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**RENEW**

**Renewable fuels for advanced powertrains**

**Integrated Project**

**Sustainable energy systems**

***D5.3.4***

# ***Energy Crop Production Costs in the EU***

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## Executive summary

Dedicated energy plantations are necessary for bioenergy to make a substantial contribution to energy supply in Europe and elsewhere. A major share of the production costs for BtL fuels (biomass to liquid fuels) will be accounted for by energy crops or other biomass feedstock costs. This report presents an economic analysis of energy crop production costs on an equal basis across regions in Europe and for different promising energy crops. The overall objective is to calculate indicative cost ranges, analyse the structure of production costs, and assess the main cost drivers. The calculation is made for three cases: the current situation with plantations limited to about 10,000 ha in a country or region, a hypothetical scenario based on the current situation with large scale energy crop production, and a scenario for 2020 with large scale energy crop production. Cost reductions can be assumed in the large scale scenario and further reductions are possible through plant breeding and other developments in the longer term.

A base case production cost calculation is made for each candidate crop based on an established method. Secondly, the production cost is adjusted to regional cost levels that have been determined by collecting data on cost indicators for different European regions. Third, the calculations are transformed to the large scale and large scale 2020 scenarios based on motivated assumptions concerning yield increases, machinery development, etc. The total production cost consists of direct input costs, land costs and costs for risk compensation. The land cost is based on the value of the main alternative land use, i.e., the opportunity cost for growing grain. Nine candidate crops were analysed: willow, poplar, eucalyptus, miscanthus, reed canary grass, switchgrass, hemp, triticale, and sorghum. Present representative yield levels, i.e, *not* yields for optimised field trials, for different regions were collected by project partners. The assumed base case annual yields range from 7.5 tons of dry matter for reed canary grass in northern and eastern Europe to 18 tons of dry matter for miscanthus in Ireland and the UK.

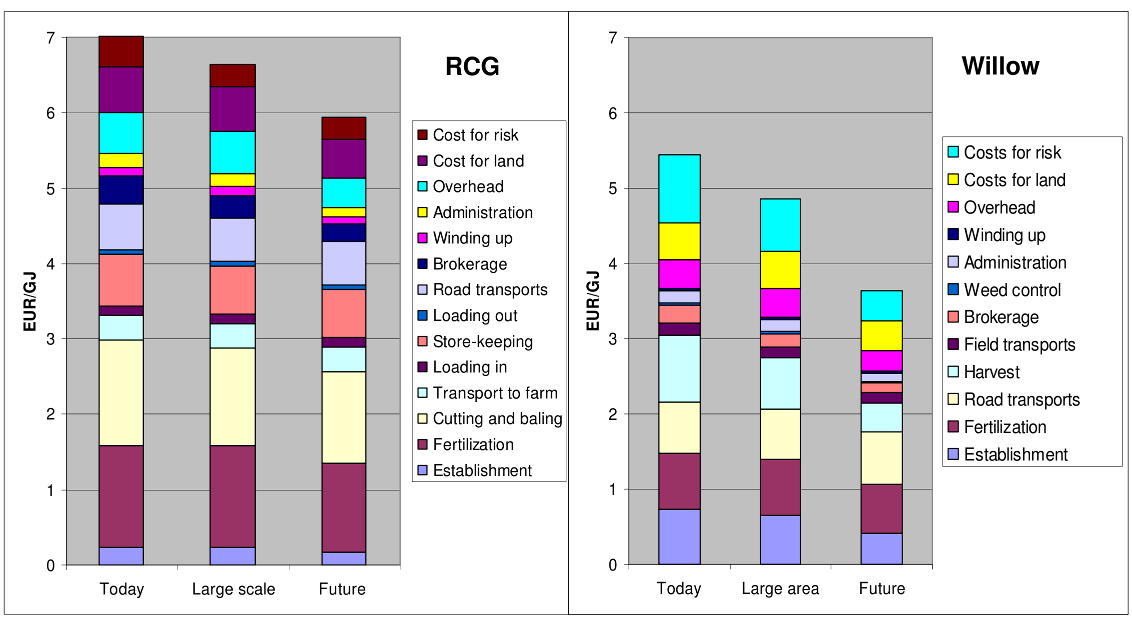


**Figure ES1. Example of cost breakdown for two candidate energy crops, reed canary grass (RCG) and willow, grown under northern European conditions.**

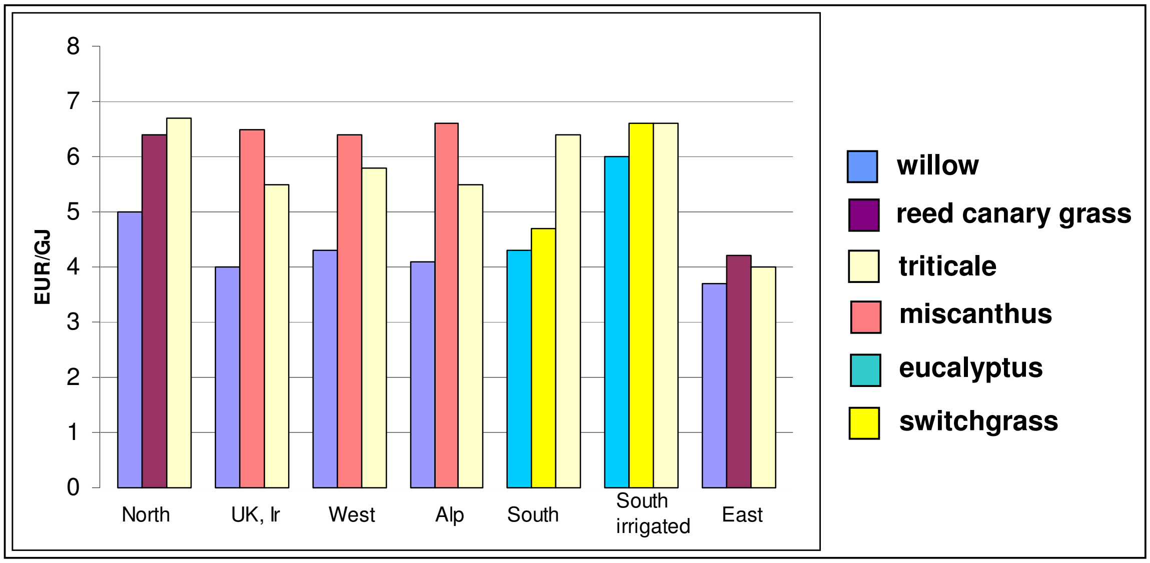


**Figure ES2. Energy crop production costs for the best candidate of each type of crop in each different region under current conditions assuming low land costs.**

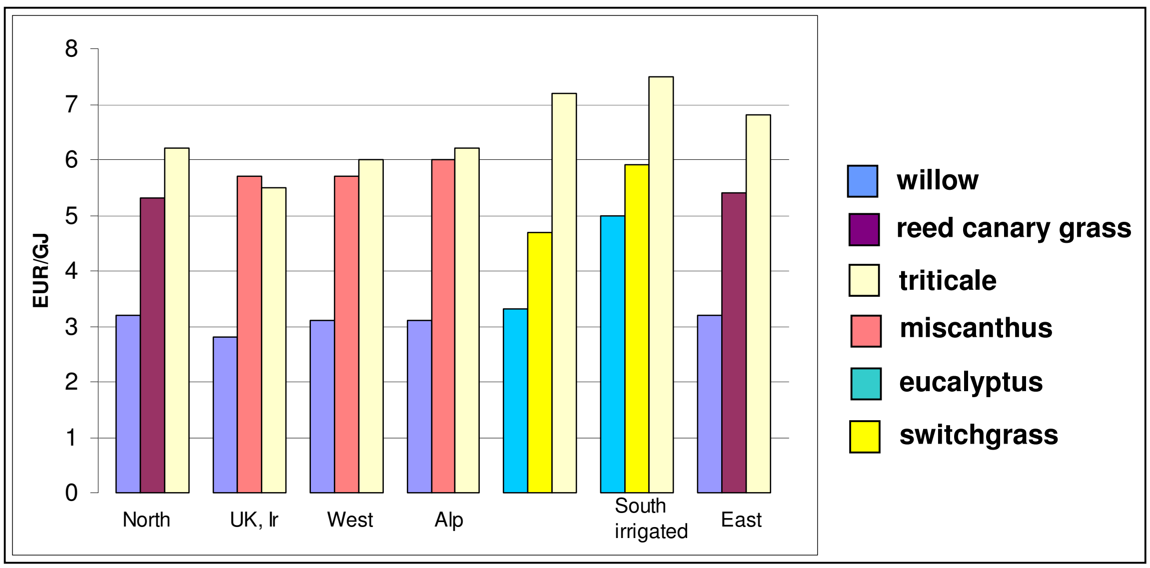


**Figure ES3. Energy crop production costs in large scale for 2020 for the best candidate of each type of crop in each different region assuming low land costs and equalised cost levels across regions.**

The results show that production costs under current conditions at about 4-5 EUR/GJ can be reduced to 3-4 GJ in the future scenario with large scale cultivation in 2020. The relatively larger cost reductions for woody crops such as willow and eucalyptus compared to straw crops such as reed canary grass and miscanthus are explained partly by that cost reductions in the handling of straw crops are difficult to achieve. Furthermore, handling costs constitute a large share of the costs for straw crops, see Figure ES1.

It may be noted in Figure ES2 and ES3 that the cost reductions in eastern Europe are relatively modest. This is explained by that the gains in overall productivity improvements are offset by the cost increases that are assumed to take place as a result of cost levelling across Europe in Figure ES3. If the differences in cost levels would remain, eastern Europe could produce energy crops at less than 2 EUR/GJ in 2020. The production cost level in eastern Europe is less than half of the cost level in northern Europe under current conditions. However, much of the difference is compensated for by higher land costs in eastern Europe, i.e., the opportunity cost of growing grain in eastern Europe (equivalent to 1.1-2.7 EUR/GJ) is higher than in northern Europe (equivalent to 0-0.5 EUR/GJ) as a result of the overall low cost level in eastern Europe.

