% compared to SP), EAST (44 to 55% and 10 to 40%), NORTH (42 to 45% and 14 to 25%), ALPINE (175 to 307% and 71 to 105%) and SOUTH (15 to 28% and 3 to 6%). This is basically due to the significantly lower area or region specific biomass potential of energy crops in S2 (Figure 3-5) and thus higher transport distances as well as related costs.
* For UK+IR the total provision costs are expected to decrease from SP to S1 (about 160 to 250%), but will slightly increase to the S2 (up to 3.5%).

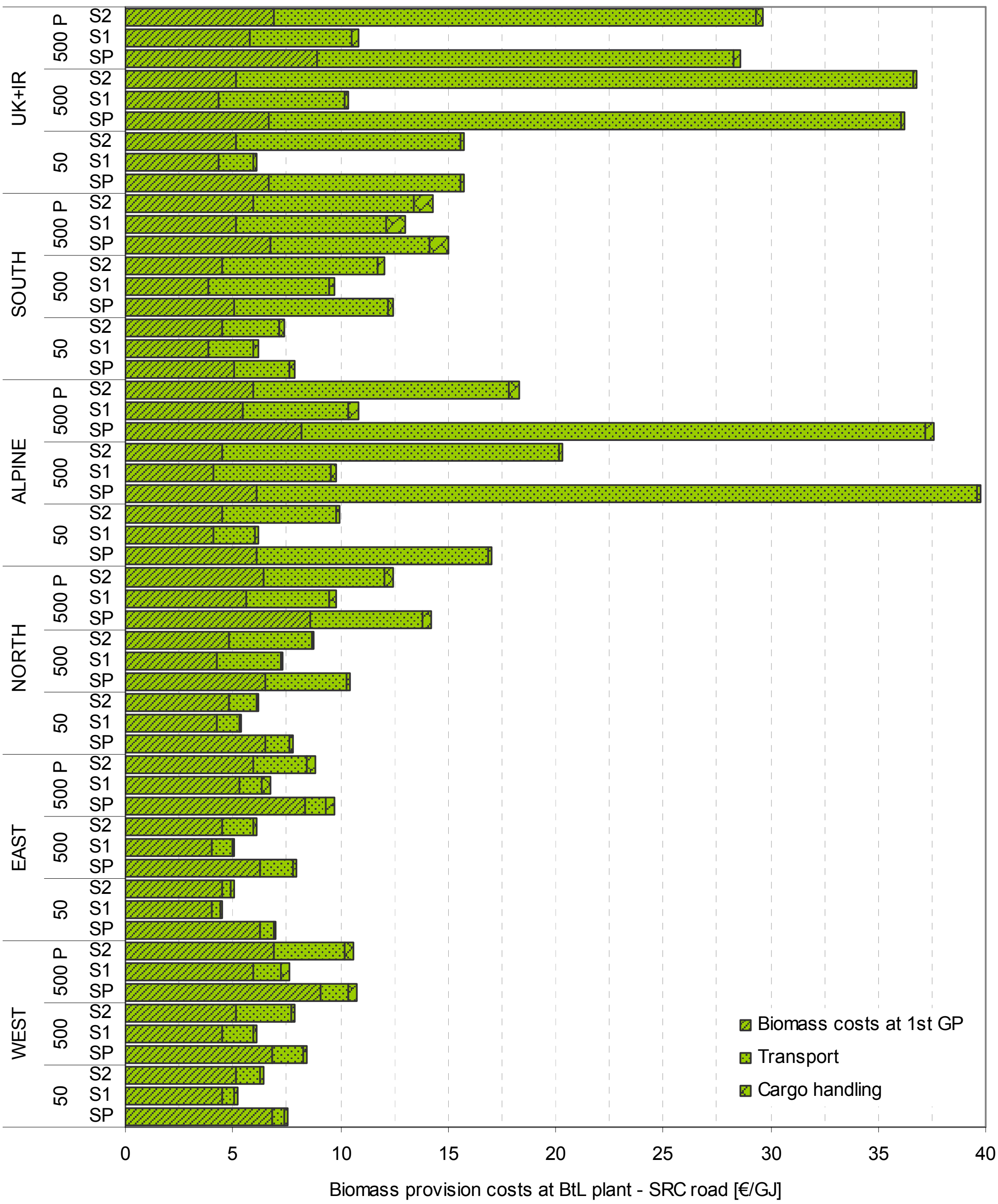

Figure 3-12 Total provision costs at BtL plant – scenario comparison, SRC, EUC for SOUTH road transport

For miscanthus (in SOUTH switch grass) basically the same is valid as for willow (Figure 3-13).

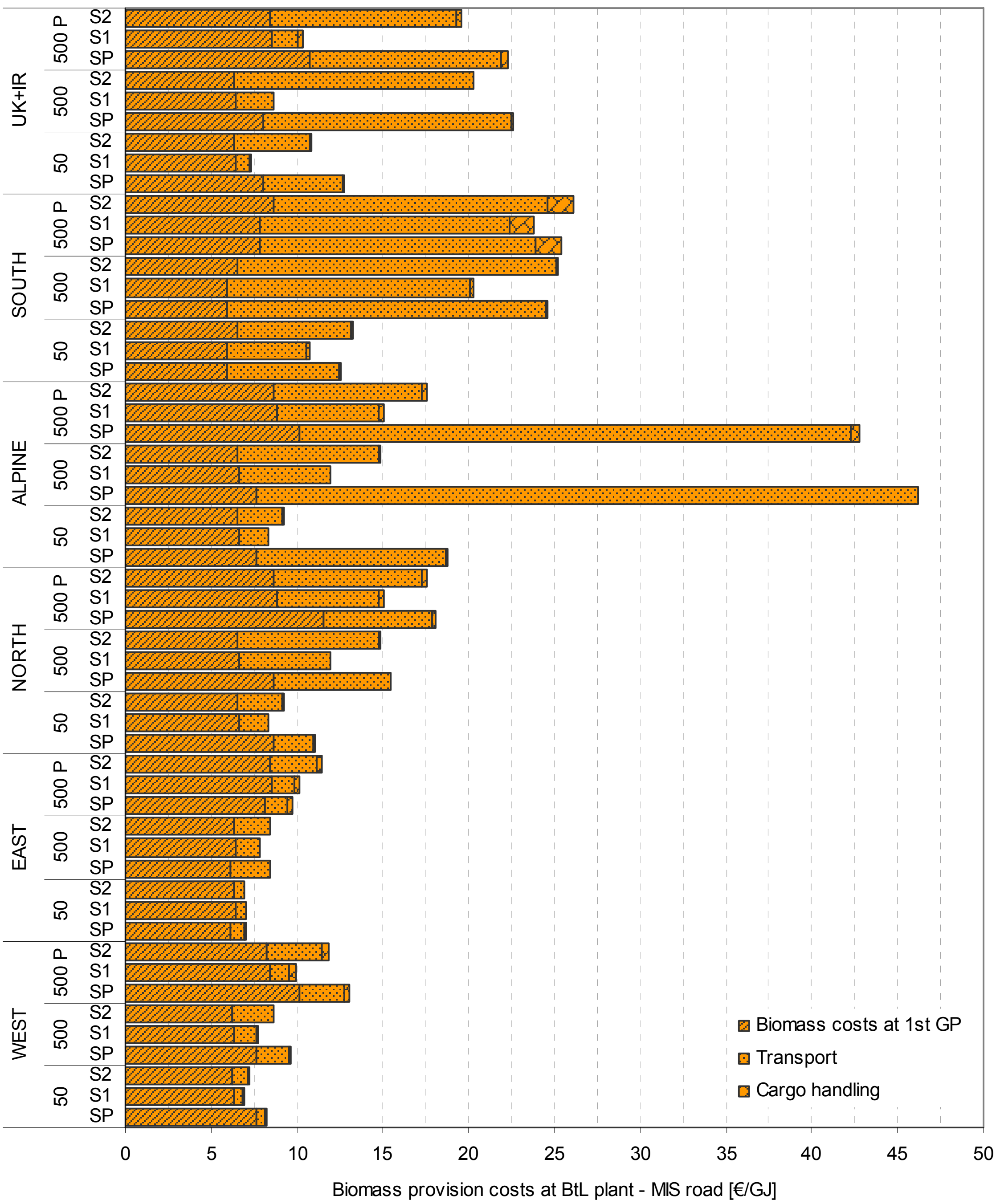

Figure 3-13 Total provision costs at BtL plant – scenario comparison, MIS, SWG for SOUTH road transport

3.3.3 Exemplarily sensitivity analyses

With regard to the fact that biomass provision costs from the 1st gathering point to the BtL decrease with increasing area or regional specific potentials exemplarily sensitivity analyses were made. The results are summarised as follows for the future scenario S1 for road transport as well as combined road-rail-transport for a BtL plant of 500 MW_{th}. The graphs allow the reader to estimate the provision costs from the 1st GP to the BtL production plant in different regions with area or regional specific potentials that are different from the average case investigated within the RENEW frame conditions for cost assessment. Moreover, the results that are used for providing simplified trend lines (see below) can be also gathered from Annex 2 (to chapter 3).

According to this, the biomass provision costs from the 1st GP to the BtL plant significantly can be reduced in region of high biomass potentials. This is due to the decreasing transport distance (cf. Figure 3-3) per transported tonne of biomass and thus reduced transport costs (i.e. especially with regard to fuel demand and annual driven km per means of transport). However, the cost reduction is limited (cf. Table A2-0-19 et seq.) since the basic frame conditions (i.e. infrastructure, specific payload per means of transport and thus the number of e.g. semi trailers, cargo handling and storage demand) will be the same independent of the area or region specific biomass potential. Thus, when comparing the different European regions the (partly significant) differences in provision costs still remain.

Agricultural residues

The results for straw (as reference for an herbaceous biomass transported in form of rectangle bales) are simplified shown in form of potential trend lines in Figure 3-14 et seq.; moreover average values per EU region are given.

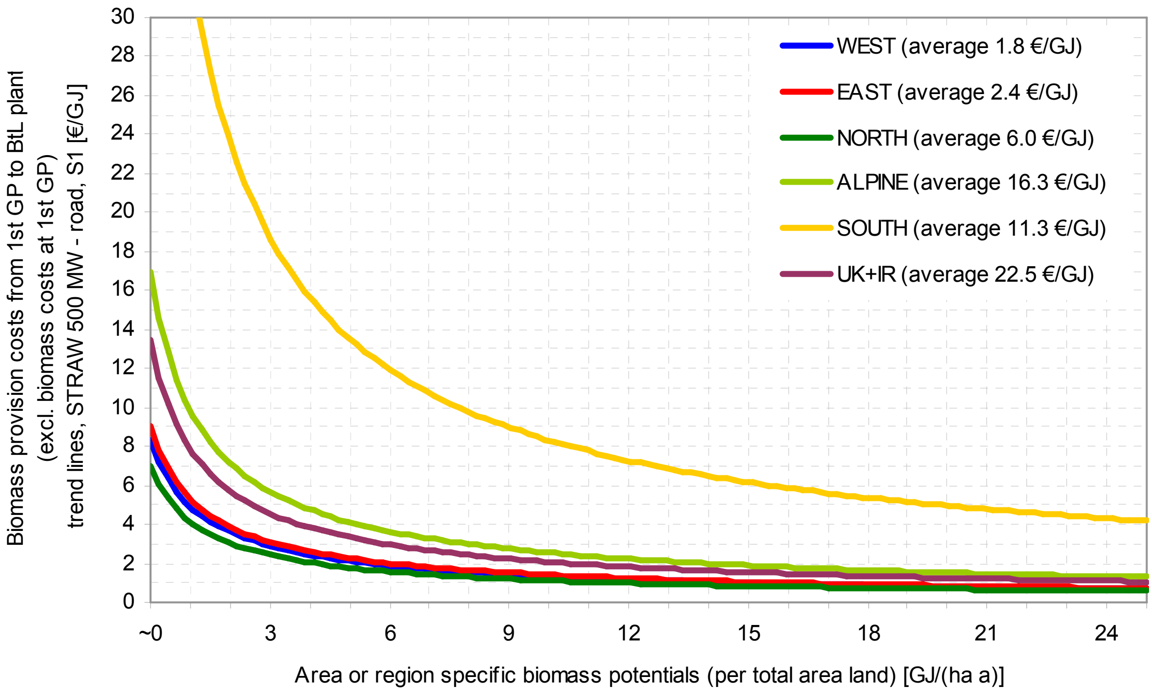

Figure 3-14 Provision costs vs. area or region specific potentials – straw, road, S1