Overall, the results show that annual crops generally have the highest production costs, 6-7 EUR/GJ in the 2020 scenario, due to annual establishment costs, intensive cultivation, and relatively high handling costs. Perennial grass crops have lower costs, about 5-6 EUR/GJ since annualised establishment costs are lower, cultivation is less intensive, but handling costs remain relatively high. This assumes that no major technical developments take place in the densification of straw crops. The lowest production costs are reached for short rotation coppices such as eucalyptus and willow, about 3-4 EUR/GJ, since annualised costs for establishment, and handling costs, are relatively low. The energy crops that require the largest changes at the farm level, e.g., short rotation coppice, have the lowest production costs. The crops with the highest production costs, e.g., triticale, require the smallest changes at the farm level. Thus, the most promising energy crops also have the greatest hurdles to overcome at the farm level.

An important result is that differences in production costs due to different cost levels, or production on poorer or better soils, level out when using the opportunity cost to estimate land cost. In this study, the alternative cost is defined by the potential income from growing grain. It is often assumed that energy crops should, or will, be grown on poorer soils, less suited for food production. However, from an economic perspective, good soils generally also have the higher energy crop yields. The relative prices of grain and energy crops will determine what is grown and where it is grown – higher grain prices will push energy crop production onto poorer soils.

The results show that energy crop production can be profitable in the short term in some conditions and assuming that bioenergy prices remain in the range of 4-5 EUR/GJ as in recent years. The potentials for cost reductions are large, especially with new crops where plant breeding and machinery development is not advanced. However, these are also the crops for which the need for risk compensation is the greatest, and policy instruments for supporting the development are necessary.

A powerful way of creating niche areas for growing energy crops is to capitalise on environmental benefits, additional to the energy production. The potential for using energy plantations for protecting and restoring polluted water and land resources, i.e., multi-functional energy plantations, is considerable. Using multi-functional energy plantations as a prime mover for energy crops, requires, however, that the value of the environmental services can be monetized and transferred to the energy crop producer.

# 1. Background and objective

With limited potentials for forest fuels and residues in Europe, the development of energy crop production is necessary for European bioenergy to make a substantial contribution to energy supply and the production of biofuels. It is also clear that energy crops will account for a major share of the total cost for producing BTL fuels (biomass-to-liquid fuels).

One main task of WP5.3 is to analyse and calculate the total cost of producing BTL fuels. This report serves as one of the inputs to that overall cost assessment. The objective here is to analyse crop production costs, including a short road transport (30 km) on an equal basis across regions, and for different promising crops. This report is motivated by that results from previous studies are difficult to compare and use in the total cost assessment. It complements a separate review on existing production cost studies (D. 5.3.3). Previous results depend on several more or less transparent assumptions and different methods are used. A consistent and transparent method is used here so that costs can be compared across regions and for different crops.

Our main ambition is not to produce exact numbers for present and future costs. Given the uncertainties concerning yields, land costs and input costs it is not possible to make such firm assessments. The objective here is to calculate indicative ranges of production costs under various assumptions in order to show the levels of cost that may be attained for different crops in different situations. One important purpose is also to identify and analyse the structure of production costs as well as the main cost-drivers. Understanding the type and weight of different cost components is important also for addressing the issue of implementation strategies.

## 2. Method for calculating the economics of different energy crops

This section describes the method used and general considerations made when calculating the costs. Specific assumptions and input data are presented in Section 3. In this study, a method was developed for the purpose of making it possible to get comparable cost estimates for different crops in different regions. The time perspective is both the present and about 15 years ahead in time, 2020. The calculations contain three basic elements, namely methods for:

1) Calculating the base case economics of growing different crops.
2) Making the cost assumptions and calculations for different regions in a similar way.
3) Transforming the calculations to large scale cultivation with present conditions and large scale cultivation in 2020.

For calculating the base-case for different crops we rely on an established method by Rosenqvist (Rosenqvist, 1997). Swedish cost levels are used to calculate the base cases. The method is unique in that it is able to capture the alternative cost of land without relying on tenancy costs or marginal land prices. Instead, the opportunity cost (of growing grain) is used to determine land cost. The method also incorporates a valuation of the risk associated with growing a new crop. For getting comparable results, it is also important to decide which level of development that the calculations refer to. Crops usually go through different development stages in terms of total crop area, breeding, machinery, knowledge and experience, as well as organisational factors. Input data for different crops and regions were gathered based on the present situation, a hypothetical present situation with large scale crop cultivation, and a possible situation with large scale cultivation in 2020. Cost levels for different regions were determined by identifying important cost indicators, thus avoiding the effort of gathering data at the level of detail used in the base case calculations. Based on these cost levels, and the base case calculation, the production costs for different regions were calculated.

### 2.1 Description of the basic method

The method is a modified total step calculation method and was originally developed to make it possible to study SRC (short rotation coppice) cultivation economy and to make comparison between SRC and other crops (Rosenqvist 1996; Rosenqvist 1997). The problems related to making a calculation for SRC cultivation are partly that production takes place over a period of several years with payments and disbursements unevenly distributed over the cultivation period, and partly that SRC cultivation does not require the same set of resources as traditional crop cultivation. The calculation method is required in order to enable comparisons between perennial crops, such as SRC and grain, and with alternative uses of land.

Utilizing the modified total step calculation method makes it possible to compare the economics of annual and perennial crops since the time aspect is taken into account in this method. This is done by combining two calculation methods: the present value method and the annuity method. One factor for each single element is multiplied by the cash flow for different payments and disbursements. This factor is based on the sum of present value factors for payments and disbursements for the total lifespan of the cultivation multiplied by the annuity factor for the interest rate and the number of years assumed for the cultivation. The method is based on a traditional calculation of variable costs extended step by step into a calculation of total costs.

The motive for utilizing a calculation method that distributes costs into steps is to obtain facts to base decisions on relating to different objects and with different scopes. The ambition is to attain, in the same calculation system, the long term stability of the calculation of total costs, as well as the flexibility of the calculation of variable costs in different calculation situations.

The more detailed properties of the total step calculation are dependent on the length and number of the steps. It is important that the planning situation and the requirements for the factual base for decisions are carefully specified. The requirements must be defined with regard to quantities that are to be estimated, i.e. primarily the separate and variable costs for different objects and the total costs for the product category. The distribution of the steps is of great importance with regard to obtaining a reliable base for decisions with a short-term and long-term view respectively. One such example, in which it is important to be able to distinguish between long-term or short-term bases for decisions, is a grain farm with an existing assembly of machinery, but which is contemplating starting an energy crop cultivation.

By making a common cost estimate outside the total step calculation and subsequently distributing the common costs between the different total step calculations, the common costs are taken into account for each individual production sector. Total step calculations are of interest above all when the object of the analysis is not the whole enterprise, but only a few production sectors.

If there is a decision to be made in the spring whether barley or oats should be cultivated is one example when it is of singular interest to study only the topmost cost steps, consisting of variable separate costs.

In a planning situation where a farmer is setting up his enterprise all the cost steps have to be taken into account in order to estimate the long-term profitability of the enterprise. In order to estimate the profitability of additional tenancy, it may be of interest to make one total step calculation for existing land and another for additional land, for the short-term as well as the long-term perspective. The purpose of the calculation is what determines the make-up of its design, and what result levels that are interesting in the analysis.

In the world of plant cultivation the modified total step calculation can be utilized to analyse the economy of a specific crop and to make comparisons between different crops. The calculation method is also applicable on calculations within other areas where payments and disbursements vary from one year to another and the required measure is the average cost per year, income per year, or result per year.

## 2.2 The main cost components for energy crops

Several factors determine the total cost and hence the compensation needed by the farmer to produce energy crops. Three categories of costs can be identified:

1) Costs for growing the crop
2) Costs for land
3) Costs for compensating the risk of growing a new crop

The level of compensation needed for the farmer, through price and subsidies, is also dependent on the total area growing the energy crop and on how fast this area will expand. In addition, the farmer's knowledge and experience of the new crop will affect the level of compensation needed. The three cost categories are discussed below.

### 2.2.1 Costs for growing the crop

The main cost components are for establishment, fertilization, harvest, field transports, road transports, brokerage, weed control, administration, overhead costs, and the costs for winding up the field when terminating the cultivation. Establishment costs include mechanical treatment of the soil and costs for planting/sowing (including costs for seeds, cuttings, etc.). Thus, several types of costs are involved, including costs for machinery and labour. Machinery and labour appear as costs also for fertilisation, weed control, harvest, transports, and winding up. Brokerage, administration, and overhead costs are also included. Of course, the specific cost, in EUR per ton of product, depends strongly on the yield.

For the purpose of comparing different crops, a distinction must be made between known crops for which there is experience and appropriate machinery available, and new crops. Cost levels for crops that are not widely cultivated at present will appear higher since little learning has taken place in cultivation and since appropriate machinery, that can be utilised effectively on many hectares, may not be available. For new crops, plant breeding can be expected to lead to faster yield increases than for established crops. Such factors need to be considered when assessing the economics of a hypothetical present or future large scale cultivation.

For the purpose of comparing across regions, without gathering the necessary detailed data required as input to the basic cost calculation method, an approach was developed by which certain key data are used as cost indicators. By weighing these data, the overall cost level for the different regions could be determined. These cost level indicators are costs of fertilizers, herbicide, farm labour, and machinery. For more detail see Section 3.2.

### 2.2.2 Costs for land

It is a general difficulty to estimate the cost for land. Costs can be a tenancy cost, interest rate of purchased land or an opportunity value of the land with an alternative crop than an energy crop. Gross margins from other crops are dependent on which costs are included in the calculations. Prices on rented land and on purchased land include other factors than the present value of future net margins from the growing on the land.

When land is rented out, the price for the tenancy is often a marginal price for the land. The farmer who has the highest bid, gets to rent the land. In that way the price for renting land is a marginal price. Farmers who rent land often already have some land, machinery, etc. Usually the farmer only pays a high tenancy for his marginal land and not for all of his land. Therefore, the price for rented land does not correspond to the opportunity value of growing on the land. If we were to use the tenancy for a whole region we would use a marginal price for land in an average calculation.

Both monetary and non-monetary values are included in the price of land. The price of land is higher in regions with a high population density (Roos, 1996). In addition, incomes and costs are reflected in the prices of land (Håkansson, 1978). The agricultural policy greatly influences both incomes and costs for the land. For example, subsidies are very important for the price of land. Effects of the agricultural policy are included in the price for land. For this reason the tenancy price for land should not be used when calculating the economics of growing energy crops in a particular region. The opportunity cost may be a better measure of the cost for land. The opportunity cost used in the calculations is based on the net gross margin from producing grain.

### 2.2.3 Risk compensation

The farmer also needs a compensation for the changed risk associated with a new crop. He cannot use the same recourses as for the crop he grows today and the farmer also has costs for finding knowledge about the new crop. For that reason, the new crop must give a higher expected income than traditional food crops in order for most farmers to grow it.

The concept of risk aversion and risk premiums are central to economic theory. Risk aversion does not mean that individuals are unwilling to take risks. Rather, risk aversion means that individuals must be compensated for taking risks in form of a premium over and above the return on a safe investment. Thus a risky investment or enterprise must yield an expected return high enough to compensate the risk-averse decision maker for accepting the risk. Or, more generally, we can anticipate that one investment that is riskier than another must offer a higher expected return to be preferred by risk-averse decision makers. Similarly, the more risk-averse the individual is, the higher the compensation must be in order to make the risky investment. Most people are risk-averse when they do medium and large investments (Sharpe, W. F. 1964).

The size of the risk premium at the farmers level depends on the farmer's level of risk aversion and also on the level of expected or perceived risk in the investment. Growing energy crops is often perceived to involve a higher risk than growing traditional crops such as wheat. The estimates of risk cost in this report is based on expert guess since there is no empirical basis for quantifying the cost.

## 2.3 Method to make consistent calculations for different regions

In order to compare the economics of different crops in different regions it is important that the calculations are made in a consistent way and include the same type of costs. By using one base-case calculation for each crop and region we reduce the differences in data collection between the regions. Different individuals may collect data in different ways so it is important to clearly guide the data collection. The cost levels and yield levels will differ between the regions and explain most of the variations in the specific production costs. The production costs for each crop can be presented in the form of a matrix, as the one below. This matrix, and the ones in Appendix 3, can be used to look at the effects of other yield and cost levels than those that have been estimated in Section 3.

Table 2.1. Example of cost matrix for willow. Costs are in EUR per GJ today with different cost level and yield level (excluding land cost and risk compensation). The base case for the Northern region is represented by 100% and 9 tDM/ha.

| Cost Level (%) | Yield level, tDM per hectare | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 60 | 3.4 | 3.0 | 2.7 | 2.5 | 2.4 | 2.3 | 2.1 | 2.1 | 2.0 | 1.9 |
| 70 | 4.0 | 3.6 | 3.2 | 3.0 | 2.8 | 2.6 | 2.5 | 2.4 | 2.3 | 2.3 |
| 80 | 4.6 | 4.1 | 3.7 | 3.4 | 3.2 | 3.0 | 2.9 | 2.8 | 2.7 | 2.6 |
| 90 | 5.2 | 4.6 | 4.2 | 3.9 | 3.6 | 3.4 | 3.3 | 3.1 | 3.0 | 2.9 |
| 100 | 5.8 | 5.2 | 4.7 | 4.3 | 4.1 | 3.9 | 3.7 | 3.5 | 3.4 | 3.3 |
| 110 | 6.5 | 5.7 | 5.2 | 4.8 | 4.5 | 4.3 | 4.1 | 3.9 | 3.7 | 3.6 |
| 120 | 7.1 | 6.3 | 5.7 | 5.3 | 4.9 | 4.7 | 4.5 | 4.3 | 4.1 | 4.0 |
| 130 | 7.7 | 6.9 | 6.2 | 5.8 | 5.4 | 5.1 | 4.9 | 4.7 | 4.5 | 4.4 |

## 2.4 Transforming the calculations to large scale and 2020

The development of modern biomass energy systems is at a relatively early stage with most of the RD&D focussing on the development of fuel supply and conversion routes (Hall & Rosillo-Calle, 1998). There are at least two reasons for a cost reduction in crop production in the future. One reason is the current small crop area. Another reason is the fact that we may expect future developments in plant breeding and machinery for energy crops.

Different crops are in different development stages. Both in terms of how well developed the crops are with breeding, special machines for the crop, etc., and organisation and markets for the crops. The main calculation refers to the knowledge and cultivation methods today. The main calculation is the basis for estimating the impact of a hypothetical large scale cultivation under present conditions, and a large scale cultivation in 2020. Three main factors influencing the production cost under these scenarios can be identified:

1) Yield levels
2) Machinery development
3) Organisation and knowledge about the crop

The analysis is done for two cases. In the first case, consequences of a hypothetical large area cultivation of the crop will be studied. In this step the analysis is based on the knowledge and technology of today. In next case the analysis will be done for a future situation (2020) with large area, higher knowledge, better technique and more high yielding crops.

With a large area, costs for special machinery such as a harvester dedicated to SRC will decrease to a cost level which is similar to that of other machines in traditional agriculture. A comparison between costs for special machinery that are used for new energy crops and machinery used today in traditional agriculture provides insight concerning the scope for decreased costs with a large area for new energy crops. Costs for administration will also decrease with a large area of energy crops.

In the future, assuming a large area of energy crops,  the costs per GJ are likely to decrease and yield levels increase. More highly bred plants, higher knowledge about how to grow the crop, better administration and more efficient machineries will also reduce the future costs if the area increases. How much the costs will decrease depends on many things, e.g. on the development stage of the crop, or the development of opportunity costs. The cost reduction for energy crops are made in comparison with traditional agricultural crops. The reason for this is that there are continued developments also for conventional crops, which give a cost reduction.

The assumed future yield increases and cost estimates deserve a special note. Underlying the calculation is a likely annual real increase in general agricultural productivity and cereals yields. However, in order to simplify the calculation, changes in costs and yields for energy crop production are consistently treated as relative to changes in costs and yields for cereals production in the economic model. All production costs are expressed in 2005 Euros.

# 3. Basic assumptions and application of the method

## 3.1 Main calculation for the different crops for year 2005

The main calculation for the different crops is based on the cost level and technical level of each country. We assume that the energy crop area per country will be at least 10 000 hectares. For collecting input data on yields, partners were encouraged to complement their own expertise through contacts with people in each country/region that have knowledge about the relevant crops. Contractor prices have been used as a basis for determining costs for various machinery. Such prices vary over time and by location, and the estimates are therefore uncertain. Data on local labour costs were also collected. The calculation also includes brokerage- and overhead costs.

## 3.2 Cost level assessment for different regions

Data were collected to determine cost levels for the different regions. To determine the overall cost level, a set of cost indicators was established. Data on the cost indicators was gathered for the different regions through partners in the RENEW project. The following step was to determine the weights for the different costs, see column 2, Table 3.1. The northern region has a base cost level of 100, and the cost levels of the other regions are determined relative to the northern region. The weights for the different inputs in the cost calculations use the base case cost distribution for willow cultivation. Machinery costs that have the highest influence on total costs where gathered and used as indicators for determining the cost levels.

Table 3.1. Prices in EUR for different inputs in the different regions. The second column shows the weights used for calculating cost levels for the different regions. The bottom line shows the actual cost level for each region.

| Cost indicator | % for cost level | North | UK, IR | West | Alp | South | East |
|---|---|---|---|---|---|---|---|
| 1 kg N | 0.129 | 0.88 | 0.71 | 0.82 | 0.80 | 0.63 | 0.46 |
| 1 kg P | 0.017 | 1.21 | 0.71 | 1.33 | 1.29 | 0.67 | 0.55 |
| 1 kg K | 0.021 | 0.44 | 0.36 | 0.36 | 0.39 | 0.67 | 0.3 |
| 1 litre Glyphosate (Roundup) | 0.007 | 5.05 | 5.60 | 4.45 | 4.50 | 4.00 | 6.40 |
| Workforce, 1 hour Farm worker | 0.217 | 18.13 | 16.00 | 17.00 | 18.40 | 8.00 | 3.80 |
| Ploughing, 1 hectare | 0.203 | 91.21 | 74.13 | 90.60 | 54.65 | 90.00 | 38.00 |
| Spraying, 1 hectare | 0.203 | 14.29 | 17.30 | 13.18 | 19.29 | 14.00 | 6.50 |
| Fertilizer spreading, 1 hectare | 0.203 | 15.38 | 14.83 | 10.43 | 6.43 | 15.00 | 7.00 |
| Cost level | 1.000 | **1.000** | **0.937** | **0.892** | **0.862** | **0.832** | **0.413** |

As seen in Table 3.1, the differences in cost levels between the UK, West and the Alp regions are not substantial. The eastern region has a much lower cost level compared with all other regions due to much lower costs for labour and machinery. It should be noted that the cost estimates are uncertain. Price quotes for standard machinery and operations may vary by +/- 20%. Labour cost may vary over time and depending on location. Hence, the cost levels should be seen as indicative rather than exact.

## 3.3 Yield levels for the different regions

The yield levels are also important for the costs per GJ. Partners in the project from the different regions have provided numbers for yield levels under present conditions. The estimates were discussed and checked against literature. It should be noted that the numbers represent potential yields under good present conditions, and not yields that can be achieved in optimized field trials. The UK and Ireland have consistently higher yield levels due to mild climatic conditions and high precipitation. Colder climate in the North region and lower precipitation in the South result in lower yield levels. It should be noted that experience is limited for some of the crops and estimates have been made based on best available knowledge.