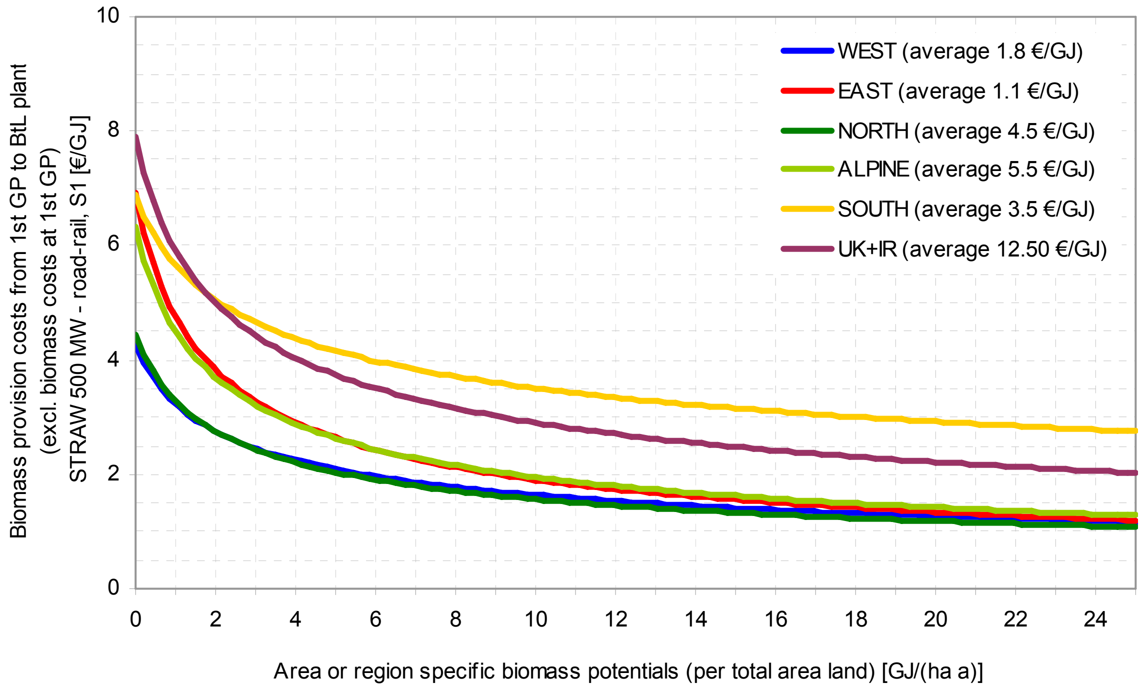

Figure 3-15 Provision costs vs. area or region specific potentials – straw, road-rail, S1

<u>Energy crops</u>

The results for willow (as reference for a woody biomass transported as wood chips) are simplified shown in form of potential trend lines in Figure 3-16 et seq.; moreover average values per EU region are given (cf. Table A2-0-20).

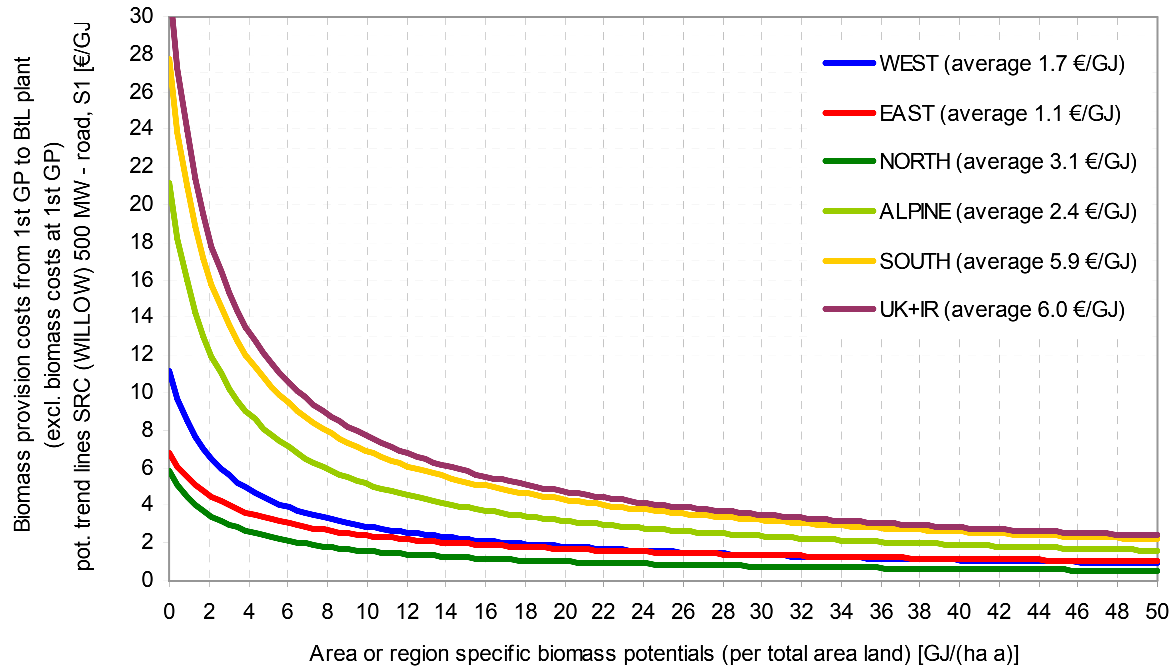

Figure 3-16 Provision costs vs. area or region specific potentials – willow, road, S1

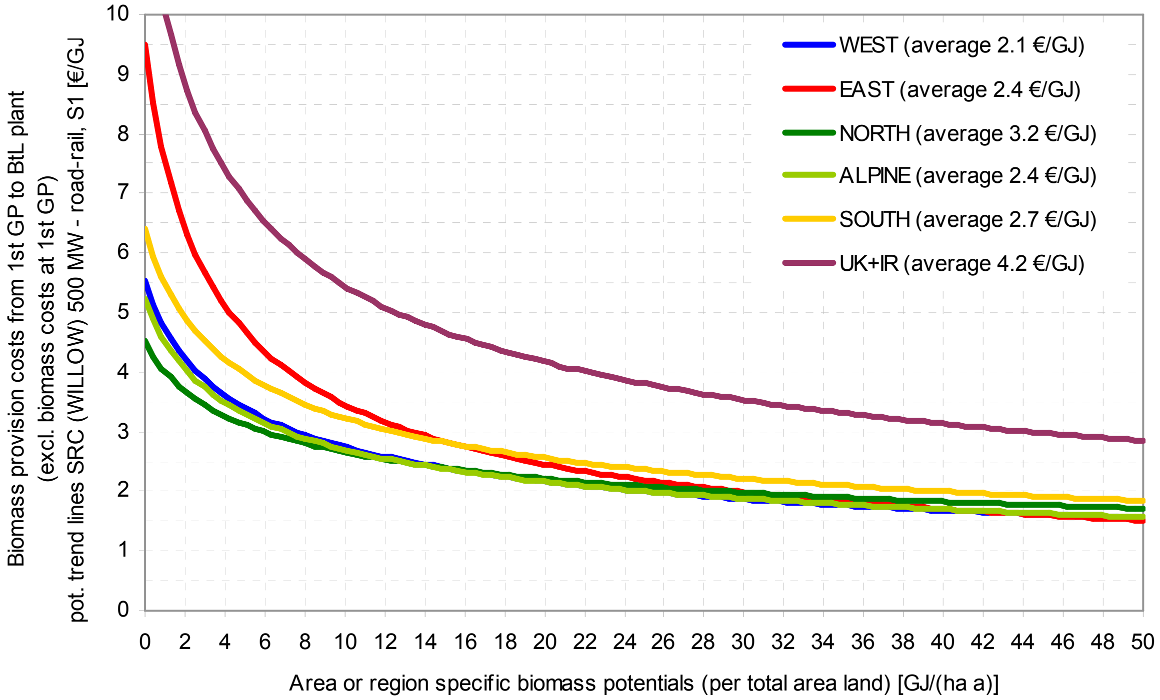

Figure 3-17 Provision costs vs. area or region specific potentials – willow, road-rail, S1

4 SUMMARY

For the cost efficient production of BtL-fuels the feedstock costs free BtL plant are one of the most important factors. Therefore, within this subtask biomass provision costs have been investigated and calculated for defined provision chains (logistic concepts) for different biomass assortments, different European regions as well as different scenarios. These concepts are divided into two main stages: (i) from production site up to the 1st gathering point (performed by EC BREC) and (ii) from the 1st gathering point to the processing plant (performed by IEE). The results of the different cost analysis have been summarised within this deliverable. From that the following conclusions can be revealed:

* Depending on the scenarios and European region the costs at the 1st gathering point vary between 2.20 to 3.90 €/GJ_{LHV} for straw, 1.30 to 2.90 €/GJ_{LHV} for logging residues and 2.40 to 7.50 €/GJ_{LHV} for thinning wood as well as 3.30 to 8.40 €/GJ_{LHV} for energy crops.
* For forestry residues (i.e. thinning wood and logging residues) provision costs at the 1st gathering point are dominated by the cutting and/or forwarding to road site. The costs for the provision of agricultural residues (i.e. straw) are primarily influenced by the expenditures for fertiliser (NPK value), balling and storage.
* One of the important factors when investigating logistic concepts and related costs are the biomass availability in the specific regions (here also at the 1st gathering point). Basically, the regions WEST and EAST show the highest potentials. The major proportion of the potential is provided by the energy crops (i.e. willow, triticale, miscanthus, except for SOUTH, where switch grass and eucalyptus are used). These potentials increase significantly from SP to the future S1; however, when comparing S1 and S2 the potentials are partly dramatically lower.
* With respect to the scenarios and regional specific conditions the calculated total provision costs at the BtL plant are in a wide range (cf. Table 4-1). Regions with favourable costs are e.g. EAST, WEST as well as partly NORTH. They are primarily dominated by the biomass provision costs at the 1st gathering point as well as transport costs which depend on the area or region specific biomass potentials as well as regional specific infrastructure aspects. These cost parameter increases when pyrolysis is applied and thus losses due to the pyrolysis conversion efficiency have been taken into account. The total provision costs increase with increasing capacity of the BtL plant.
* As shown within the exemplarily sensitivity analyses, provision costs from 1st gathering point to BtL plant (i.e. excluding biomass costs at the 1st GP) are significant lower for regions with a high area or region specific biomass potential.

Table 4-1 Min and max total provision costs per biomass assortment and EU regions (overview)

European region		WEST	EAST	NORTH	ALPINE	SOUTH	UK + IR
Reference country		Germany	Poland	Sweden	Switzer-land	Greece	Ireland
WC (wood chips)	[€/GJ]	3.94 – 9.98	3.09 – 8.48	4.05 – 10.11	5.13 – 11.19	-	4.28-11.70
WB (wood bundles)	[€/GJ]	-	-	3.60 – 7.11	-	-	-
SRC (willow chips)	[€/GJ]	5.23 – 10.77	4.54 – 9.73	5.41 – 14.19	6.00 – 37.63	-	6.09 – 29.74
MIS (miscanthus bales)	[€/GJ]	6.89 – 13.06	6.95 – 11.47	8.37 – 18.11	8.33 – 42.82	-	7.32 – 23.31
WCC (triticale bales)	[€/GJ]	7.47 – 12.93	6.65 – 13.49	8.62 – 17.98	7.89 – 40.64	11.61 – 36.92	7.49 – 25.55
STR (straw bales)	[€/GJ]	4.08 – 6.45	3.04 – 6.67	5.48 – 11.45	7.59 – 19.69	6.20 – 14.25	6.30 – 21.85
EUC (eucalyptus chips)	[€/GJ]	-	-	-	-	6.08 – 15.03	-
SWG (switch grass bale)	[€/GJ]	-	-	-	-	10.42 – 26.13	-

The most promising biomass assortment options (i.e. agricultural and forestry residues as well as energy crops) for the investigated regions and BtL plant sizes can be summarised as follows (Table 4-2 et seq.). For direct biomass provision (50 MW_{th} and 500 MW_{th}) straw is basically the favourable biomass in WEST, EAST, SOUTH and UK+IR. For NORTH and ALPINE the use of wood chips or bundles are the most promising. For biomass provision including pyrolysis (500 MW_{th} – pyrolysis) the use of wood chips is the most cost effective.

Table 4-2 Most promising provision options per EU regions – residues

European region		WEST	EAST	NORTH	ALPINE	SOUTH	UK + IR
Reference country		Germany	Poland	Sweden	Switzer-land	Greece	Ireland
BIOMASS AND TOTAL BIOMASS PROVISION COSTS AT BTL PLANT – SP [€/GJ]							
50 MW_{th}	[-]	STR[a]	STR[a]	WB[a]	WC[b]	STR[b]	STR[a]
	[€/GJ]	4.28	3.04	4.04	7.12	6.20	6.30
500 MW_{th}	[-]	STR[b]	WC[a]	WB[b]	WC[b]	STR[b]	STR[a]
	[€/GJ]	5.24	4.06	6.07	7.74	6.47	9.17
500 MW_{th} – Pyrolysis	[-]	STR[c]	STR[c]	WB[c]	WC[c]	STR[c]	WC[e]
	[€/GJ]	6.15	4.44	6.42	10.77	11.78	11.18
BIOMASS AND TOTAL BIOMASS PROVISION COSTS AT BTL PLANT – S1 [€/GJ]							
50 MW_{th}	[-]	STR[a]	STR[a]	WB[a]	WC[a]	STR[b]	WC[a]
	[€/GJ]	4.08	3.57	3.60	5.44	6.27	6.09
500 MW_{th}	[-]	STR[a]	STR[a]	WB[a]	WC[b]	STR[b]	WC[a]
	[€/GJ]	5.08	4.99	4.72	5.84	6.54	7.70
500 MW_{th} – Pyrolysis	[-]	STR[c]	STR[c]	WB[c]	WC[c]	STR[c]	WC[e]
	[€/GJ]	5.77	5.10	5.67	8.13	11.23	8.64
BIOMASS AND TOTAL BIOMASS PROVISION COSTS AT BTL PLANT – S2 [€/GJ]							
50 MW_{th}	[-]	WC[a]	WC[a]	WC[a]	WC[b]	STR[b]	WC[a]

European region		WEST	EAST	NORTH	ALPINE	SOUTH	UK + IR
	[€/GJ]	3.94	3.65	4.05	5.13	6.36	4.28
500 MW_{th}	[-]	WC[b]	WC[a]	WC[c]	WC[b]	STR[b]	WC[a]
	[€/GJ]	5.06	4.67	5.71	5.51	6.71	5.88
500 MW_{th} – Pyrolysis	[-]	WC[c]	WC[c]	WC[c]	WC[c]	STR[c]	WC[e]
	[€/GJ]	5.84	5.58	6.40	7.78	11.30	6.21

[a] road, [b] road-rail, [c] road-pyrolysis-road-rail, [d] road-rail-road, [e] road-pyrolysis-road

Regarding energy crops, in the majority of the European regions SRC is the most promising energy crops in terms of total provision costs. In UK+IR also WCC and MIS are relevant.

Table 4-3 Most promising provision options per EU regions – energy crops

European region		WEST	EAST	NORTH	ALPINE	SOUTH	UK + IR
Reference country		Germany	Poland	Sweden	Switzer-land	Greece	Ireland
BIOMASS AND TOTAL BIOMASS PROVISION COSTS AT BTL PLANT – SP [€/GJ]							
50 MW_{th}	[-]	SRC[a]	WCC[a]	SRC[a]	SRC[b]	EUC[b]	WCC[a]
	[€/GJ]	7.59	6.65	7.78	9.39	7.29	11.80
500 MW_{th}	[-]	SRC[a]	SRC[a]	SRC[a]	SRC[b]	EUC[b]	MIS[b]
	[€/GJ]	8.46	7.92	10.13	15.45	7.83	15.66
500 MW_{th} – Pyrolysis	[-]	SRC[c]	MIS[c]	SRC[c]	SRC[c]	EUC[c]	WCC[e]
	[€/GJ]	10.67	8.56	12.27	29.89	12.52	21.94
BIOMASS AND TOTAL BIOMASS PROVISION COSTS AT BTL PLANT – S1 [€/GJ]							
50 MW_{th}	[-]	SRC[a]	SRC[a]	SRC[a]	SRC[b]	EUC[b]	SRC[a]
	[€/GJ]	5.23	4.54	5.41	6.00	6.08	6.09
500 MW_{th}	[-]	SRC[a]	SRC[a]	SRC[a]	SRC[b]	EUC[b]	SRC[b]
	[€/GJ]	6.13	5.10	7.33	6.48	6.61	8.54
500 MW_{th} – Pyrolysis	[-]	SRC[c]	SRC[c]	SRC[c]	SRC[c]	EUC[c]	MIS[e]
	[€/GJ]	7.43	6.46	8.41	9.55	10.22	10.37
BIOMASS AND TOTAL BIOMASS PROVISION COSTS AT BTL PLANT – S2 [€/GJ]							
50 MW_{th}	[-]	SRC[a]	SRC[a]	SRC[a]	SRC[b]	EUC[b]	MIS[b]
	[€/GJ]	6.41	5.02	6.22	6.59	6.71	10.05
500 MW_{th}	[-]	SRC[b]	SRC[a]	SRC[b]	SRC[b]	EUC[b]	MIS[b]
	[€/GJ]	7.63	6.10	8.51	8.63	7.25	13.41
500 MW_{th} – Pyrolysis	[-]	SRC[c]	SRC[c]	SRC[c]	SRC[c]	EUC[c]	MIS[e]
	[€/GJ]	9.69	7.90	10.15	15.20	15.20	19.57

[a] road, [b] road-rail, [c] road-pyrolysis-road-rail, [d] road-rail-road, [e] road-pyrolysis-road

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ANNEX 1 (TO CHAPTER 2)

Some indicative input data for cost calculation model for the different regions

Table A1-0-1 Some indicative input data – Agriculture

Specification	Unit	NORTH	UK+IR	WEST	ALPINE	SOUTH	EAST
Labour cost	€/h	17.60	16.00	17.00	18.40	8.00	4.60
Fuel cost	€/l	0.63	0.80	0.76	1.06	0.60	0.89
Fertilizer N	€/kg	0.88	0.71	0.82	0.80	0.63	0.46
Fertilizer P	€/kg	1.21	0.71	1.33	1.29	0.67	0.55
Fertilizer K	€/kg	0.44	0.36	0.36	0.39	0.67	0.30
Baling							
Capital investment tractor	1000 €	85	80	60	45/60*	48/60*	42
Capital investment baler	1000 €	109	100	104	31/100*	41/90*	89
Efficiency	t/h	12	12	12	8	8	12
Annual use	a/h	300	400	400	300	300	400
Telescopic loader							
Capital investment	1000 €	80	80	71	71	57	50
Efficiency	t/h	25	25	25	25	25	25
Annual use	a/h	500	500	500	400	400	400
Transport (straw)	€/t	8.09	6.57	6.42	6.42	6.65	4.19
Storage (straw)	€/t	8.91	8.56	7.31	8.66	5.70	3.25

* round baler (tractor) / large rectangular baler (tractor)

Table A1-0-2 Some indicative input data – Forestry

Specification	Unit	NORTH	UK+IR	WEST	ALPINE	SOUTH	EAST
Labour cost	€/DM t	17.00	17.00	20.00	20.00	8.00	6.00
Fuel cost	€/l	0.63	0.80	0.76	1.06	0.60	0.89
Thinning harvester							
Investment cost	1000 €	400	400	400	400	400	400
Efficiency	DM t/h	4.1	4.1	3.9	4.0	4.0*	4.1*
Annual use	a/h	2500	1600	1600	1600	1000*	1800*
Truck mounted chipper							
Capital investment	1000 €	320	320	320	320	320	320
Efficiency	DM t/h	6.7	6.7	6.7	6.7	6.7	6.7
Annual use	a/h	1500	1000	1000	1000	800	1000

* data for S1

A brief characteristic of energy wood harvesting technologies across European regions

Large scale biomass procurement for energy with technologically advanced solutions are developed nowadays commercially only in Scandinavia. Logging residues and thinning wood are harvested for energy use. Logging residues are commonly harvested from clear cuts areas, they are piled with a harvester and then delivered to a roadside with a forwarder. Roadside chipping technology is the most common solution, however in Finland and Sweden logging residues balling technology has been developed on a commercial scale (Hakkila, 2004). Thinning is performed almost 100% mechanically in Scandinavian countries. Accumulating feller-heads are used for harvesting small-diameter trees from early thinnings in young forests; the use of accumulating feller-heads improved the productivity of work and has paved the way for cost reductions (Hakkila & Aarniala, 2004).

In Western Europe, in ALPINE region and IE and UK energy wood harvesting is performed mechanically. Logging residues are harvested with harvester and forwarder. Logging residues baling is not common as this technology can be performed with high efficiency only on clear cuts areas, which are not common outside Scandinavia. Thinning is done mechanically due to relatively high labour costs. For example, in France energy wood is produced in coppice designed for producing firewood for a society that once depended on it and presently neglected it. These coppices still represent an immense resource, which needs heavy thinning nowadays, designed to steer stand development towards the high forest structure (Spinelli et al., 2006a). In IE and UK plantations of Sitka Spruce established during last hundred years are an important source of logging residues and thinning wood. Wood provision chain is fully mechanized (D 5.1.1).

In Eastern Europe logging residues are harvested to a vary little extend and mainly manually. Logging residues have been traditionally collected by local societies for residential heating, while large-scale logging residues procurement for energy is not performed (IBL, 2006). Thinning operations are the most important source of energy wood. So far, they have been performed 100% manually in Poland. The most important barrier for mechanization of forest operation are the investment cost of dedicated machineries.

In Southern Europe energy wood is typically produced in even-aged tree plantations with the length of rotation 5-25 years (even 35 years), depending on the site, climatic zone and the species growing (Spinelli et al., 2006a; D 5.1.1). A specific example can be single-row plantations in Northern Italy, which are an important source of firewood. In Greece wood harvesting is done manually, due to difficult harvesting conditions (steep slopes), sensitive soil and high harvesting machineries costs. Logging residues are not harvested (CRES, 2006).

Provision costs at 1st GP

Table A1-0-3 Straw provision costs at 1st GP for SP, S1 and S2

	NORTH	UK+IR	WEST	ALPINE	SOUTH	EAST
	€/GJ	€/GJ	€/GJ	€/GJ	€/GJ	€/GJ
SP						
Straw NPK value	0.86	0.65	0.78	0.80	0.91	0.50
Balling	0.92	0.88	0.86	0.93	0.68	0.55
Bales collecting	0.32	0.32	0.30	0.31	0.20	0.17
Loading out	0.15	0.14	0.13	0.13	0.08	0.08
Transport	0.62	0.50	0.49	0.49	0.39	0.32
Storage	0.68	0.65	0.56	0.66	0.40	0.30
Administration	0.12	0.10	0.10	0.10	0.06	0.06
Brokerage	0.22	0.24	0.22	0.22	0.18	0.18
TOTAL	3.88	3.48	3.43	3.65	2.90	2.15
S1						
Straw NPK value	0.86	0.70	0.78	0.80	0.85	0.78
Balling	0.83	0.82	0.79	0.84	0.74	0.64
Bales collecting	0.23	0.24	0.28	0.23	0.19	0.18
Loading out	0.13	0.13	0.12	0.13	0.10	0.10
Transport	0.59	0.48	0.47	0.49	0.43	0.38
Storage	0.65	0.62	0.53	0.66	0.44	0.36
Administration	0.12	0.10	0.09	0.09	0.06	0.06
Brokerage	0.16	0.18	0.17	0.17	0.16	0.16
TOTAL	3.56	3.26	3.23	3.41	2.97	2.67
S2						
Straw NPK value	0.86	0.70	0.78	0.80	0.85	0.78
Balling	0.90	0.90	0.86	0.91	0.81	0.74
Bales collecting	0.28	0.29	0.34	0.28	0.22	0.22
Loading out	0.13	0.13	0.12	0.13	0.10	0.11
Transport	0.59	0.48	0.47	0.49	0.43	0.38
Storage	0.63	0.61	0.52	0.65	0.43	0.35
Administration	0.12	0.10	0.09	0.09	0.06	0.06
Brokerage	0.16	0.18	0.17	0.17	0.16	0.16
TOTAL	3.67	3.37	3.34	3.52	3.06	2.81

Table A1-0-4 Logging residues provision costs at 1st GP for SP. S1 and S2

	NORTH	UK+IR	WEST	ALPINE	SOUTH[a]	EAST
	€/GJ	€/GJ	€/GJ	€/GJ		€/GJ
SP						
Forwarding	1.18	1.25	1.24	1.31		0.58
Chipping at roadside	0.76	0.79	0.79	0.84		0.44
Administration	0.20	0.20	0.20	0.20		0.10
Brokerage	0.40	0.40	0.40	0.40		0.20
TOTAL	2.54	2.64	2.63	2.74		1.32
S1						
Forwarding	1.43	1.24	1.18	1.62		1.00
Chipping at roadside	0.69	0.72	0.72	0.76		0.71
Administration	0.20	0.20	0.20	0.20		0.20
Brokerage	0.30	0.30	0.30	0.30		0.30
TOTAL	2.61	2.45	2.40	2.88		2.21
S2						
Forwarding	1.44	1.35	1.32	1.70		1.14
Chipping at roadside	0.73	0.84	0.84	0.93		0.90
Administration	0.20	0.20	0.20	0.20		0.20
Brokerage	0.40	0.40	0.40	0.40		0.40
TOTAL	2.77	2.79	2.76	3.24		2.65

[a] *logging residues are not relevant for SOUTH*

Table A1-0-5 Thinning wood provision costs at 1st GP for SP. S1 and S2

	NORTH	UK+IR	WEST	ALPINE	SOUTH	EAST
	€/GJ	€/GJ	€/GJ	€/GJ	€/GJ	€/GJ
SP						
Thinning (cutting)	2.53	2.99	3.17	3.19	1.20	0.95
Forwarding	1.18	1.25	1.24	1.31	0.70	0.62
Chipping at roadside	0.76	0.79	0.79	0.84	0.60	0.44
Administration	0.20	0.20	0.20	0.20	0.10	0.10
Brokerage	0.40	0.40	0.40	0.40	0.28	0.26
TOTAL	5.07	5.62	5.80	5.93	2.88	2.37
S1						
Thinning (cutting)	2.37	2.85	3.02	2.98	2.53	3.05

	NORTH	UK+IR	WEST	ALPINE	SOUTH	EAST
Forwarding	1.43	1.24	1.18	1.62	1.70	1.00
Chipping at roadside	0.69	0.72	0.72	0.76	1.10	0.71
Administration	0.20	0.20	0.20	0.20	0.20	0.20
Brokerage	0.30	0.30	0.30	0.30	0.30	0.30
TOTAL	4.99	5.30	5.42	5.86	5.83	5.26
S2						
Thinning (cutting)	3.45	3.99	4.12	4.32	3.29	3.83
Forwarding	1.44	1.35	1.32	1.70	1.50	1.14
Chipping at roadside	0.73	0.84	0.84	0.93	1.50	0.90
Administration	0.20	0.20	0.20	0.20	0.20	0.20
Brokerage	0.30	0.30	0.30	0.30	0.30	0.30
TOTAL	6.12	6.68	6.78	7.46	6.79	6.38