Table 3.2. Commercial annual yields for non irrigated crops grown on soils of average quality, tDM per hectare and year (except for barley and wheat).

| Crop | North | UK, IR | West | Alp | South | East |
|---|---|---|---|---|---|---|
| Willow | 9 | 13 | 10 | 10 | ---- | 9 |
| Poplar | 9 | 13 | 10 | 10 | ---- | 9 |
| Eucalyptus | ---- | ---- | ---- | ---- | 12 | ---- |
| Miscantus | 10 | 18 | 16 | 11 | ---- | 11 |
| RCG | 7.5 | ---- | ---- | ---- | ---- | 7.5 |
| Switch grass | ---- | ---- | ---- | ---- | 13 | ---- |
| Hemp (whole crop) | 10 | ---- | 11 | 10 | ---- | 10 |
| Triticale (whole crop) | 11 | ---- | 12 | 11 | 8 | 9 |
| Sorghum (whole crop) | ---- | ---- | 10 | ---- | ---- | ---- |
| Barley (wet) | 4.2 | 8.1 | 5.5 | 6.4 | 2.0 | 4.2 |
| Winter wheat (wet) | 6.2 | 10.2 | 7.9 | 6.0 | 2.0 | 5.5 |

In the Appendix, Table A.1.1, the yield levels for poorer and better soils than average are shown. Yield levels for irrigated crops are also shown.

## 3.4 Crop lifetimes

Different crops have different lifetimes. A longer lifetime means that establishment costs can be distributed over a longer period.

Table 3.3. Assumed lifetimes for the different crops.

| Crop | | Years |
|---|---|---|
| Willow | | 22 |
| Poplar | | 22 |
| Eucalyptus | | 22 |
| Miscantus | | 21 |
| RCG | | 10 |
| Switch grass | | 10 |
| Hemp (whole crop) | | 1 |
| Triticale | | 1 |
| Sorghum | | 1 |
| Barley | | 1 |
| Winter wheat | | 1 |

## 3.5 Additional assumptions

Additional important assumptions for the calculations include:

- Road transport 30 km to a gathering point is included
- The use of large square straw bales is assumed
- Straw is stored indoors
- All crops are fertilized
- Wood crops such as SRC are chipped at harvest[1]
- No costly storage for wood chips is assumed
- No irrigation is assumed in the main calculations
- No subsidies are included in main calculations
- Price level are those in the winter of 2004/2005
- Discount rate used is 6 percent

[1] This assumption diverges from the scenarios and boundary conditions used elsewhere in RENEW where it is assumed that bundles are handled and transported before chipping.

## 4. Cost reduction with large scale cultivation for 2005 and 2020

The main calculations for the different crops are based on the cost and technical levels for 2005. We assume that the energy crop area per country will be at least 10 000 hectares for each energy crop. The next step are calculations for 2005 with a large growing area. Finally, calculations for large growing areas of energy crops in year 2020 are done. The large scale scenario for 2005 is purely hypothetical. For the scenario 2020 to be realised would require a rapid introduction and expansion of energy crop cultivation. If not, the cost reduction will be lower than in this report. Estimates have been made for how future production costs can decrease with crop area expansion, machinery development, organisational efficiency, increased crop knowledge and higher yields through crop breeding.

Table 4.1. Current development levels of different energy crops.

| Crop | Low | Medium | Well |
|---|---|---|---|
| Willow (SRC) | X | | |
| Poplar (SRC) | X | | |
| Eucalyptus (SRC) | X | | |
| Miscantus | X | | |
| RCG | | X | |
| Switch grass | | X | |
| Hemp | | X | |
| Triticale | | | X |
| Sorghum | | | X |

A less developed crop has a higher potential for cost reduction in the future compared with a well developed crop. A rough qualitative judgement of the level of development status for different crops is shown in Table 4.1. One way to calculate cost reductions for machinery in the future is to compare costs for special machinery for energy crops with traditional agricultural machinery. Scenarios for cost reductions and the corresponding discussion about future costs with technical development, reduction of costs with future growing techniques, increased knowledge and yield increases for different crops are listed below. Short rotation coppice, which is the more promising energy crop, is treated in more detail than herbaceous crops and annual plant species.

### 4.1. SRC crops

In Table 4.2, cost components in SRC cultivation are shown along with how these costs may change in the future due to an expanded production and increased knowledge. The rate at which cost reduction takes place is uncertain. This depends on both time itself and the rate of growth in overall SRC production. The assumed cost reductions are discussed in detail below.

Table 4.2. Cost reduction in percent with large growing area year 2005 and 2020 for SRC crops (willow, poplar and eucalyptus).

| | Large area 2005<br>% change from base case | Large area 2020<br>% change from base case |
|---|---|---|
| Yield increase Willow | 0 | +40 |
| Yield increase, Poplar | 0 | +25 |
| Yield increase, Eucalyptus | 0 | +25 |
| Cuttings | -10 | -20 |
| Transplanter | -25 | -50 |
| Cuttings transport | -5 | -10 |
| Cuttings severing | 0 | -5 |
| Control with Glyphosphate | 0 | 0 |
| Control with wetting agent | 0 | 0 |
| Mechanical weed control | -5 | -5 |
| Fertilizer N | 0 | 0 |
| Fertilizer P | 0 | 0 |
| Fertilizer K | 0 | 0 |
| High fertilizer spreading | -10 | -15 |
| Brokerage | -15 | -25 |
| Harvest | -25 | -50 |
| Field transport | -5 | -10 |
| Road transport | -5 | -5 |
| Winding up | 0 | -5 |
| Harrowing | 0 | 0 |
| Rolling | 0 | 0 |
| Spraying | 0 | 0 |
| Low fertilizer spreading | 0 | 0 |
| Administration | -5 | -5 |
| Land cost | 0 | 0 |
| Overhead | 0 | 0 |

**<u>Large area cost reductions 2005</u>**

There are numerous reasons why costs will decrease with large SRC growing areas. For example, competition between companies involved in energy crops will increase, the distance between fields with SRC will decrease, organisational measures will develop, advising and brokerage costs will decrease with larger volumes. The fixed costs for special machineries will also decrease per hectare, both through utilizing machinery more hours per year, accelerated competition between different contractors and it will be cheaper to manufacture machinery in longer production runs, compared to producing single custom made machines.

Cuttings: With large volumes of cuttings, costs for cutting production will decrease. It is possible that much of the relatively labour intensive cutting production will be in regions with lower salaries compared with the situation today. Each cutting producer will also increase his production. The competition between companies involved in energy crops will increase.

Transplanter: The average transplanter will be used on a larger area during a year. This will lead to a decreased fixed cost for transplanters. The distance between fields will also decrease. Transplanter costs will also descrease as more transplanters become produced. The competition between companies involved in energy crops will also increase.

Transport of cuttings: Larger volumes will reduce costs for transport of cuttings.

Mechanical weed control: The contractors will manage larger areas, leading to decreased fixed costs for machinery. The distance between fields will also decrease. The competition between companies involved in energy crops production will increase.

Fertilization – elevated spreader: The fertilizer spreader used today is a custom-built machine. Manufacturing in long series will be cheaper than custom-built machinery. Increased use of the elevated spreader will lead to decreased fixed cost per unit area. The distance between fields will also decrease and the competition between companies involved in energy crops will increase.

Brokerage: With large volumes, brokerage costs will decrease. The competition between companies will also increase. New ways to sell the chips will also reduce the cost. One example is long-term contracts directly between the farmer and the user of the chips.

Harvest: The distance between fields will decrease. The heads of the harvester are specially designed equipment. Manufacturing of harvester heads in longer series will reduce costs. The other part of the harvester is today a conventional large grass harvester. The competition between companies involved in energy crops may increase with larger scale production.

Field transport: The distance between fields will decrease and subsequently decrease costs.

Road transport: Average distances can be shorter if SRC is more common.

Administration: With a larger SRC area, the time for administration per unit harvested biomass, will be lower. Administration costs will also be reduced if the average area per farm producing SRC increases.

## Large area cost reductions 2020

A main factor for how large the cost reduction will be in year 2020 is the speed of establishment of new SRC fields and the rate of plant breeding and resulting yield increases. Since we cannot predict the speed in establishment of new plantations, there is a large uncertainty about the cost reductions in year 2020. The assumed cost reduction in this report assumes that planting in larger scales will begin very soon and develop rapidly. It should be noted that the calculated costs represent those of plantations established in 2020 rather than the average costs for energy crops harvested in 2020.

Future scenarios may include unforeseen changes. For example, harvests in the future may not be plagued with the rebuilding of grass and corn harvesters due to problems with thick stems. In other words, harvesters will be more suited for SRC. Higher capacity and the possibility to harvest thicker stems would increase the profitability in SRC growing. Another example are new planting techniques where cheaper planting materials will also decrease establishment costs. Such advancements in the past have demonstrated this for example with the changes in planting techniques in 1992 when SRC long stick planting was replaced with planting short cuttings. The year that the Step planting technique was introduced also decreased costs for the transplanter by 36 percent (Rosenqvist 1997). Today we obviously cannot know precisely how developmental paths will be played out in the future, but we can be sure that there will be cost reductions as the area of SRC will increase. Yields will increase both due to plant breeding improvements and increased knowledge about SRC growing.

All of the cost reductions with large growing area in 2005 are also assumed to have happened by year 2020 with a large area, but the element of time offers greater reductions. The cost reduction is cost reduction relative to traditional crops like cereals.

Yield increase: Both breeding and better management of the crop will give higher yields in the future. Willow is not as well developed in breeding as poplar and eucalyptus. A yield increase of about 40 percent by year 2020 for willow can an expected; whereas the increase for poplar and eucalyptus is roughly 25 percent. The yield increase is relative to that for cereals.

Cuttings: The technique for cutting production will be more mechanised and efficient. The average cutting producer will produce more cuttings. There may also be a change in the shape of cuttings. New techniques for planting with cheaper cuttings, e.g. fresh direct-harvested pieces for planting, will lead to a decrease in cutting costs .

Transplanter: The transplanter will have a higher capacity. The number of rows will increase from four or six rows to a higher number of rows. For example, sowing machines for sugar beets can reach nine meters today, this corresponds to approximately eight rows of SRC.

Transport of cuttings: Organisation and logistics will improve.

Severing of cuttings: More knowledge and better techniques will lower the costs. Contractors that are more specialised to cut back cuttings can be used. In a future with better clones and other planting techniques, fewer fields are motivated to cut back cuttings.

Mechanical weed control: The machinery will be developed and knowledge about weed control will improve. New clones and/or new planting techniques leading to improved competitiveness against weeds will reduce cost for weed control. It is uncertain whether mechanical or chemical weed control will be least expensive in the future.