ANNEX 2 (TO CHAPTER 3)

Data base

Table A2-0-1 Regional specific basic data (delivered by the WP5.3 partners)

European region		WEST	EAST	NORTH	ALPINE	SOUTH	UK + IR
Reference country		Germany	Poland	Sweden	Switzer-land	Greece	Ireland
Responsibility		IEE	ECBREC	LU	ESU	CRES	UCD
total area land	[ha]	35.702.200	31.268.500	44.996.400	4.128.500	13.199.000	7.027.308
agricultural (arable) land	[ha]	11.800.300	13.302.000	2.599.300	1.073.410	3.959.700	4.497.477
share of agricultural on total land area	[%]	33	43	6	26	30	64
typical size of agricultural farms	[ha]	71	8,4	39	17	5	33
number of agricultural farms per agricultural land	[-]	166.201	1.583.571	66.649	63.142	791.940	137.917
commercially exploitable forest area	[ha]	10.143.000	8.942.000	22.948.164	1.238.550	2.507.810	660.567
share of forest on total land area	[%]	28	29	51	30	19	9
typical size of forest enterprise	[ha]	674	500	100	417	200	150
number of forestry enterprises per forestry land	[-]	15.049	2.163.000	229.482	2.970	12.539	4.404

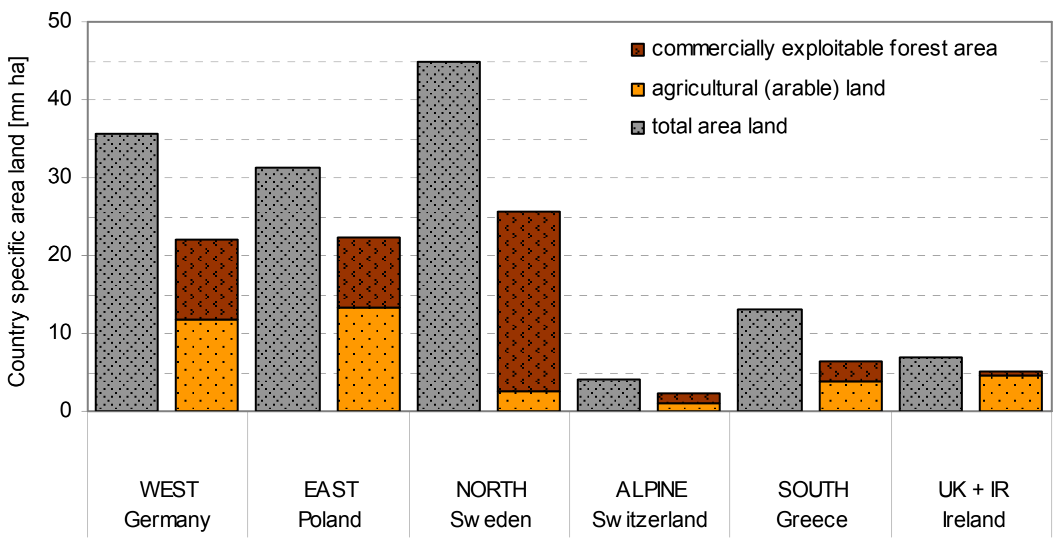

Figure A1-0-1 Overview area land as well as farm and forest areas

Table A2-0-2 Data summary of basic biomass assortment characteristics (as received at BtL plant)

Biomass assortment	Abbreviation	Bulk density	LHV	water content
(average data)		[kg_{ar}/m^3]	[GJ/t_d]	[kg/kg_d] or [%]
wood chips (LR, TW)	WC	221.00	19.00	40.00
wood bundles (TW)	WB	328.00	19.00	40.00
SRC chips (willow salix)	SRC	295.00	18.80	40.00
eucalyptus chips*	EUC	295.00	18.80	40.00
miscanthus bales	MIS	148.00	18.40	20.00
switch grass bales*	SWG	148.00	18.40	20.00
triticale bales (WCC)	WCC	148.00	17.20	15.00
straw bales (wheat straw)	STR	140.00	17.20	15.00
pyrolysis slurry	P	1,250	21.50	

* simplified assumptions, only relevant for SOUTH/Greece, SRC – short rotation coppice, WCC – whole cereal crops

Table A2-0-3 Data summary of regional specific data for biomass treatment and provision (delivered by the WP5.3 partners, assumption by IEE, if data are not reproducible or have been not delivered)

European region		WEST	EAST	NORTH	ALPINE	SOUTH	UK + IR
Reference country		Germany	Poland	Sweden	Switzer-land	Greece	Ireland
Responsibility		IEE	ECBREC	LU	ESU	CRES	UCD
MEANS OF TRANSPORT							
<u>Train</u>							
max. allowed gross weight	[t]	1,600	3,200	1,600	1,600	1,600	600
max. allowed volume	[m³]		3,000				
capital investment (average)	[1,000 €]	3,520	2,700	3,520	3,520	3,520	3,500
service life locomotive	[a]	25	25	25	40	25	25
service life wagon	[a]	35	30	30	40	30	30
annual use	[h/a]	3,120	3,120	3,120	3,120	3,120	3,120
train line	[€/tkm]	2,100	0.003	2,100	2,100	2,100	2,500
<u>Semi trailer</u>							
capital investment (average)	[€]	130,000	80,000	255,000	157,165	100,000	94,000
service life truck	[a]	6	8	6	7.7	6	6
service life semi-trailer	[a]	10	10	10	10	10	10
annual use	[h/a]	2,700	2,700	4,900	1,750	1,440	1,896
annual vehicle kilometre	[km/a]	70,000	100,000	240,000	70,000	72,000	100,000

European region		WEST	EAST	NORTH	ALPINE	SOUTH	UK + IR
Reference country		Germany	Poland	Sweden	Switzer-land	Greece	Ireland
Responsibility		IEE	ECBREC	LU	ESU	CRES	UCD
toll / road tax	[€/km]	0.12	0.0055	0.06	0.158	0.15	0.026
pallet trailer (bales)							
payload/allowed gross weight	[t]	21	24	25	25	18	44
volume	[m³]	64	90	100	79	38	80
container trailer (chips)							
payload/allowed gross weight	[t]	28.5	24	33	36	18	12
volume	[m³]	110	86	105	40	38	34
truck + trailer (typ.)							
payload/allowed gross weight	[t]	25	40	37	40	40	44
volume	[m³]	110	86	130	110	90	80
Inland navigation vessel							
payload/allowed gross weight	[t]	1,000					
volume	[m³]	1,500					
TEU	[-]	66					
capital investment	[1,000 €]	4,500					
service life	[a]	12					
annual use	[h/a]	5,120					
harbour fee	[€/d]	50					
CARGO HANDLING							
mobile crane - container	[€/pass]	10.00	14.00				50.00
mobile crane - bulk freight	[€/pass]	2.50	3.00				7.50
mobile crane - unit load	[€/pass]	5.00	4.50				7.50
wheel loader (e.g. clamshell or bucket)	[€/h]	50.00	30.00	50.00	50.00	30.00	30.00
STORAGE							
outdoor – bales	[€/m³]	0.50	0.50	0.50	0.50	0.50	0.50
outdoor – wood	[€/t]	10.00	10.00	10.00	10.00	10.00	10.00
outdoor – chips	[€/t]	12.50	12.50	12.50	12.50	12.50	12.50
indoor – bales	[€/m³]	4.00	4.00	4.00	4.00	4.00	4.00
indoor – chips	[€/t]	20.00	10.00	20.00	20.00	10.00	5.00
FURTHER O&M							

European region		WEST	EAST	NORTH	ALPINE	SOUTH	UK + IR
Reference country		Germany	Poland	Sweden	Switzer-land	Greece	Ireland
Responsibility		IEE	ECBREC	LU	ESU	CRES	UCD
personnel	[1,000 €/a]	50	9.3	55	56.58	40	22
transportation fuel – SP (diesel)	[€/l]	0.76	0.89	0.80	1.05	1.05	1.04
transportation fuel – S2 (BtL)	[€/l]	1.00	1.00	1.00	1.00	1.00	1.00
electricity	[€/MWh_{el}]	60.00	73.00	60.00	50.30	60.00	127.00
DETOUR FACTOR							
train line	[-]	1.4	1.4	1.3	1.42	1.4	1.4
road	[-]	1.3	1.3	1.3	1.37	1.3	1.3
inland waterways	[-]	1.6					
CONNECTION POINTS							
siding tracks	[-]	1,600	1,020	1,480	1,700	1,460	906
inland waterway ports	[-]	105					

Results

Table A2-0-4 Calculated biomass availability at the 1st gathering point – agricultural residues

European region		WEST	EAST	NORTH	ALPINE	SOUTH	UK + IR
Reference country		Germany	Poland	Sweden	Switzer-land	Greece	Ireland
ASPECTS 1ST GP							
catchment radius 1st GP (r_{GP})	[km]	15	15	15	15	15	15
catchment area 1st GP (A_{GP})	[ha]	70,686	70,686	70,686	70,686	70,686	70,686
number of 1st GP per total area land	[-]	505	442	637	58	187	99
single provision area	[ha]	215	20	675	65	17	51
BIOMASS AVAILABILITY AT ONE 1ST GP – SP							
straw amount	[t_d/a]	17,063	13,157	1,033	-	17,489	1,697
straw potential	[PJ/a]	0.29	0.23	0.02	-	0.30	0.03
BIOMASS AVAILABILITY AT ONE 1ST GP – S1							
straw amount	[t_d/a]	15,683	13,181	1,020	-	16,272	267
straw potential	[PJ/a]	0.27	0.23	0.02	-	0.28	0.00
BIOMASS AVAILABILITY AT ONE 1ST GP – S2							
straw amount	[t_d/a]	13,871	11,871	911	-	16,208	-
straw potential	[PJ/a]	0.24	0.20	0.02	-	0.28	-

Table A2-0-5 Calculated biomass availability at the 1st gathering point – forestry wood

European region		WEST	EAST	NORTH	ALPINE	SOUTH	UK + IR
Reference country		Germany	Poland	Sweden	Switzer-land	Greece	Ireland
ASPECTS 1ST GP							
catchment radius 1st GP (r_{GP})	[km]	1	1	1	1	1	1
catchment area 1st GP (A_{GP})	[ha]	314	314	314	314	314	314
number of 1st GP per total area land	[-]	113,644	99,531	143,228	13,141	42,014	2,103
single provision area	[ha]	2,372	1,748	196	1,390	1,053	1,596
BIOMASS AVAILABILITY AT ONE 1ST GP – SP							
logg. residues amount	[t_d/a]	63	55	4	69	-	278
logg. residues potential	[PJ/a]	0.001	0.001	0.000	0.001	-	0.005
thinning wood amount	[t_d/a]	411	212	29	169	-	1,046
thinning wood potential	[PJ/a]	0.008	0.004	0.001	0.003	-	0.020
BIOMASS AVAILABILITY AT ONE 1ST GP – S1							
logg. residues amount	[t_d/a]	93	77	4	103	-	414
logg. residues potential	[PJ/a]	0.002	0.001	0.000	0.002	-	0.008
thinning wood amount	[t_d/a]	499	239	35	284	-	4,772
thinning wood potential	[PJ/a]	0.009	0.005	0.001	0.005	-	0.091
BIOMASS AVAILABILITY AT ONE 1ST GP – S2							
logg. residues amount	[t_d/a]	52	40	4	57	-	229
logg. residues potential	[PJ/a]	0.001	0.001	0.000	0.001	-	0.004
thinning wood amount	[t_d/a]	479	219	34	215	-	4,581
thinning wood potential	[PJ/a]	0.009	0.004	0.001	0.004	-	0.087

Table A2-0-6 Calculated biomass availability at the 1st gathering point – energy crops

European region		WEST	EAST	NORTH	ALPINE	SOUTH	UK + IR
Reference country		Germany	Poland	Sweden	Switzer-land	Greece	Ireland
ASPECTS 1ST GP							
catchment radius 1st GP (r_{GP})	[km]	30	30	30	30	30	30
catchment area 1st GP (A_{GP})	[ha]	282,743	282,743	282,743	282,743	282,743	282,743
number of 1st GP per total area land	[-]	126	111	159	15	47	25

European region		WEST	EAST	NORTH	ALPINE	SOUTH	UK + IR
Reference country		Germany	Poland	Sweden	Switzer-land	Greece	Ireland
single provision area	[ha]	215	20	675	65	17	51
BIOMASS AVAILABILITY AT ONE 1ST GP – SP							
triticale amount	[t_d/a]	65,989	26,194	3,571	584	13,670	1,763
triticale potential	[PJ/a]	1.14	0.45	0.06	0.01	0.24	0.03
miscanthus amount	[t_d/a]	52,792	33,925	2,594	519	25,061	2,034
miscanthus potential	[PJ/a]	0.91	0.58	0.04	0.01	0.43	0.03
SRC amount	[t_d/a]	65,989	26,298	3,184	519	22,783	1,492
SRC potential	[PJ/a]	1.14	0.45	0.05	0.01	0.39	0.03
BIOMASS AVAILABILITY AT ONE 1ST GP – S1							
triticale amount	[t_d/a]	47,070	57,191	4,685	54,872	15,484	42,816
triticale potential	[PJ/a]	0.81	0.98	0.08	0.94	0.27	0.74
miscanthus amount	[t_d/a]	78,880	110,582	4,165	26,789	37,531	75,558
miscanthus potential	[PJ/a]	1.36	1.90	0.07	0.46	0.65	1.30
SRC amount	[t_d/a]	58,085	77,063	5,165	21,996	30,493	43,446
SRC potential	[PJ/a]	1.00	1.33	0.09	0.38	0.52	0.75
BIOMASS AVAILABILITY AT ONE 1ST GP – S2							
triticale amount	[t_d/a]	18,408	29,443	2,361	1,943	9,903	1,291
triticale potential	[PJ/a]	0.32	0.51	0.04	0.03	0.17	0.02
miscanthus amount	[t_d/a]	29,169	57,095	2,055	2,890	24,451	2,278
miscanthus potential	[PJ/a]	0.50	0.98	0.04	0.05	0.42	0.04
SRC amount	[t_d/a]	24,449	39,586	3,328	2,292	19,847	1,310
SRC potential	[PJ/a]	0.42	0.68	0.06	0.04	0.34	0.02