Elevated fertilizer spreading : There is a potential for further development of machinery in the future.

Brokerage: Better organisation and more competition will reduce the costs.

Harvest: Development of the harvester head will increase the harvesting efficiently: higher harvesting speed and also possibility to harvest thicker stems. The other part of the harvester is today a conventional large grass harvester. In the future, machinery may become developed especially for SRC harvesting, making possible harvest every fourth year instead of every third year as today. This will increase the number of tons per hectare per harvest time. It will also will also increase the total yield level from the plantation. The plantation growth is lower the first year after harvest. Longer rotations will lead to lower harvesting costs, lower transport costs both on field and road. Start-up costs for harvest will decrease and the average annual growth will be higher.

Field transport: Field transport per tonne will decrease with higher yield levels and higher harvesting capacities. It will take less time to fill wagons with increased harvester capacities. Organisation, wagons and tyres will also be more adapted to the use.

Road transport: Higher quantity per field and harvest moment lead to lower road transport costs. Shorter transport distances can also lead to lower costs.

Winding up: The knowledge about how to restore the land after short rotation coppice production will increase and the cost will decrease.

## Comparison with common agricultural machinery

One important question is why machinery for SRC should be more expensive to use compared with conventional agricultural machinery. Answers to that question could be that machinery for SRC are special, meaning that it is produced in shorter series, is less developed, there are larger distances between SRC fields, it is used fewer hours per year and there is little competition between suppliers. If the area of SRC would be similar to, for example, sugar beets, the costs for machinery should, after some years, decrease to a level similar to that of other agricultural machinery in relation to capacities, maintenance, fuel consumption and manufacturing costs. Following this line of thought, future cost assumptions for machinery are elaborated in more detail below.

Transplanter: The costs for sugar beet sowing is about 52 EUR per hectare and take about 0.6 hour and hectare with a 12-row sowing machine and about 0.4 hour per hectare with a 18-row sowing machine. Assuming that the SRC planting costs would be reduced to a level twice that of sowing sugar beets, the cost would be about 100 EUR per hectare, or half the present cost.

Mechanical weed control: Mechanical weed harrowing in organic growing (i.e., herbicides are not used) costs about 9 EUR per hectare. There are differences between harrowing weeds in a grain crop compared to SRC crops. For comparison, the costs for mechanical weed control between the rows for sugar beet is about 44 EUR per hectare, which is similar to SRC today.

Elevated fertilizer spreading: A traditional fertilizer spreader, equipped with a telescope spreader, is used today in SRC cultivation. An elevated fertilizer spreader has a capacity today of about 5 hectares per hour. A traditional fertilizer spreader costs about 15 EUR per hectare and has a similar capacity. The investment might be somewhat higher for an elevated fertilizer spreader, compared to a traditional fertilizer spreader.

The distances between SRC fields will also be longer than for traditional crops. This leads to higher costs compared to traditional fertilization. It is estimated that the costs will be about 50 percent higher for elevated fertilization. This leads to a cost of about 22 EUR per hectare, which is 10 percent lower than the present cost. The equipment will be further developed and the costs might continue to decrease, possibly to a level of about 15 percent below the present cost for 2020.

Harvest: Today, the harvesting capacity is about one hectare per hour. In the future the capacity in tons per hour will increase. The hourly cost with the use of a contractor for a grain harvester is about 0.08 percent of the price for a new grain harvester. A large sugar beet harvester also has an hourly cost of about 0.08 percent of the price for a new harvester. Thus, given that a new SRC harvester costs about 220 000 EUR, the price per hour should be about 180 EUR, corresponding to 180 EUR per hectare at the capacity given above. Due to differences in field size, maintenance, fuel consumption and annual hours in operation, the grain harvester, sugar beet harvester and SRC harvester will differ in cost per hectare. Today the cost for the first SRC harvest is about 330 EUR per hectare, which is 80 percent higher than 180 EUR. In the future, higher capacity will lead to reduced costs, maybe to half of the present level.

## 4.2 Herbaceous crops

The management of straw, and the use of straw for feed and energy purposes, are not new activities. We cannot expect the technical performance of machinery for the management of straw to develop more quickly than for other machinery in the agricultural sector. Reed canary grass, switchgrass and miscanthus are not as common crops as other grasses for feeding. That means that we can expect higher yield increases than with grasses for feeding. Techniques for the establishment of miscanthus are not well developed, so we can expect higher cost reductions for miscanthus than for reed canary grass and switchgrass.

The systems to manage grasses after cutting could be shifted in the future. If it will be a shift to a system with a product with higher density than the bales today, the costs for handling the crop can be reduced to much lower level compared with the system with bales today. For example, a system with a more pulverization and crop compaction could reduce the costs for handling more than what is assumed in this report.

Table 4.3. Cost reduction in percent with large area year 2005 and 2020 for herbaceous crops like reed canary grass (RCG), switchgrass and miscanthus.

| | Large area 2005<br>% change | Large area 2020<br>% change |
|---|---|---|
| Yield increase, RCG | 0 | +40 |
| Yield increase, Switchgrass | 0 | +40 |
| Yield increase, Miscanthus | 0 | +60 |
| Rhizome pieces, Miscanthus | -25 | -50 |
| Planting rhizomes, Miscanthus | -25 | -50 |
| Brokerage | -15 | -25 |
| Baling | -10 | -10 |
| Field transport | -5 | -5 |
| Loading | -5 | -5 |
| Store keeping | -5 | -5 |
| Road transport | -5 | -5 |
| Administration | -5 | -5 |

Both breeding and better management of the crop will give higher yields in the future. Miscanthus is the crop with lowest degree of breeding of the three crops. Therefore, it is expected that yield increases in future will be largest for miscanthus. With a large area of each of the three crops, the yields are estimated to increase by 60 percent for miscanthus and by 40 percent for reed canary grass and switchgrass by 2020, relative to cereals.

Rhizome pieces: Miscanthus is a very small crop today. This makes for a large possibility to reduce costs both with better techniques, competition and organisational improvements. With large scale cultivation of miscanthus, the costs of rhizomes are estimated to decrease by approximately 25 percent and in the future scenario for 2020 by about 50 percent.

Planting rhizomes: Miscanthus is presently planted with a "home-built" planting machine. With a large scale growing of miscanthus, the costs of planting are estimated to decrease by roughly 25 percent and in the future scenario for 2020 by about 50 percent.

Cutting and baling: If the crop is harvested during springtime it means a better utilization of machinery, which can also be used in feed production during other times of the year. That will keep the costs at a lower level. The distance between fields will also decrease, contributing to decreased costs.

Storekeeping and loading: If there is a large number of growers of reed canary grass, switchgrass and Miscanthus, the storage and loading costs can decrease since the capacity can be utilized by many.

Field transport: Field transport costs will decrease with higher yield levels and shorter distances between fields.

Road transport: Shorter transport distances as a result of more plantations can correspond to slightly lower costs for road transport.

Brokerage: With larger volumes, the costs for brokerage will decrease. The competition between companies will also increase. New ways to sell the crops will also reduce costs. Better organisation and more competition will reduce the costs

Administration: If these crops become more common, the time for administration may be reduced. Cost for administration will also be reduced if the average area per farm of this crop increases.

## 4.3 Annual plant species

Sorghum, as well as whole-plant cereals like wheat, rye and triticale are well developed crops for grain production. Similarly, the techniques for harvest, baling and transport are well developed. Hemp is a less developed crop but we can use the same techniques as we now use in grain production and grass production. In that way there are no large cost reduction potentials with large scale production or in the future.

Table 4.4. Cost reduction in percent with large area year 2005 and 2020 for annual plant species crops like hemp and whole-plant cereals like wheat, rye and triticale.

| | Large area 2005 % change | Large area 2020 % change |
|---|---|---|
| Yield increase, cereals | 0 | +5 |
| Yield increase, hemp | 0 | +25 |
| Brokerage | -15 | -25 |
| Baling | -5 | -5 |
| Field transport | -5 | -5 |
| Loading | -5 | -5 |
| Store keeping | -5 | -5 |
| Road transport | -5 | -5 |
| Administration | -5 | -5 |

Both more effective breeding and better management of the hemp will give higher yields in the future. For other crops, yield increases compared with cereals for food or feed production are not expected to be significantly higher. The yield may increase a little with varieties that are bred to give a high yield of total biomass and not only a high grain yield. With a large area of each of these crops for energy purposes the yield will increase 25 percent for hemp and about 5 percent for the other cereal crops by year 2020 compared with traditional cereal production which may also improve.

## 4.4 Straw as a residue

After the grain crop is harvested, handling systems for straw and grass are similar. In that way, the expected cost reductions are also similar.

Table 4.5. Cost reduction in percent with large area year 2005 and 2020 for straw as a residue.

| | Large area 2005 % change | Large area 2020 % change |
|---|---|---|
| Brokerage | -15 | -25 |
| Baling | -5 | -5 |
| Field transport | -5 | -5 |
| Loading | -5 | -5 |
| Store keeping | -5 | -5 |
| Road transport | -5 | -5 |
| Administration | -5 | -5 |

# 5. Costs for land and risks

As discussed in section 2.2-2.3, it is not straightforward how costs for land and risks should be quantified. The methodology and assumptions used in this report are elaborated below.

## 5.1 Costs for land

The individual farmer must make decisions about the different fields on the farm. Should he grow cereals for food production, have the land in fallow or grow an energy crop? Incomes from the different ways to use the land is one important factor in the decisions. If the grain prices are expected to increase in the future, the farmer will demand even better incomes from energy crops. Hence, the opportunity costs for land increase with higher expected cereal prices.

If turning to energy crops, the farmer cannot use the same resources as for the crop he grows today and there are also costs associated with finding knowledge about the new crop. For that reason, the new crop must give a higher expected income than traditional food crops in order for most farmers to grow it. In the short run, farmers expect costs for his own workforce and machinery to be lower than in the long run. How much lower these costs are depends on the farmer's planning situation. In the short run the opportunity costs for machinery and workforce are lower than in a long run perspective. That will make grain production more profitable in the short run compared with the long run.

Table 5.1. Increased costs per GJ assuming 100 EUR land use cost with different yield levels for willow. The increased costs per GJ in this case are independent of the cost level.

| | Yield level in willow, tDM per hectare, yr | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Cost | 1.6 | 1.3 | 1.2 | 1 | 0.9 | 0.8 | 0.7 | 0.7 | 0.6 | 0.6 |

Table 5.1 shows how much the production cost per GJ will increase with a 100 EUR/ha,yr opportunity cost for land. Tables 5.2 and 5.3 show the variation in opportunity cost for land, i.e., in this case gross margin for wheat, as a function of wheat yields. Table 5.2 represents a long term perspective. Table 5.3 represents a short term perspective where the farmer sees a 50% lower marginal cost for machinery, workforce and overhead.

Table 5.2. Annual gross margin in EUR per hectare for winter wheat with different cost levels and yield levels. Reduced soil cultivation.

| Cost level (%) | Yield level tons (14% water content) per hectare | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 60 | -32 | 27 | 86 | 145 | 204 | 263 | 321 | 380 | 439 | 498 |
| 70 | -86 | -34 | 18 | 70 | 122 | 174 | 227 | 279 | 331 | 383 |
| 80 | -141 | -96 | -50 | -5 | 41 | 86 | 132 | 177 | 223 | 268 |
| 90 | -196 | -157 | -118 | -79 | -41 | -2 | 37 | 75 | 115 | 153 |
| 100 | -250 | -218 | -186 | -154 | -122 | -90 | -58 | -26 | 7 | 38 |
| 110 | -305 | -278 | -254 | -229 | -203 | -178 | -152 | -127 | -102 | -76 |
| 120 | -360 | -341 | -322 | -304 | -285 | -266 | -247 | -228 | -210 | -191 |
| 130 | -415 | -403 | -390 | -378 | -366 | -354 | -342 | -330 | -318 | -306 |

Table 5.3. Annual gross margin in EUR per hectare for winter wheat with different cost levels and yield levels. Reduced soil cultivation. Cost reduction for machinery, workforce and overhead is 50 percent. A short run calculation.

| Cost level (%) | Yield level: tons (14% water content) per hectare | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 60 | 84 | 145 | 206 | 268 | 329 | 390 | 451 | 512 | 574 | 635 |
| 70 | 48 | 103 | 158 | 213 | 268 | 323 | 378 | 433 | 488 | 543 |
| 80 | 13 | 62 | 110 | 159 | 208 | 256 | 304 | 354 | 402 | 451 |
| 90 | -22 | 20 | 62 | 105 | 147 | 189 | 232 | 274 | 317 | 359 |
| 100 | -58 | -22 | 14 | 50 | 86 | 123 | 159 | 195 | 231 | 267 |
| 110 | -93 | -64 | -34 | -4 | 26 | 56 | 85 | 115 | 145 | 175 |
| 120 | -129 | -105 | -82 | -58 | -35 | -11 | 12 | 36 | 59 | 83 |
| 130 | -164 | -147 | -130 | -113 | -95 | -78 | -61 | -44 | -26 | -9 |

If the farmer expects a short run income (Table 5.3) from cereal production which is about 200 EUR more per hectare than in the long term calculation (Table 5.2), this increases the required income from willow production (with yield level 9 tDM) by about 1.8 EUR per GJ. With negative income from cereal production in long term calculations, it will be better to make comparisons with fallow land. A willow plantation has an approximate lifetime of about 20 years. During this time the differences between the long term calculations and short term calculations will be reduced.

Table 5.4. Opportunity cost for land with 100 percent of costs for all inputs. Crops are barley and winter wheat, and results are expressed in EUR per hectare, yr. A long run calculation.

| Region | Average soils | Poor soils | Good soils |
|---|---|---|---|
| North | 0 | 0 | 0 |
| UK/Ireland | 0 | 0 | 0 |
| West | 0 | 0 | 0 |
| Alp | 0 | 0 | 0 |
| South | 0 | 0 | 0 |
| East | 140 | 50 | 220 |

Table 5.5. Opportunity cost for land with 50 percent of costs for machinery, workforce, overhead and with reduced soil preparation, winter wheat in EUR per hectare, yr. A short run calculation.

| Region | Average soils | Poor soils | Good soils |
|---|---|---|---|
| North | 60 | 20 | 120 |
| UK/Ireland | 260 | 110 | 320 |
| West | 190 | 110 | 280 |
| Alp | 130 | 90 | 170 |
| South | 0 | 0 | 0 |
| East | 320 | 200 | 370 |

As we can see from the Tables 5.4 and 5.5, there are large differences between different farms and different planning situations. The higher opportunity costs in the short term reflects the fact that the farmer has access to machinery for grain cultivation, i.e., the marginal cost for extending the grain cultivation is low. Most farmers have calculated incomes somewhere between the results in the two tables. Both situations in the tables are extremes and most growers lie between these two cost scenarios.

## 5.2 Costs for risk

The amount of income for the farmer needed for risk compensation is difficult to determine on a general level. Risk compensation is dependent on several aspects, some of which have been described in section 2.2.3. The risk compensation needed is dependent both on how the grower views the risk and how many hectares that are in question. If there is a desire for switching to growing a large number of hectares during a short time, the risk compensation will have to be higher. Table 5.6 shows costs per GJ for different risk compensation levels per hectare.

Table 5.6. Increased costs per GJ with 100 EUR per hectare,yr risk compensation with different yield levels for willow. The increased costs per GJ are independent of cost level.

| | Yield level in willow, tDM per hectare | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Cost | 1.6 | 1.3 | 1.2 | 1 | 0.9 | 0.8 | 0.7 | 0.7 | 0.6 | 0.6 |

In this report we assume a risk decrease with a larger area of energy crops and also with future developments like better knowledge, better clones and a more well developed market. The risk is assumed to be different for different crops. Crops that are new to individual farmers, crops for which there is little experience in general, and perennial crops that should be grown for many years (like short rotation coppice) need a larger risk compensation compared to well known annual crops like triticale. The risk costs used here are based on expert guess since there is no empirical basis for quantifying the cost.

## 6. Resulting total costs for different crops

Crops can be categorized in three main groups in terms of the cost level. The group with the lowest costs is the group with short rotation coppice woody crops. There are at least two reasons for this. One reason is the reasonably low annualised establishment costs for the crop. There are only costs for cuttings and soil preparation once during a period of about 20 years. The other reason is the low handling cost after harvest. It is less expensive to handle wood chips compared to straw bales. There is also less need for storage of the product compared to straw fuels.

In the second group there are perennial grasses, which have low establishment costs but relatively high handling costs. It is expensive to handle and store bales and this increases the costs significantly for this group. Crops that give higher densities for the bales give a lower handling cost.

The third group is straw crops which should be established every year and have a high cost for handling and storing.

Regions with generally high cost levels have a relatively low cost for land. This is because the opportunity cost for land is low in these regions. In contrast, the cost for land is relatively high in region East, due to the high opportunity costs for growing grain. The land use factor evens out the differences in total energy crop production costs between the regions. For example, willow production costs are only about 10% lower in the East than in the high cost level regions. In the southern region the grain yields are very low, which corresponds to a low opportunity cost of land and hence lower production costs for the region. The eastern region has slightly lower total costs for the energy crops compared with the other regions, except the southern region.

There are relatively large differences between the costs of different crops when comparing within the different regions. Woody crops have the lowest production costs per GJ. But woody crops represent a large change for the farmer compared to straw crops and annual energy crops. In the short run, some farmers may prefer straw crops to wood crops, even if they are not as profitable as woody crops. Different farmers need different risk premiums for different crops, which can make straw crop more interesting for growers who need high risk premiums for woody crops. Some farmers also have machinery which can be used for growing straw crops. Hence, straw crops may be more interesting for some farmers, even if woody crops are more profitable.

Table 6.1. Production costs for different energy crops in different regions, present situation.

| Crop | Yield | Region | EUR/GJ | EUR/GJ | EUR/GJ | EUR/GJ |
|---|---|---|---|---|---|---|
| | | | Growing | Land | Risk and | Total |
| | | | | | New crop | |
| Willow | 9 | North | 4.1 | 0.0-0.5 | 0.9 | 5.0-5.5 |
| Reed canary grass | 7.5 | North | 6.0 | 0.0-0.6 | 0.4 | 6.4-7.0 |
| Triticale whole crop | 11 | North | 6.5 | 0.0-0.4 | 0.2 | 6.7-7.1 |
| | | | | | | |
| Willow | 13 | UK, Ir | 3.1 | 0.0-1.7 | 0.9 | 4.0-5.7 |
| Miscanthus | 18 | UK, Ir | 5.7 | 0.0-1.3 | 0.8 | 6.5-7.8 |
| Triticale whole crop | 16 | UK, Ir | 5.3 | 0.0-1.1 | 0.2 | 5.5-6.6 |
| | | | | | | |
| Willow | 10 | West | 3.4 | 0.0-1.5 | 0.9 | 4.3-5.8 |
| Miscanthus | 16 | West | 5.6 | 0.0-1.0 | 0.8 | 6.4-7.4 |
| Triticale whole crop | 12 | West | 5.6 | 0.0-1.0 | 0.2 | 5.8-6.8 |
| | | | | | | |
| Willow | 10 | Alp | 3.2 | 0.0-1.1 | 0.9 | 4.1-5.2 |
| Miscanthus | 11 | Alp | 5.8 | 0.0-0.8 | 0.8 | 6.6-7.4 |
| Triticale whole crop | 11 | Alp | 5.6 | 0.0-0.8 | 0.2 | 5.5-6.6 |
| | | | | | | |
| Eucalyptus | 12 | South | 3.2 | 0.0-0.0 | 1.1 | 4.3-4.3 |
| Switch grass | 13 | South | 4.3 | 0.0-0.0 | 0.4 | 4.7-4.7 |
| Triticale whole crop | 8 | South | 6.2 | 0.0-0.0 | 0.2 | 6.4-6.4 |
| | | | | | | |
| Eucalyptus Irrigated | 15 | South | 4.9 | 0.0-0.0 | 1.1 | 6.0-6.0 |
| Switch grass Irrigated | 18 | South | 5.7 | 0.0-0.0 | 0.4 | 6.1-6.1 |
| Triticale whole crop Irr. | 15 | South | 6.4 | 0.0-0.0 | 0.2 | 6.6-6.6 |
| | | | | | | |
| Willow | 9 | East | 1.7 | 1.1-2.7 | 0.9 | 3.7-5.3 |
| Reed canary grass | 7.5 | East | 2.3 | 1.5-3.4 | 0.4 | 4.2-6.1 |
| Triticale whole crop | 9 | East | 2.8 | 1.0-2.3 | 0.2 | 4.0-5.3 |