Table A2-0-7 Biomass provision costs at BtL plant – direct provision WEST

[€/GJ$_{LHV}$]	LR, TW chips (WC)					SRC chips					MIS bales					WCC bales					STR bales		
Route	road	road-rail	road-rail-road	road-water	road-water-road	road	road-rail	road-rail-road	road-water	road-water-road	road	road-rail	road-rail-road	road-water	road-water-road	road	road-rail	road-rail-road	road-water	road-water-road	road	road-rail	road-rail-road
50 MW																							
Starting point - SP																							
Biomass costs 1st GP	5.97	5.97	5.97	5.97	5.97	6.82	6.82	6.82	6.82	6.82	7.63	7.68	7.68	7.68	7.68	7.01	7.06	7.06	7.06	7.06	3.50	3.53	3.53
Storage	-	-	-	-	-	-	-	-	-	-	-	0.03	0.03	0.01	0.01	-	0.03	0.03	0.01	0.01	-	0.10	0.10
Transport	0.61	0.59	0.93	0.83	1.17	0.60	0.85	1.10	0.94	1.19	0.55	0.67	0.89	0.76	0.98	0.55	0.68	0.90	0.77	0.99	0.65	0.48	0.71
Cargo handling	0.23	1.16	1.16	2.35	2.35	0.16	0.86	0.86	1.68	1.68	0.06	0.59	0.59	1.27	1.27	0.12	0.83	0.83	2.04	2.04	0.12	0.87	0.87
Total provision costs	6.82	7.72	8.06	9.15	9.49	7.59	8.54	8.78	9.45	9.69	8.23	8.97	9.19	9.73	9.94	7.68	8.59	8.81	9.88	10.09	4.28	4.97	5.20
S1																							
Biomass costs 1st GP	5.21	5.49	5.49	5.49	5.49	4.47	4.47	4.47	4.47	4.47	6.29	6.33	6.33	6.23	6.19	6.80	6.85	6.85	6.85	6.80	3.29	3.31	3.31
Storage	-	-	-	-	-	-	-	-	-	-	-	0.02	0.02	0.00	-	-	0.04	0.04	0.00	-	-	0.10	0.10
Transport	0.58	0.54	0.88	0.81	1.16	0.60	0.85	1.10	1.86	2.10	0.55	0.67	0.89	1.98	2.94	0.55	0.68	0.90	1.84	2.75	0.67	0.48	0.71
Cargo handling	0.24	1.16	1.16	2.35	2.35	0.16	0.86	0.86	1.68	1.68	0.06	0.59	0.59	1.27	2.57	0.12	0.83	0.83	2.04	2.59	0.12	0.87	0.87
Total provision costs	6.02	7.19	7.53	8.66	9.00	5.23	6.19	6.43	8.01	8.25	6.89	7.61	7.83	9.49	11.70	7.47	8.39	8.61	10.74	12.15	4.08	4.77	5.00
S2																							
Biomass costs 1st GP	3.06	3.06	3.06	3.06	3.06	5.18	5.18	5.18	5.18	5.18	6.19	6.23	6.23	6.23	6.19	7.01	7.06	7.06	7.06	7.01	3.41	3.53	3.53
Storage	-	-	-	-	-	-	-	-	-	-	-	0.06	0.06	0.00	-	-	0.10	0.10	0.01	-	-	0.12	0.12
Transport	0.65	0.40	0.77	0.72	1.09	1.07	1.06	1.33	1.99	2.25	0.98	0.83	1.06	1.98	2.94	1.27	0.89	1.13	1.99	2.96	0.74	0.51	0.76
Cargo handling	0.23	1.16	1.16	2.35	2.35	0.16	0.86	0.86	1.68	1.68	0.06	0.59	0.59	1.27	2.57	0.12	0.83	0.83	2.04	2.59	0.12	0.87	0.87
Total provision costs	3.94	4.62	4.99	6.13	6.51	6.41	7.10	7.36	8.84	9.11	7.22	7.70	7.93	9.49	11.70	8.40	8.88	9.11	11.10	12.56	4.28	5.03	5.28
500 MW																							
Starting point - SP																							
Biomass costs 1st GP	5.97	5.97	5.97	5.97	5.97	6.82	6.82	6.82	6.82	6.82	7.63	7.68	7.68	7.68	7.68	7.01	7.06	7.06	7.06	7.06	3.50	3.53	3.53
Storage	-	-	-	-	-	-	-	-	-	-	-	0.03	0.03	0.01	0.01	-	0.03	0.03	0.01	0.01	-	0.10	0.10
Transport	1.71	1.17	1.51	1.24	1.58	1.47	1.26	1.51	1.22	1.46	1.94	1.07	1.28	1.49	1.70	1.85	1.05	1.27	1.15	1.37	1.64	0.75	0.98
Cargo handling	0.23	1.16	1.16	2.35	2.35	0.16	0.86	0.86	1.68	1.68	0.06	0.59	0.59	1.27	1.27	0.12	0.83	0.83	2.04	2.04	0.12	0.87	0.87
Total provision costs	7.91	8.30	8.64	9.56	9.90	8.46	8.95	9.19	9.72	9.96	9.63	9.36	9.58	9.88	10.09	8.98	8.96	9.18	11.57	11.78	5.27	5.24	5.47

[€/GJ$_{LHV}$]	LR, TW chips (WC)					SRC chips					MIS bales					WCC bales					STR bales		
Route	road	road-rail	road-rail-road	road-water	road-water-road	road	road-rail	road-rail-road	road-water	road-water-road	road	road-rail	road-rail-road	road-water	road-water-road	road	road-rail	road-rail-road	road-water	road-water-road	road	road-rail	road-rail-road
S1																							
Biomass costs 1st GP	5.49	5.49	5.49	5.49	5.49	4.47	4.47	4.47	4.47	4.47	6.29	6.33	7.68	6.33	6.29	6.80	6.85	6.85	6.85	6.80	3.29	3.31	3.31
Storage	-	-	-	-	-	-	-	-	-	-	-	0.02	0.02	0.00	-	-	0.04	0.04	0.00	-	-	0.10	0.10
Transport	1.55	1.10	1.44	1.23	1.57	1.49	1.28	1.52	2.38	2.62	1.37	0.89	1.11	2.27	3.21	2.05	1.09	1.31	2.67	3.67	1.66	0.84	1.07
Cargo handling	0.23	1.16	1.16	2.35	2.35	0.16	0.86	0.86	1.68	1.68	0.06	0.59	0.59	1.27	2.57	0.12	0.83	0.83	2.04	2.59	0.12	0.87	0.87
Total provision costs	7.27	7.75	8.09	9.07	9.41	6.13	6.61	6.85	8.53	8.77	7.72	7.83	9.39	9.88	12.07	8.98	8.81	9.02	11.57	13.06	5.08	5.13	5.36
S2																							
Biomass costs 1st GP	3.06	3.06	3.06	3.06	3.06	5.18	5.18	5.18	5.18	5.18	6.19	6.23	6.23	6.23	6.23	7.32	7.37	7.37	7.37	7.37	3.41	3.44	3.44
Storage	-	-	-	-	-	-	-	-	-	-	-	0.06	0.06	0.00	0.00	-	0.10	0.10	0.01	0.01	-	0.12	0.12
Transport	1.76	0.72	1.09	1.36	1.73	2.56	1.60	1.86	2.79	3.06	2.40	1.32	1.55	3.04	3.27	3.29	1.40	1.63	3.20	3.44	2.15	0.87	1.13
Cargo handling	0.23	1.16	1.16	2.35	2.35	0.16	0.86	0.86	1.68	1.68	0.06	0.59	0.59	1.27	1.27	0.12	0.83	0.83	2.04	2.04	0.12	0.87	0.87
Total provision costs	5.06	4.94	5.31	6.77	7.14	7.90	7.63	7.90	9.65	9.91	8.65	8.19	8.42	10.54	10.78	10.73	9.69	9.93	12.62	12.85	5.68	5.30	5.55

Table A2-0-8 Biomass provision costs at BtL plant – provision including pyrolysis WEST

[€/GJ$_{LHV}$]	LR, TW chips		SRC chips		MIS bales		WCC bales		STR bales	
Route	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail
500 MW P										
Starting point - SP										
Biomass costs 1st GP	7.97	7.97	9.10	9.10	10.17	10.17	8.67	8.76	4.38	4.38
Storage	-	-	-	-	-	-	-	-	-	-
Transport	1.51	1.30	1.26	1.07	2.53	1.70	2.48	1.61	1.66	1.30
Cargo handling	0.50	0.59	0.41	0.50	0.36	0.45	0.36	0.46	0.36	0.46
Total provision costs	9.98	9.86	10.77	10.67	13.06	12.33	11.52	10.84	6.41	6.15
S1										
Biomass costs 1st GP	7.33	7.33	5.96	5.96	8.38	8.38	8.51	8.51	4.12	4.12
Storage	-	-	-	-	-	-	-	-	-	-
Transport	1.35	1.16	1.26	1.05	1.20	0.99	2.73	1.86	1.67	1.29
Cargo handling	0.50	0.50	0.41	0.41	0.36	0.36	0.36	0.36	0.36	0.37
Total provision costs	9.17	8.99	7.63	7.43	9.94	9.73	11.60	10.73	6.15	5.77
S2										
Biomass costs 1st GP	4.09	4.09	6.90	6.90	8.25	8.25	9.15	9.15	4.27	4.27
Storage	-	-	-	-	-	-	-	-	-	-
Transport	1.47	1.25	3.31	2.37	3.21	2.25	3.42	2.43	1.83	1.39
Cargo handling	0.50	0.50	0.41	0.41	0.36	0.36	0.36	0.36	0.36	0.37
Total provision costs	6.05	5.84	10.63	9.69	11.82	10.86	12.93	11.94	6.45	6.02

Table A2-0-9 Biomass provision costs at BtL plant – direct provision EAST

[€/GJ_{LHV}]	LR, TW chips (WC)			SRC chips			MIS bales			WCC bales			STR bales		
Route	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road
50 MW															
Starting point - SP															
Biomass costs 1st GP	2.40	2.40	2.40	6.24	6.24	6.24	6.08	6.12	6.12	5.46	5.50	5.50	2.19	2.21	2.21
Storage	-	-	-	-	-	-	-	0.05	0.05	-	0.07	0.07	-	0.12	0.12
Transport	0.52	0.93	1.23	0.64	1.28	1.50	0.86	1.10	1.34	1.09	1.23	1.46	0.75	0.75	1.00
Cargo handling	0.18	0.86	0.86	0.13	0.62	0.62	0.05	0.44	0.44	0.09	0.62	0.62	0.09	0.65	0.65
Total provision costs	3.09	4.19	4.49	7.00	8.13	8.35	6.99	7.71	7.95	6.65	7.41	7.65	3.04	3.73	3.98
S1															
Biomass costs 1st GP	4.93	4.93	4.93	4.00	4.00	4.00	6.39	6.43	6.43	7.22	7.26	7.26	2.72	2.74	2.74
Storage	-	-	-	-	-	-	-	0.02	0.02	-	0.03	0.03	-	0.12	0.12
Transport	0.47	0.92	1.22	0.41	0.95	1.17	0.59	0.90	1.13	0.59	0.90	1.14	0.75	0.75	1.00
Cargo handling	0.18	0.86	0.86	0.13	0.62	0.62	0.05	0.44	0.44	0.09	0.62	0.62	0.09	0.65	0.65
Total provision costs	5.58	6.72	7.02	4.54	5.57	5.79	7.02	7.79	8.02	7.90	8.81	9.05	3.57	4.26	4.51
S2															
Biomass costs 1st GP	2.94	2.94	2.94	4.47	4.47	4.47	6.29	6.33	6.33	7.84	7.89	7.89	2.86	2.88	2.88
Storage	-	-	-	-	-	-	-	0.03	0.03	-	0.06	0.06	-	0.14	0.14
Transport	0.54	0.70	1.02	0.43	1.16	1.39	0.61	0.92	1.17	1.06	1.21	1.46	0.80	0.77	1.03
Cargo handling	0.18	0.86	0.86	0.13	0.62	0.62	0.05	0.44	0.44	0.09	0.62	0.62	0.09	0.65	0.65
Total provision costs	3.65	4.51	4.83	5.02	6.25	6.47	6.95	7.72	7.97	8.99	9.78	10.02	3.76	4.44	4.70