Table 6.2. Costs for different energy crops. The calculation is done for the future year 2020 perspective but maintaining the same cost level differences between regions as today.

| Crop | Yield | Region | EUR/GJ Growing | EUR/GJ Land | EUR/GJ Risk and New crop | EUR/GJ Total |
|---|---|---|---|---|---|---|
| Willow | 12.6 | North | 2.8 | 0.0-0.4 | 0.4 | 3.2-3-6 |
| Reed canary grass | 10.5 | North | 5.1 | 0.0-0.5 | 0.2 | 5.3-5.8 |
| Triticale whole crop | 11.5 | North | 6.1 | 0.0-0.4 | 0.1 | 6.2-6.6 |
| | | | | | | |
| Willow | 18.2 | UK, Ir | 2.2 | 0.0-0.9 | 0.4 | 2.6-3.5 |
| Miscanthus | 28.8 | UK, Ir | 5.1 | 0.0-0.5 | 0.2 | 5.4-5.9 |
| Triticale whole crop | 16.8 | UK, Ir | 5.1 | 0.0-0.8 | 0.1 | 5.2-6.0 |
| | | | | | | |
| Willow | 14 | West | 2.4 | 0.0-0.7 | 0.4 | 2.8-3.5 |
| Miscanthus | 25.6 | West | 4.8 | 0.0-0.4 | 0.3 | 5.1-5.5 |
| Triticale whole crop | 12.6 | West | 5.3 | 0.0-0.6 | 0.1 | 5.4-6.0 |
| | | | | | | |
| Willow | 14 | Alp | 2.4 | 0.0-0.3 | 0.4 | 2.7-3.1 |
| Miscanthus | 17.6 | Alp | 4.9 | 0.0-0.2 | 0.3 | 5.2-5.4 |
| Triticale whole crop | 11.6 | Alp | 5.3 | 0.0-0.3 | 0.1 | 5.4-5.7 |
| | | | | | | |
| Eucalyptus | 15 | South | 2.4 | 0.0-0.0 | 0.4 | 2.8-2.8 |
| Switch grass | 18.2 | South | 3.7 | 0.0-0.0 | 0.2 | 3.9-3.9 |
| Triticale whole crop | 8.4 | South | 5.9 | 0.0-0.0 | 0.1 | 6.0-6.0 |
| | | | | | | |
| Eucalyptus Irrigated | 18.8 | South | 3.8 | 0.0-0.0 | 0.4 | 4.2-4.2 |
| Switch grass Irrigated | 25.2 | South | 4.7 | 0.0-0.0 | 0.2 | 4.9-4.9 |
| Triticale whole crop Irr. | 15.8 | South | 6.2 | 0.0-0.0 | 0.1 | 6.3-6.3 |
| | | | | | | |
| Willow | 12.6 | East | 1.2 | 0.0-0.2 | 0.4 | 1.6-1.8 |
| Reed canary grass | 10.5 | East | 2.1 | 0.0-0.2 | 0.2 | 2.3-2.5 |
| Triticale whole crop | 9.5 | East | 2.8 | 0.0-0.2 | 0.1 | 2.9-3.1 |

In the future scenario, higher yields, lower costs for machinery, lower opportunity costs for land, and reduced risk compensation as a result of more knowledge and experience, results in overall lower production costs per GJ. The relative differences in costs between regions have been kept the same as today in Table 6.2. This results in quite low total production costs in region East. However, a more reasonable development is that cost differences between regions will level out as a result of economic growth and integration. Such a scenario is shown in Table 6.3.

Table 6.3. Costs for different energy crops. The calculation is done for the future perspective, 2020. The calculations are done assuming that the cost level for the northern region applies to all regions.

| Crop | Yield | Region | EUR/GJ Growing | EUR/GJ Land | EUR/GJ Risk and New crop | EUR/GJ Total |
|---|---|---|---|---|---|---|
| Willow | 12.6 | North | 2.8 | 0.0-0.4 | 0.4 | 3.2-3-6 |
| Reed canary grass | 10.5 | North | 5.1 | 0.0-0.5 | 0.2 | 5.3-5.8 |
| Triticale whole crop | 11.5 | North | 6.1 | 0.0-0.4 | 0.1 | 6.2-6.6 |
| | | | | | | |
| Willow | 18.2 | UK, Ir | 2.4 | 0.0-0.9 | 0.4 | 2.8-3.7 |
| Miscanthus | 28.8 | UK, Ir | 5.4 | 0.0-0.5 | 0.2 | 5.7-6.2 |
| Triticale whole crop | 16.8 | UK, Ir | 5.4 | 0.0-0.8 | 0.1 | 5.5-6.3 |
| | | | | | | |
| Willow | 14 | West | 2.7 | 0.0-0.7 | 0.4 | 3.1-3.8 |
| Miscanthus | 25.6 | West | 5.4 | 0.0-0.4 | 0.3 | 5.7-6.1 |
| Triticale whole crop | 12.6 | West | 5.9 | 0.0-0.6 | 0.1 | 6.0-6.6 |
| | | | | | | |
| Willow | 14 | Alp | 2.7 | 0.0-0.3 | 0.4 | 3.1-3.5 |
| Miscanthus | 17.6 | Alp | 5.7 | 0.0-0.2 | 0.3 | 6.0-6.2 |
| Triticale whole crop | 11.6 | Alp | 6.1 | 0.0-0.3 | 0.1 | 6.2-6.5 |
| | | | | | | |
| Eucalyptus | 15 | South | 2.9 | 0.0-0.0 | 0.4 | 3.3-3.3 |
| Switch grass | 18.2 | South | 4.5 | 0.0-0.0 | 0.2 | 4.7-4.7 |
| Triticale whole crop | 8.4 | South | 7.1 | 0.0-0.0 | 0.1 | 7.2-7.2 |
| | | | | | | |
| Eucalyptus Irrigated | 18.8 | South | 4.6 | 0.0-0.0 | 0.4 | 5.0-5.0 |
| Switch grass Irrigated | 25.2 | South | 5.7 | 0.0-0.0 | 0.2 | 5.9-5.9 |
| Triticale whole crop Irr. | 15.8 | South | 7.4 | 0.0-0.0 | 0.1 | 7.5-7.5 |
| | | | | | | |
| Willow | 12.6 | East | 2.8 | 0.0-0.2 | 0.4 | 3.2-3.4 |
| Reed canary grass | 10.5 | East | 5.2 | 0.0-0.2 | 0.2 | 5.4-5.6 |
| Triticale whole crop | 9.5 | East | 6.7 | 0.0-0.2 | 0.1 | 6.8-7.0 |

In Table 6.3, the differences in crop production costs between regions are relatively small, mainly because cost level differences have evened out. Woody crops are consistently less costly than straw crops and annual crops, and the cost gap has increased compared to the costs shown in Table 6.1. This reflects the assumption that the potential for cost reductions is higher for short rotation coppice than for the other crops. For example, it is difficult to reduce the handling costs substantially for low density bales. The following sections show in greater detail how the break-down of costs develops for different types of crops.

## 6.2 Breakdown of costs for growing the different crops

Some costs are dependent on the number of hectares each farmer grows the crop on. An example of these costs are establishment costs. Other costs are more dependent on total production quantities, for example, road transport costs. Table 6.4 shows the cost break-down for growing willow in the Northern region in the different scenarios.

Table 6.4. Production costs for willow (EUR per GJ) in the Northern region today, for a large area, and a future large area with improved yields, technology and knowledge.

| | Present situation | Large area | Future large area |
|---|---|---|---|
| Establishment | 0.73 | 0.65 | 0.42 |
| Fertilization | 0.74 | 0.74 | 0.65 |
| Road transports | 0.69 | 0.68 | 0.69 |
| Harvest | 0.89 | 0.67 | 0.39 |
| Field transports | 0.15 | 0.15 | 0.14 |
| Brokerage | 0.25 | 0.18 | 0.12 |
| Weed control after harvest | 0.03 | 0.03 | 0.02 |
| Administration | 0.15 | 0.15 | 0.11 |
| Winding up | 0.04 | 0.04 | 0.03 |
| Overhead | 0.37 | 0.37 | 0.27 |
| *Total direct production cost* | *4.1* | *3.7* | *2.8* |
| Costs for land | 0.5 | 0.5 | 0.4 |
| Costs for risk | 0.9 | 0.7 | 0.4 |
| **Total costs** | **5.5** | **4.9** | **3.6** |

Table 6.5. Production cost breakdown in percent for willow in the Northern region today, for a large area, and a future large area with improved yields, technology and knowledge.

| | Present situation | Large area | Future large area |
|---|---|---|---|
| Establishment | 13 | 13 | 12 |
| Fertilization | 13 | 15 | 18 |
| Road transports | 13 | 14 | 19 |
| Harvest | 16 | 14 | 11 |
| Field transports | 3 | 3 | 4 |
| Brokerage | 5 | 4 | 3 |
| Weed control after harvest | 1 | 1 | 1 |
| Administration | 3 | 3 | 3 |
| Winding up | 1 | 1 | 1 |
| Overhead | 7 | 8 | 8 |
| *Total direct production cost* | *75* | *76* | *78* |
| Costs for land | 9 | 10 | 11 |
| Costs for risk | 16 | 14 | 11 |
| Total costs | 100 | 100 | 100 |

As shown in Tables 6.4 and 6.5, cost distributions are expected to change in the future. The important costs that will not be reduced as much as other costs are costs for transport and fertilizer. In order to keep costs for transport at an acceptable level, it is important to work with logistics for different biofuels and different users of biofuels. The costs for fertilizers can be reduced by using sewage sludge and waste water irrigation for providing nutrients.