500 MW															
Starting point - SP															
Biomass costs 1st GP	2.40	2.40	2.40	6.24	6.24	6.24	6.08	6.12	6.12	5.46	5.50	5.50	2.19	2.21	2.21
Storage	-	-	-	-	-	-	-	0.05	0.05	-	0.07	0.07	-	0.12	0.12
Transport	1.48	2.26	2.56	1.56	2.45	2.67	2.34	1.95	2.18	3.04	2.43	2.66	2.18	1.64	1.89
Cargo handling	0.18	0.86	0.86	0.13	0.62	0.62	0.05	0.44	0.44	0.09	0.62	0.62	0.09	0.65	0.65
Total provision costs	4.06	5.52	5.83	7.92	9.30	9.52	8.47	8.56	8.79	8.59	8.61	8.85	4.46	4.62	4.87

[€/GJ$_{LHV}$]	LR, TW chips (WC)			SRC chips			MIS bales			WCC bales			STR bales		
Route	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road
S1															
Biomass costs 1st GP	4.93	4.93	4.93	4.00	4.00	4.00	6.39	6.43	6.43	7.22	7.26	7.26	2.72	2.74	2.74
Storage	-	-	-	-	-	-	-	0.02	0.02	-	0.03	0.03	-	0.12	0.12
Transport	1.38	2.24	2.55	0.97	1.79	2.01	1.41	1.38	1.62	2.11	1.85	2.09	2.17	1.63	1.88
Cargo handling	0.18	0.86	0.86	0.13	0.62	0.62	0.05	0.44	0.44	0.09	0.62	0.62	0.09	0.65	0.65
Total provision costs	6.49	8.04	8.35	5.10	6.41	6.63	7.84	8.27	8.50	9.42	9.76	10.00	4.99	5.15	5.40
S2															
Biomass costs 1st GP	2.94	2.94	2.94	4.47	4.47	4.47	6.29	6.33	6.33	7.84	7.89	7.89	2.86	2.88	2.88
Storage	-	-	-	-	-	-	-	0.03	0.03	-	0.06	0.06	-	0.14	0.14
Transport	1.56	1.74	2.06	1.51	2.00	2.23	2.14	1.84	2.09	3.07	2.41	2.66	2.32	1.67	1.93
Cargo handling	0.18	0.86	0.86	0.13	0.62	0.62	0.05	0.44	0.44	0.09	0.62	0.62	0.09	0.65	0.65
Total provision costs	4.67	5.55	5.87	6.10	7.09	7.31	8.48	8.64	8.89	10.99	10.97	11.22	5.28	5.34	5.60

Table A2-0-10 Biomass provision costs at BtL plant – provision including pyrolysis EAST

[€/GJ_{LHV}]	LR, TW chips		SRC chips		MIS bales		WCC bales		STR bales	
Route	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail
500 MW P										
Starting point - SP										
Biomass costs 1st GP	3.10	3.10	8.31	8.31	8.11	6.12	6.83	6.83	2.74	2.74
Storage	-	-	-	-	-	0.05	-	-	-	-
Transport	1.46	1.21	1.04	0.87	1.28	1.95	2.76	1.99	1.80	1.48
Cargo handling	0.45	0.32	0.38	0.26	0.34	0.44	0.35	0.21	0.35	0.21
Total provision costs	5.00	4.63	9.73	9.44	9.73	8.56	9.94	9.03	4.90	4.44
S1										
Biomass costs 1st GP	6.58	6.58	5.33	5.33	8.52	6.43	9.02	9.02	3.40	3.40
Storage	-	-	-	-	-	0.02	-	-	-	-
Transport	1.45	1.20	1.04	0.87	1.28	1.38	2.76	1.99	1.80	1.48
Cargo handling	0.45	0.32	0.38	0.26	0.34	0.44	0.35	0.21	0.35	0.21
Total provision costs	8.48	8.10	6.75	6.46	10.15	8.27	12.13	11.23	5.56	5.10
S2										
Biomass costs 1st GP	3.92	3.92	5.96	5.96	8.38	6.33	9.79	9.79	3.58	3.58
Storage	-	-	-	-	-	0.03	-	-	-	-
Transport	1.65	1.33	2.48	1.69	2.74	1.84	3.34	2.51	2.74	2.07
Cargo handling	0.45	0.32	0.38	0.26	0.34	0.44	0.35	0.21	0.35	0.21
Total provision costs	6.01	5.58	8.83	7.90	11.47	8.64	13.49	12.51	6.67	5.86

Table A2-0-11 Biomass provision costs at BtL plant – direct provision NORTH

[€/GJ$_{LHV}$]	LR, TW bundles (WB)			LR, TW chips (WC)			SRC chips			MIS bales			WCC bales			STR bales		
Route	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road
50 MW																		
Starting point - SP																		
Biomass costs 1st GP	3.29	3.33	3.33	5.30	5.30	5.30	6.47	6.47	6.47	8.66	8.72	8.72	7.32	7.37	7.37	3.96	3.99	3.99
Storage	-	0.50	0.50	-	-	-	-	-	-	-	0.64	0.64	-	0.50	0.50	-	1.58	1.58
Transport	0.60	0.43	0.55	0.78	0.81	1.10	1.17	1.34	1.54	2.29	1.14	1.32	1.82	0.98	1.16	1.75	0.78	0.97
Cargo handling	0.14	1.21	1.21	0.19	1.16	1.16	0.14	0.86	0.86	0.05	0.57	0.57	0.10	0.82	0.82	0.10	0.86	0.86
Total provision costs	4.04	5.48	5.60	6.27	7.26	7.56	7.78	8.67	8.88	11.00	11.07	11.25	9.24	9.66	9.85	5.81	7.21	7.41
S1																		
Biomass costs 1st GP	2.90	2.93	2.93	5.32	5.32	5.32	4.24	4.24	4.24	6.60	6.64	6.64	6.80	6.85	6.85	3.63	3.65	3.65
Storage	-	0.35	0.35	-	-	-	-	-	-	-	0.40	0.40	-	0.38	0.38	-	1.61	1.61
Transport	0.56	0.43	0.55	0.72	0.83	1.12	1.04	1.14	1.35	1.73	0.95	1.13	1.72	0.95	1.14	1.75	0.86	1.06
Cargo handling	0.14	1.21	1.21	0.19	1.16	1.16	0.14	0.86	0.86	0.05	0.57	0.57	0.10	0.82	0.82	0.10	0.86	0.86
Total provision costs	3.60	4.92	5.04	6.23	7.30	7.59	5.41	6.24	6.45	8.37	8.57	8.75	8.62	9.00	9.19	5.48	6.98	7.18
S2																		
Biomass costs 1st GP	-	-	-	3.07	3.07	3.07	4.82	4.82	4.82	6.49	6.54	6.54	7.32	7.37	7.37	3.74	3.77	3.77
Storage	-	-	-	-	-	-	-	-	-	-	0.81	0.81	-	0.75	0.75	-	1.80	1.80
Transport	-	-	-	0.78	0.66	0.98	1.26	1.37	1.60	2.66	1.21	1.41	2.64	1.21	1.41	2.22	0.89	1.11
Cargo handling	-	-	-	0.19	1.16	1.16	0.14	0.86	0.86	0.05	0.57	0.57	0.10	0.82	0.82	0.10	0.86	0.86
Total provision costs	-	-	-	4.05	4.89	5.21	6.22	7.06	7.28	9.21	9.13	9.33	10.05	10.15	10.35	6.06	7.32	7.54

500 MW																		
Starting point - SP																		
Biomass costs 1st GP	3.33	3.33	3.33	5.30	5.30	5.30	6.47	6.47	6.47	8.66	8.72	8.72	7.32	7.37	7.37	3.96	3.99	3.99
Storage	-	0.50	0.50	-	-	-	-	-	-	-	0.64	0.64	-	0.50	0.50	-	1.58	1.58
Transport	2.40	1.03	1.15	2.40	1.62	1.91	3.83	2.80	3.00	6.79	2.66	2.84	6.07	2.27	2.46	5.94	2.07	2.26
Cargo handling	0.19	1.21	1.21	0.19	1.16	1.16	0.14	0.86	0.86	0.05	0.57	0.57	0.10	0.82	0.82	0.10	0.86	0.86
Total provision costs	7.89	6.07	6.19	7.89	8.07	8.37	10.44	10.13	10.34	15.50	12.59	12.77	13.49	10.96	11.14	10.00	8.50	8.70

[€/GJ$_{LHV}$]	LR, TW bundles (WB)			LR, TW chips (WC)			SRC chips			MIS bales			WCC bales			STR bales		
Route	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road
S1																		
Biomass costs 1st GP	2.90	2.93	2.93	5.32	5.32	5.32	4.24	4.24	4.24	6.60	6.64	6.64	6.80	6.85	6.85	3.63	3.65	3.65
Storage	-	0.35	0.35	-	-	-	-	-	-	-	0.40	0.40	-	0.38	0.38	-	1.61	1.61
Transport	1.68	1.02	1.14	2.22	1.76	2.05	2.96	2.32	2.53	5.34	2.04	2.23	5.32	2.05	2.23	5.94	2.07	2.26
Cargo handling	0.14	1.21	1.21	0.19	1.16	1.16	0.14	0.86	0.86	0.05	0.57	0.57	0.10	0.82	0.82	0.10	0.86	0.86
Total provision costs	4.72	5.51	5.63	7.73	8.23	8.52	7.33	7.42	7.62	11.98	9.66	9.84	12.23	10.10	10.28	9.67	8.19	8.39
S2																		
Biomass costs 1st GP	-	-	-	3.07	3.07	3.07	4.82	4.82	4.82	6.49	6.54	6.54	7.32	7.37	7.37	3.74	3.77	3.77
Storage	-	-	-	-	-	-	-	-	-	-	0.81	0.81	-	0.75	0.75	-	1.80	1.80
Transport	-	-	-	2.45	1.56	1.87	3.82	2.83	3.05	8.30	2.93	3.13	8.25	2.76	2.96	6.93	2.21	2.42
Cargo handling	-	-	-	0.19	1.16	1.16	0.14	0.86	0.86	0.05	0.57	0.57	0.10	0.82	0.82	0.10	0.86	0.86
Total provision costs	-	-	-	5.71	5.79	6.10	8.78	8.51	8.74	14.84	10.85	11.05	15.66	11.70	11.90	10.77	8.63	8.85

Table A2-0-12 Biomass provision costs at BtL plant – provision including pyrolysis NORTH

[€/GJ$_{LHV}$]	LR, TW bundles		LR, TW chips		SRC chips		MIS bales		WCC bales		STR bales	
Route	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail
500 MW P												
Starting point - SP												
Biomass costs 1st GP	4.39	4.39	7.06	7.06	8.63	8.63	11.55	11.55	9.15	9.15	4.95	4.95
Storage	-	-	-	-	-	-	-	-	-	-	-	-
Transport	2.36	1.56	2.62	1.85	5.21	3.19	6.29	4.53	6.11	4.30	5.87	4.19
Cargo handling	0.36	0.47	0.42	0.53	0.35	0.46	0.27	0.39	0.27	0.41	0.27	0.41
Total provision costs	7.11	6.42	10.11	9.44	14.19	12.27	18.11	16.47	15.54	13.85	11.09	9.55
S1												
Biomass costs 1st GP	3.86	3.86	7.09	7.09	5.65	5.65	8.80	8.80	8.51	8.51	4.54	4.54
Storage	-	-	-	-	-	-	-	-	-	-	-	-
Transport	2.15	1.42	2.38	1.68	3.81	2.38	5.96	4.18	5.93	4.09	5.86	4.17
Cargo handling	0.36	0.39	0.42	0.45	0.35	0.38	0.27	0.33	0.27	0.34	0.27	0.34
Total provision costs	6.37	5.67	9.90	9.23	9.81	8.41	15.03	13.31	14.70	12.93	10.67	9.05
S2												
Biomass costs 1st GP	-	-	4.10	4.10	6.43	6.43	8.66	8.66	9.15	9.15	4.68	4.68
Storage	-	-	-	-	-	-	-	-	-	-	-	-
Transport	-	-	2.67	1.84	5.65	3.34	8.65	5.98	8.56	5.80	6.51	4.55
Cargo handling	-	-	0.42	0.45	0.35	0.38	0.27	0.33	0.27	0.34	0.27	0.34
Total provision costs	-	-	7.20	6.40	12.43	10.15	17.58	14.97	17.98	15.29	11.45	9.57

Table A2-0-13 Biomass provision costs at BtL plant – direct provision ALPINE

[€/GJ$_{LHV}$]	LR, TW chips (WC)			SRC chips			MIS bales			WCC bales			STR bales		
Route	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road
50 MW															
Starting point - SP															
Biomass costs 1st GP	5.57	5.57	5.57	6.12	6.12	6.12	7.63	7.68	7.68	6.80	6.85	6.85	3.72	3.75	3.75
Storage	-	-	-	-	-	-	-	3.21	3.21	-	3.05	3.05	-	2.28	2.28
Transport	1.47	0.45	0.86	10.73	2.44	2.74	11.07	2.54	2.97	11.07	2.38	2.82	5.06	1.20	1.67
Cargo handling	0.25	1.11	1.11	0.18	0.83	0.83	0.08	0.60	0.60	0.15	0.83	0.83	0.16	0.87	0.87
Total provision costs	7.29	7.12	7.53	17.03	9.39	9.68	18.78	14.02	14.46	18.03	13.10	13.54	8.93	8.10	8.57
S1															
Biomass costs 1st GP	4.00	4.00	4.00	4.12	4.12	4.12	6.39	6.43	6.43	6.70	6.75	6.75	3.48	3.50	3.50
Storage	-	-	-	-	-	-	-	0.06	0.06	-	0.03	0.03	-	2.03	2.03
Transport	1.19	0.39	0.80	1.91	1.06	1.35	1.87	1.25	1.69	1.04	1.15	1.59	4.96	1.19	1.66
Cargo handling	0.25	1.11	1.11	0.18	0.83	0.83	0.08	0.60	0.60	0.15	0.83	0.83	0.16	0.87	0.87
Total provision costs	5.44	5.50	5.91	6.20	6.00	6.29	8.33	8.34	8.78	7.89	8.75	9.19	8.60	7.59	8.06
S2															
Biomass costs 1st GP	3.60	3.60	3.60	4.47	4.00	4.00	6.29	6.33	6.33	7.11	7.16	7.16	-	-	-
Storage	-	-	-	-	-	-	-	0.58	0.58	-	0.92	0.92	-	-	-
Transport	1.32	0.43	0.83	5.30	1.67	1.99	4.24	1.66	2.09	5.81	1.72	2.16	-	-	-
Cargo handling	0.25	1.11	1.11	0.18	0.92	0.92	0.08	0.60	0.60	0.15	0.83	0.83	-	-	-
Total provision costs	5.16	5.13	5.53	9.94	6.59	6.91	10.60	9.16	9.59	13.08	10.63	11.06	-	-	-
500 MW															
Starting point - SP															
Biomass costs 1st GP	5.57	5.57	5.57	6.12	6.12	6.12	7.63	7.68	7.68	6.80	6.85	6.85	3.72	3.75	3.75
Storage	-	-	-	-	-	-	-	3.21	3.21	-	3.05	3.05	-	2.28	2.28
Transport	4.28	1.09	2.08	33.49	8.52	9.46	38.52	5.76	6.21	38.55	5.60	6.06	17.13	2.68	3.15
Cargo handling	0.25	1.08	1.08	0.18	0.81	0.81	0.08	0.60	0.60	0.15	0.82	0.82	0.16	0.87	0.87
Total provision costs	10.09	7.74	8.73	39.79	15.45	16.40	46.22	17.24	17.70	45.51	16.32	16.78	21.01	9.58	10.05

[€/GJ$_{LHV}$]	LR, TW chips (WC)			SRC chips			MIS bales			WCC bales			STR bales		
Route	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road
S1															
Biomass costs 1st GP	4.00	4.00	4.00	4.12	4.12	4.12	6.39	6.43	6.43	6.70	6.75	6.75	3.48	3.50	3.50
Storage	-	-	-	-	-	-	-	0.06	0.06	-	0.03	0.03	-	2.03	2.03
Transport	3.40	0.73	1.14	5.47	1.54	1.83	5.46	1.69	2.12	3.92	1.50	1.94	16.14	2.56	3.03
Cargo handling	0.25	1.11	1.11	0.18	0.83	0.83	0.08	0.60	0.60	0.15	0.83	0.83	0.16	0.87	0.87
Total provision costs	7.66	5.84	6.25	9.77	6.48	6.77	11.92	8.78	9.22	10.77	9.11	9.55	19.78	8.95	9.43
S2															
Biomass costs 1st GP	3.60	3.60	3.60	4.47	4.47	4.47	6.29	6.33	6.33	7.11	7.16	7.16	-	-	-
Storage	-	-	-	-	-	-	-	0.58	0.58	-	0.92	0.92	-	-	-
Transport	3.91	0.81	1.21	15.68	3.33	3.62	15.72	2.95	3.38	19.46	3.41	3.85	-	-	-
Cargo handling	0.25	1.11	1.11	0.18	0.83	0.83	0.08	0.60	0.60	0.15	0.83	0.83	-	-	-
Total provision costs	7.76	5.51	5.91	20.33	8.63	8.91	22.09	10.46	10.89	26.72	12.32	12.75	-	-	-

Table A2-0-14 Biomass provision costs at BtL plant – provision including pyrolysis ALPINE

[€/GJ$_{LHV}$]	LR, TW chips		SRC chips		MIS bales		WCC bales		STR bales	
Route	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail
500 MW P										
Starting point - SP										
Biomass costs 1st GP	7.42	7.42	8.16	8.16	10.17	10.17	8.51	8.51	4.65	4.65
Storage	-	-	-	-	-	-	-	-	-	-
Transport	3.21	2.73	29.01	21.21	32.09	21.88	31.57	21.00	14.47	9.93
Cargo handling	0.55	0.62	0.46	0.53	0.55	0.56	0.57	0.58	0.57	0.58
Total provision costs	11.19	10.77	37.63	29.89	42.82	32.62	40.64	30.08	19.69	15.16
S1										
Biomass costs 1st GP	5.34	5.34	5.49	5.49	8.52	10.17	8.38	8.38	4.35	4.35
Storage	-	-	-	-	-	-	-	-	-	-
Transport	2.67	2.28	4.89	3.63	5.31	3.65	4.59	2.88	14.30	9.74
Cargo handling	0.55	0.52	0.46	0.43	0.55	0.40	0.57	0.40	0.57	0.40
Total provision costs	8.56	8.13	10.84	9.55	14.38	14.21	13.54	11.65	19.22	14.49
S2										
Biomass costs 1st GP	4.80	4.80	5.96	5.96	8.38	8.38	8.89	8.89	-	-
Storage	-	-	-	-	-	-	-	-	-	-
Transport	2.90	2.46	11.87	8.82	12.90	8.88	16.38	10.97	-	-
Cargo handling	0.55	0.52	0.46	0.43	0.55	0.40	0.57	0.40	-	-
Total provision costs	8.25	7.78	18.29	15.20	21.84	17.66	25.84	20.26	-	-

Table A2-0-15 Biomass provision costs at BtL plant – direct provision SOUTH

[€/GJ_{LHV}]	LR, TW chips (WC)			EUC chips			SWG bales			WCC bales			STR bales		
Route	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road
50 MW															
Starting point - SP															
Biomass costs 1st GP	-	-	-	5.06	5.06	5.06	5.88	5.92	5.92	6.60	6.64	6.64	2.96	2.98	2.98
Storage	-	-	-	-	-	-	-	0.07	0.07	-	0.13	0.13	-	0.09	0.09
Transport	-	-	-	2.54	1.39	1.75	6.58	3.83	5.29	8.49	3.91	5.39	4.24	2.16	3.74
Cargo handling	-	-	-	0.24	0.85	0.85	0.13	0.70	0.70	0.26	0.92	0.92	0.26	0.97	0.97
Total provision costs	-	-	-	7.84	7.29	7.66	12.59	10.50	11.97	15.35	11.61	13.09	7.46	6.20	7.78
S1															
Biomass costs 1st GP	-	-	-	3.88	3.88	3.88	5.88	5.92	5.92	7.42	7.47	7.47	3.03	3.05	3.05
Storage	-	-	-	-	-	-	-	0.04	0.04	-	0.11	0.11	-	0.10	0.10
Transport	-	-	-	2.03	1.35	1.71	4.70	3.76	5.23	8.23	3.91	5.38	4.33	2.16	3.74
Cargo handling	-	-	-	0.24	0.85	0.85	0.13	0.70	0.70	0.26	0.92	0.92	0.26	0.97	0.97
Total provision costs	-	-	-	6.15	6.08	6.44	10.71	10.42	11.89	15.92	12.41	13.89	7.62	6.27	7.85
S2															
Biomass costs 1st GP	-	-	-	4.47	4.47	4.47	6.49	6.54	6.54	7.94	7.99	7.99	3.13	3.15	3.15
Storage	-	-	-	-	-	-	-	0.07	0.07	-	0.18	0.18	-	0.10	0.10
Transport	-	-	-	2.70	1.39	1.75	6.62	3.80	5.26	8.95	3.90	5.37	4.30	2.14	3.71
Cargo handling	-	-	-	0.24	0.85	0.85	0.13	0.70	0.70	0.26	0.92	0.92	0.26	0.97	0.97
Total provision costs	-	-	-	7.41	6.71	7.07	13.25	11.10	12.56	17.15	13.00	14.46	7.69	6.36	7.92
500 MW															
Starting point - SP															
Biomass costs 1st GP	-	-	-	5.06	5.06	5.06	5.88	5.92	5.92	6.60	6.64	6.64	2.96	2.98	2.98
Storage	-	-	-	-	-	-	-	0.07	0.07	-	0.13	0.13	-	0.09	0.09
Transport	-	-	-	7.11	1.92	2.29	18.63	4.32	5.78	25.27	4.60	6.08	10.97	2.43	4.01
Cargo handling	-	-	-	0.24	0.85	0.85	0.13	0.70	0.70	0.26	0.92	0.92	0.26	0.97	0.97
Total provision costs	-	-	-	12.41	7.83	8.19	24.63	11.00	12.46	32.13	12.30	13.77	14.19	6.47	8.05

[€/GJ$_{LHV}$]	LR, TW chips (WC)			EUC chips			SWG bales			WCC bales			STR bales		
Route	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road
S1															
Biomass costs 1st GP	-	-	-	3.88	3.88	3.88	5.88	5.92	5.92	7.42	7.47	7.47	3.03	3.05	3.05
Storage	-	-	-	-	-	-	-	0.04	0.04	-	0.11	0.11	-	0.10	0.10
Transport	-	-	-	5.60	1.88	2.24	14.23	4.12	5.59	24.52	4.58	6.06	11.08	2.43	4.00
Cargo handling	-	-	-	0.24	0.85	0.85	0.13	0.70	0.70	0.26	0.92	0.92	0.26	0.97	0.97
Total provision costs	-	-	-	9.73	6.61	6.97	20.24	10.78	12.25	32.20	13.09	14.57	14.37	6.54	8.12
S2															
Biomass costs 1st GP	-	-	-	4.47	4.47	4.47	6.49	6.54	6.54	7.94	7.99	7.99	3.13	3.15	3.15
Storage	-	-	-	-	-	-	-	0.07	0.07	-	0.18	0.18	-	0.10	0.10
Transport	-	-	-	7.29	1.93	2.29	18.61	4.29	5.75	30.20	4.80	6.26	11.00	2.50	4.06
Cargo handling	-	-	-	0.24	0.85	0.85	0.13	0.70	0.70	0.26	0.92	0.92	0.26	0.97	0.97
Total provision costs	-	-	-	12.01	7.25	7.61	25.23	11.60	13.05	38.40	13.89	15.36	14.39	6.71	8.28

Table A2-0-16 Biomass provision costs at BtL plant – provision including pyrolysis SOUTH

[€/GJ$_{LHV}$]	LR, TW chips		EUC chips		SWG bales		WCC bales		STR bales	
Route	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail
500 MW P										
Starting point - SP										
Biomass costs 1st GP	-	-	6.75	6.75	7.84	7.84	8.25	8.25	3.70	3.70
Storage	-	-	-	-	-	-	-	-	-	-
Transport	-	-	7.40	4.99	16.04	11.78	17.16	12.79	8.82	6.93
Cargo handling	-	-	0.88	0.79	1.48	1.10	1.54	1.14	1.54	1.14
Total provision costs	-	-	15.03	12.52	25.35	20.72	26.95	22.17	14.07	11.78
S1										
Biomass costs 1st GP	-	-	5.18	5.18	7.84	7.84	9.28	9.28	3.78	3.78
Storage	-	-	-	-	-	-	-	-	-	-
Transport	-	-	6.99	4.53	14.51	10.19	16.98	12.52	8.87	6.90
Cargo handling	-	-	0.88	0.52	1.48	0.54	1.54	0.54	1.54	0.54
Total provision costs	-	-	13.05	10.22	23.83	18.56	27.80	22.34	14.20	11.23
S2										
Biomass costs 1st GP	-	-	5.96	5.96	8.66	8.66	9.92	9.92	3.91	3.91
Storage	-	-	-	-	-	-	-	-	-	-
Transport	-	-	7.47	5.04	15.98	11.69	25.46	17.75	8.80	6.85
Cargo handling	-	-	0.88	0.52	1.48	0.54	1.54	0.54	1.54	0.54
Total provision costs	-	-	14.31	11.52	26.13	20.90	36.92	28.21	14.25	11.30

Table A2-0-17 Biomass provision costs at BtL plant – direct provision UK+IR

[€/GJ$_{LHV}$]	LR, TW chips (WC)			SRC chips			MIS bales			WCC bales			STR bales		
Route	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road
50 MW															
Starting point - SP															
Biomass costs 1st GP	5.55	5.55	5.55	6.71	6.71	6.71	8.04	8.10	8.10	6.80	6.85	6.85	3.55	3.58	3.58
Storage	-	-	-	-	-	-	-	0.35	0.35	-	0.40	0.40	-	0.41	0.41
Transport	1.50	0.66	1.17	8.90	3.57	3.93	4.65	2.43	2.78	4.87	3.00	3.35	2.62	1.36	1.73
Cargo handling	0.21	2.32	2.32	0.15	1.79	1.79	0.06	1.01	1.01	0.12	1.59	1.59	0.12	1.56	1.56
Total provision costs	7.26	8.53	9.04	15.76	12.06	12.43	12.75	11.89	12.24	11.80	11.84	12.19	6.30	6.91	7.28
S1															
Biomass costs 1st GP	4.92	4.92	4.92	4.35	4.35	4.35	6.39	6.43	6.43	6.49	6.54	6.54	3.33	3.35	3.35
Storage	-	-	-	-	-	-	-	0.01	0.01	-	0.02	0.02	-	2.63	2.63
Transport	0.96	0.49	1.00	1.58	1.45	1.82	0.87	1.12	1.47	0.87	1.27	1.62	6.91	2.90	3.27
Cargo handling	0.21	2.32	2.32	0.15	1.79	1.79	0.06	1.01	1.01	0.12	1.59	1.59	0.12	1.56	1.56
Total provision costs	6.09	7.73	8.24	6.09	7.60	7.96	7.32	8.58	8.93	7.49	9.42	9.77	10.36	10.44	10.81
S2															
Biomass costs 1st GP	3.09	3.09	3.09	5.18	5.18	5.18	6.29	6.33	6.33	6.91	6.95	6.95	-	-	-
Storage	-	-	-	-	-	-	-	0.31	0.31	-	0.54	0.54	-	-	-
Transport	0.97	0.49	1.00	10.44	3.61	3.97	4.47	2.39	2.73	5.97	3.11	3.45	-	-	-
Cargo handling	0.21	2.32	2.32	0.15	1.79	1.79	0.06	1.01	1.01	0.12	1.59	1.59	-	-	-
Total provision costs	4.28	5.90	6.41	15.77	10.57	10.94	10.82	10.05	10.39	13.00	12.19	12.53	-	-	-
500 MW															
Starting point - SP															
Biomass costs 1st GP	5.55	5.55	5.55	6.71	6.71	6.71	8.04	8.10	8.10	6.80	6.85	6.85	3.55	3.58	3.58
Storage	-	-	-	-	-	-	-	0.35	0.35	-	0.40	0.40	-	0.41	0.41
Transport	4.91	1.44	1.96	29.37	9.17	9.54	14.44	6.20	6.55	16.93	7.29	7.64	8.54	3.62	3.99
Cargo handling	0.21	2.32	2.32	0.15	1.79	1.79	0.06	1.01	1.01	0.12	1.59	1.59	0.12	1.56	1.56
Total provision costs	10.68	9.31	9.83	36.23	17.67	18.04	22.54	15.66	16.01	23.85	16.12	16.47	12.21	9.17	9.54

[€/GJ$_{LHV}$]	LR, TW chips (WC)			SRC chips			MIS bales			WCC bales			STR bales		
Route	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road	road	road-rail	road-rail-road
S1															
Biomass costs 1st GP	4.92	4.92	4.92	4.35	4.35	4.35	6.39	6.43	6.43	6.49	6.54	6.54	3.33	3.35	3.35
Storage	-	-	-	-	-	-	-	0.01	0.01	-	0.02	0.02	-	2.63	2.63
Transport	2.56	0.84	1.36	5.82	2.40	2.77	2.20	1.56	1.91	3.36	2.08	2.43	22.40	8.30	8.68
Cargo handling	0.21	2.32	2.32	0.15	1.79	1.79	0.06	1.01	1.01	0.12	1.59	1.59	0.12	1.56	1.56
Total provision costs	7.70	8.08	8.60	10.33	8.54	8.91	8.65	9.02	9.37	9.98	10.23	10.58	25.85	15.85	16.22
S2															
Biomass costs 1st GP	3.09	3.09	3.09	5.18	5.18	5.18	6.29	6.33	6.33	6.91	6.95	6.95	-	-	-
Storage	-	-	-	-	-	-	-	0.31	0.31	-	0.54	0.54	-	-	-
Transport	2.57	0.91	1.42	31.44	9.78	10.14	13.97	5.75	6.09	19.48	8.34	8.69	-	-	-
Cargo handling	0.21	2.32	2.32	0.15	1.79	1.79	0.06	1.01	1.01	0.12	1.59	1.59	-	-	-
Total provision costs	5.88	6.32	6.83	36.77	16.74	17.11	20.32	13.41	13.75	26.51	17.43	17.77	-	-	-

Table A2-0-18 Biomass provision costs at BtL plant – provision including pyrolysis UK+IR

[€/GJ_{LHV}]	LR, TW chips		SRC chips		MIS bales		WCC bales		STR bales	
Route	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail	road-pyrolysis-road	road-pyrolysis-road-rail
500 MW P										
Starting point - SP										
Biomass costs 1st GP	7.40	7.40	8.94	8.94	10.72	10.72	8.51	8.51	4.44	4.44
Storage	-	-	-	-	-	-	-	-	-	-
Transport	3.37	3.42	19.34	19.04	11.20	11.79	13.09	13.85	6.86	7.28
Cargo handling	0.40	0.87	0.32	0.80	0.33	0.79	0.34	0.83	0.34	0.83
Total provision costs	11.18	11.70	28.60	28.78	22.25	23.31	21.94	23.19	11.64	12.55
S1										
Biomass costs 1st GP	6.56	6.56	5.80	5.80	8.52	8.52	8.12	8.12	4.16	4.16
Storage	-	-	-	-	-	-	-	-	-	-
Transport	1.67	1.74	4.72	4.68	1.51	1.64	3.23	3.48	16.12	16.95
Cargo handling	0.40	0.82	0.32	0.74	0.33	0.71	0.34	0.74	0.34	0.74
Total provision costs	8.64	9.12	10.85	11.23	10.37	10.87	11.68	12.34	20.62	21.85
S2										
Biomass costs 1st GP	4.13	4.13	6.90	6.90	8.38	8.38	8.63	8.63	-	-
Storage	-	-	-	-	-	-	-	-	-	-
Transport	1.68	1.74	22.44	22.10	10.85	11.48	15.25	16.18	-	-
Cargo handling	0.40	0.82	0.32	0.74	0.33	0.71	0.34	0.74	-	-
Total provision costs	6.21	6.68	29.67	29.74	19.57	20.58	24.22	25.55	-	-

Table A2-0-19 Results sensitivity analysis – straw, S1, 500 MW_{th}

Area or region specific potential	WEST		EAST		NORTH		ALPINE		SOUTH		UK+IR	
	road	road-rail	road	road-rail	road	road-rail	road	road-rail	road	road-rail	road	road-rail
[GJ/(ha a)]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]
~0	24.83	11.50	26.98	20.70	20.93	14.10	50.29	31.16	168.59	16.80	39.85	24.85
1	3.54	2.48	3.84	3.24	2.98	2.38	7.05	2.68	23.48	4.29	5.66	4.10
2	2.59	2.05	2.80	2.81	2.18	1.94	5.13	2.25	16.97	3.83	4.12	3.49
3	2.14	1.86	2.30	2.43	1.80	1.75	4.21	2.07	13.89	3.64	3.39	3.20
4	1.76	1.71	1.88	2.34	1.48	1.62	3.40	1.93	11.31	3.49	2.77	3.14
5	1.69	1.68	1.81	2.08	1.42	1.58	3.30	1.90	10.83	3.46	2.66	2.93
6	1.62	1.65	1.74	2.03	1.36	1.56	3.19	1.88	10.36	3.43	2.56	2.90
7	1.33	1.55	1.41	1.99	1.11	1.54	2.52	1.86	8.34	3.41	2.06	2.87
8	1.30	1.54	1.38	1.77	1.09	1.45	2.47	1.77	8.17	3.32	2.02	2.69
9	1.28	1.53	1.35	1.75	1.07	1.44	2.43	1.76	7.99	3.31	1.99	2.67
10	1.25	1.52	1.33	1.74	1.05	1.43	2.39	1.75	7.82	3.30	1.95	2.66
11	1.23	1.51	1.30	1.72	1.02	1.42	2.35	1.74	7.65	3.29	1.91	2.65
12	1.20	1.50	1.28	1.70	1.00	1.41	2.31	1.74	7.48	3.28	1.87	2.64
13	1.18	1.49	1.25	1.69	0.98	1.41	2.27	1.73	7.30	3.27	1.83	2.63
14	1.15	1.49	1.22	1.67	0.96	1.40	2.22	1.72	7.13	3.26	1.79	2.62
15	1.13	1.48	1.20	1.66	0.94	1.39	2.18	1.72	6.96	3.26	1.75	2.60
16	0.89	1.47	1.17	1.65	0.92	1.39	2.14	1.71	6.78	3.25	1.71	2.59
17	0.89	1.40	0.92	1.63	0.74	1.38	1.62	1.71	5.33	3.17	1.35	2.58
18	0.88	1.39	0.92	1.46	0.73	1.31	1.62	1.64	5.30	3.17	1.34	2.44
19	0.88	1.39	0.91	1.46	0.73	1.31	1.61	1.64	5.27	3.17	1.33	2.44
20	0.87	1.39	0.91	1.45	0.72	1.31	1.60	1.64	5.23	3.17	1.33	2.43
21	0.87	1.39	0.90	1.45	0.72	1.31	1.59	1.63	5.20	3.17	1.32	2.43
22	0.86	1.39	0.90	1.44	0.71	1.31	1.58	1.63	5.17	3.16	1.31	2.43
23	0.86	1.38	0.89	1.44	0.71	1.30	1.57	1.63	5.13	3.16	1.30	2.43
24	0.85	1.38	0.89	1.44	0.71	1.30	1.56	1.63	5.10	3.16	1.29	2.42
25	0.85	1.38	0.88	1.43	0.70	1.30	1.55	1.63	5.07	3.16	1.29	2.42
average costs Del. 5.3.6	*1.78*	*1.81*	*2.41*	*1.10*	*6.04*	*4.54*	*16.30*	*5.45*	*11.34*	*3.49*	*22.52*	*12.50*

Table A2-0-20 Results sensitivity analysis – willow, S1, 500 MW_{th}

Area or region specific potential	WEST		EAST		NORTH		ALPINE		SOUTH		UK+IR	
	road	road-rail	road	road-rail	road	road-rail	road	road-rail	road	road-rail	road	road-rail
[GJ/(ha a)]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]	[€/GJ]
~0	45.86	20.94	30.41	37.74	23.78	16.18	87.44	15.19	113.42	20.50	130.30	38.05
2	4.96	2.44	3.14	5.85	2.64	2.93	9.28	3.03	12.15	3.51	13.83	6.58
4	3.21	2.44	2.34	2.61	1.74	2.44	5.90	2.55	7.80	2.97	8.79	5.28
6	2.48	2.39	2.03	2.61	1.35	2.22	4.43	2.34	5.96	2.75	6.66	4.73
8	2.35	2.19	1.77	2.61	1.29	2.03	4.24	2.15	5.66	2.54	6.31	4.23
10	2.23	2.17	1.74	2.57	1.23	2.02	4.04	2.14	5.35	2.52	5.97	4.19
12	2.10	2.15	1.70	2.53	1.17	2.00	3.84	2.12	5.04	2.50	5.62	4.14
14	1.64	2.13	1.67	2.48	0.92	1.98	2.83	2.10	3.87	2.48	4.25	4.09
16	1.61	2.11	1.65	2.44	0.90	1.96	2.78	2.09	3.82	2.46	4.18	4.05
18	1.59	1.95	1.46	2.40	0.89	1.82	2.74	2.07	3.76	2.31	4.11	4.00
20	1.57	1.95	1.45	2.08	0.88	1.81	2.70	1.94	3.70	2.30	4.05	3.65
22	1.54	1.94	1.44	2.07	0.87	1.81	2.66	1.94	3.64	2.30	3.98	3.64
24	1.52	1.94	1.44	2.07	0.85	1.80	2.62	1.93	3.58	2.29	3.91	3.63
26	1.49	1.93	1.43	2.06	0.84	1.80	2.58	1.93	3.52	2.29	3.84	3.62
28	1.47	1.93	1.42	2.05	0.83	1.80	2.54	1.92	3.46	2.28	3.78	3.61
30	1.44	1.92	1.42	2.04	0.82	1.79	2.49	1.92	3.40	2.28	3.71	3.60
32	1.42	1.92	1.41	2.03	0.81	1.79	2.45	1.92	3.34	2.27	3.64	3.59
34	1.39	1.92	1.40	2.02	0.79	1.78	2.41	1.91	3.28	2.27	3.57	3.58
36	1.37	1.91	1.40	2.01	0.78	1.78	2.37	1.91	3.22	2.27	3.51	3.57
38	1.34	1.91	1.39	2.00	0.77	1.77	2.33	1.91	3.16	2.26	3.44	3.56
40	1.32	1.90	1.39	1.99	0.76	1.77	2.29	1.90	3.10	2.26	3.37	3.55
42	1.30	1.90	1.39	1.98	0.74	1.77	2.25	1.90	3.04	2.25	3.30	3.54
44	1.27	1.89	1.38	1.97	0.73	16.18	2.20	1.89	2.98	2.25	3.24	3.53
46	1.25	1.89	1.37	1.96	0.72	1.76	2.16	1.89	2.92	2.24	3.17	3.52
48	1.22	1.88	1.36	1.95	0.71	1.75	2.12	1.89	2.86	2.24	3.10	3.51
50	1.20	1.88	1.36	1.94	0.70	1.75	2.08	1.88	2.80	2.23	3.03	3.50
average costs Del. 5.3.6	*1.65*	*2.14*	*1.10*	*2.41*	*3.10*	*3.18*	*5.65*	*2.36*	*5.85*	*2.73*	*5.98*	*4.19*