In the case of straw crops, it is important to work on reducing handling costs, in addition to increasing the yields for reed canary grass, switchgrass and miscanthus. If the density in the bales can be increased, this will lead to decreased handling costs. Cost breakdowns for straw crops are shown in Tables 6.6. and 6.7.

Table 6.6. Production costs for reed canary grass or switch grass (EUR per GJ) in the Northern region today, for a large area, and for a future large area with improved yields, technology and knowledge.

| | Present situation | Large area | Future large area |
|---|---|---|---|
| Establishment | 0.24 | 0.24 | 0.17 |
| Fertilization | 1.34 | 1.34 | 1.19 |
| Cutting and baling | 1.41 | 1.30 | 1.21 |
| Transport to farm | 0.33 | 0.33 | 0.33 |
| Loading in | 0.12 | 0.12 | 0.12 |
| Store keeping | 0.68 | 0.64 | 0.64 |
| Loading out | 0.06 | 0.06 | 0.06 |
| Road transports | 0.61 | 0.58 | 0.58 |
| Brokerage | 0.37 | 0.29 | 0.23 |
| Winding up | 0.12 | 0.12 | 0.09 |
| Administration | 0.18 | 0.18 | 0.13 |
| Overhead | 0.55 | 0.55 | 0.39 |
| *Total direct production costs* | *6.01* | *5.75* | *5.14* |
| Costs for land | 0.6 | 0.6 | 0.5 |
| Costs for risk | 0.4 | 0.3 | 0.2 |
| **Total costs** | **7.01** | **6.65** | **5.84** |

Table 6.7. Production costs breakdown in percent for reed canary grass or switch grass in the Northern region today, for a large area, and for a future large area with improved yields, technology and knowledge.

| | Present situation | Large area | Future large area |
|---|---|---|---|
| Establishment | 4 | 4 | 4 |
| Fertilization | 19 | 20 | 21 |
| Cutting and baling | 20 | 20 | 21 |
| Transport to farm | 5 | 5 | 6 |
| Loading in | 2 | 2 | 2 |
| Store keeping | 10 | 10 | 11 |
| Loading out | 1 | 1 | 1 |
| Road transports | 9 | 9 | 10 |
| Brokerage | 6 | 4 | 4 |
| Winding up | 1 | 1 | 1 |
| Administration | 3 | 3 | 2 |
| Overhead | 8 | 8 | 7 |
| *Total direct production costs* | *86* | *86* | *88* |
| Costs for land | 9 | 9 | 9 |
| Costs for risk | 5 | 5 | 3 |
| Total costs | 100 | 100 | 100 |

As seen in Table 6.6 and 6.7, there are no substantial differences in the breakdown of costs between the situation today and a large scale or future situation. However, the total production cost per GJ has decreases by 17 percent in the future perspective for reed canary grass and switchgrass.

If the bales can be delivered directly from the field to the user, the cost significantly decreases – by about 16 percent (or 1.1 EUR per GJ) in comparison to the situation today. In a future large scale perspective, it would reduce the cost by about 18 percent or 1.0 EUR per GJ. One way to keep the costs for straw fuels low is to find systems with a minimum need for storage.

If the user of energy crops can use a grass, which is harvested during early springtime (e.g. reed canary grass, switch grass or hemp) and a whole grain crop which is harvested during the autumn, there will be less need for storage, compared to if only one crop is used. It is also possible to use straw crops like reed canary grass, switch grass and hemp during the autumn after the grain crops are harvested. If there is only a need for storing half of the quantity of straw, the costs will be reduced by about 0.5 EUR per GJ for straw crops and for straw as a residue. With a longer harvesting season, the fixed costs for baling can also be reduced.

Costs connected to harvesting, storage, transport and brokerage constitute a little more than 50 percent of total cost, both today and in the calculations for the other scenarios. The yield per hectare can be higher with straw crops than with SRC, but the total costs per hectare are also higher. The main reason for the resulting higher cost per GJ is the high costs for managing the crop after harvest. Developing technology for high density bales is important to keep the costs of straw crops at a low level.

## 6.3 Straw as a residue

The focus of this report is on energy crops. Straw as a residue is usually not considered an energy crop but a residue. The reason to include straw in the calculations is to make the calculations between energy crops and straw as a residue comparable. We apply the same basic method of calculation as for energy crops, and also the system for handling the straw is the same as for grass energy crops. The costs for straw include collecting and handling the straw, and compensating the loss of phosphor and potassium from removing the straw.

Compared with the situation of today, straw is less expensive than dedicated straw crops, as shown in Table 6.8. Reasons for this are that there are no growing costs, no land costs and a low need for risk compensation. On the other hand, we can expect higher cost reductions for energy crops compared to straw as a residue in the future.

Table 6.8. Cost for different crops and straw, current conditions, northern region with average soil quality.

| Crop | Yield, tDM/ha | Growing costs, EUR/GJ | Costs for land, EUR/GJ | Costs for risk, EUR/GJ | Total cost, EUR/GJ |
|---|---|---|---|---|---|
| Willow | 9 | 4.1 | 0.0-0.5 | 0.9 | 5.0-5.5 |
| Poplar | 9 | 4.4 | 0.0-0.5 | 1.1 | 5.5-6.0 |
| Reed canary grass | 7.5 | 6.0 | 0.0-0.6 | 0.4 | 6.4-7.0 |
| Miscanthus | 10 | 7.1 | 0.0-0.6 | 0.8 | 7.9-8.4 |
| Hemp | 10 | 8.2 | 0.0-0.4 | 0.4 | 8.6-9.0 |
| Triticale, whole crop | 11 | 6.5 | 0.0-0.4 | 0.2 | 6.7-7.1 |
| Straw | | 3.7 | 0 | 0.1 | 3.8 |

Table 6.9. Cost for different crops, large scale 2020, northern region with average soil quality.

| Crop | Yield, tDM/ha | Growing costs, EUR/GJ | Costs for land, EUR/GJ | Costs for risk, EUR/GJ | Total cost, EUR/GJ |
|---|---|---|---|---|---|
| Willow | 12.6 | 2.8 | 0.0-0.4 | 0.4 | 3.2-3.6 |
| Poplar | 11.25 | 3.1 | 0.0-0.4 | 0.4 | 3.5-3.9 |
| Reed canary grass | 10.5 | 5.1 | 0.0-0.5 | 0.2 | 5.3-5.8 |
| Miscanthus | 16 | 5.8 | 0.0-0.3 | 0.3 | 6.1-6.4 |
| Hemp | 12.5 | 7.2 | 0.0-0.4 | 0.2 | 7.4-7.8 |
| Triticale, whole crop | 11.55 | 6.1 | 0.0-0.4 | 0.1 | 6.2-6.6 |
| Straw | | 3.5 | 0 | 0.1 | 3.6 |

## 6.4 The effect of higher cereals prices

If the prices of cereals and other crops for food and feed increase, the opportunity value of land will also increase. If an energy crop will be grown on a large growing area in the world, that in turn can increase the prices for cereals and other products for food and feed.

Table 6.10. Examples of how total costs increase with a 10 percent higher grain price. The calculation is done for the large scale future perspective. Yields for grain are winter wheat.

| Crop | Yield | Region | EUR/GJ<br>With grain price today | EUR/GJ<br>Increased |
|---|---|---|---|---|
| | | | | |
| Willow | 12.6 | North | 3.2-3.6 | 0.39 |
| Reed canary grass | 10.5 | North | 5.3-5.8 | 0.46 |
| Triticale whole crop | 11.5 | North | 6.2-6.6 | 0.35 |
| | | | | |
| Willow | 18.2 | UK, Ir | 2.8-3.7 | 0.40 |
| Miscanthus | 28.8 | UK, Ir | 5.7-6.2 | 0.29 |
| Triticale whole crop | 16.8 | UK, Ir | 5.5-6.3 | 0.39 |
| | | | | |
| Willow | 14 | West | 3.1-3.8 | 0.45 |
| Miscanthus | 25.6 | West | 5.7-6.1 | 0.25 |
| Triticale whole crop | 12.6 | West | 6.0-6.6 | 0.40 |
| | | | | |
| Willow | 14 | Alp | 3.1-3.5 | 0.35 |
| Miscanthus | 17.6 | Alp | 6.0-6.2 | 0.27 |
| Triticale whole crop | 11.6 | Alp | 6.2-6.5 | 0.33 |
| | | | | |
| Eucalyptus | 15 | South | 3.3-3.3 | 0.11 |
| Switch grass | 18.2 | South | 4.7-4.7 | 0.09 |
| Triticale whole crop | 8.4 | South | 7.2-7.2 | 0.15 |
| | | | | |
| Willow | 12.6 | East | 3.7-5.3 | 0.35 |
| Reed canary grass | 10.5 | East | 4.2-6.1 | 0.41 |
| Triticale whole crop | 9.5 | East | 4.0-5.3 | 0.37 |

The assumed basic price for winter wheat is 0.0989 EUR per kg. If the cereal prices increase by one percent, that increase will increase the production costs by about 0.04 EUR per GJ in the future scenario. Hence, a one percent increase in the cereals prices correspond to about one percent increase in energy crop production cost. The example refers to winter wheat, which has a higher yield than barley and oats. If the opportunity cost for land increases in the future, it has a lesser impact on the cost of high yield energy crops than on low yield energy crops.

## 6.5 The effect of less intensive production

In the Renew project a Scenario 2 has been defined in which potential yields with a minimum of pesticides and fertilizers should be considered. One difficulty is assessing what would happen to the potential land available in such an eco-scenario. With resulting cost increases from ecological/organic food production, one result may be increased food imports and thus more land available for energy crops. Alternatively, with high tariffs on food imports, the lower yields in ecological European food production could result in no land available for energy crops. Another problem is that ecological energy crop production, or “a minimum of pesticides and fertilizers,” is yet undefined. To our knowledge there are no criteria for this in the area of energy crops. There is also no or very little experience of ecological energy crop production and data is lacking on how a measure, such as minimizing pesticides, would influence yields. Generally, it may be assumed that ecological production would result in considerably higher specific costs. Relatively small savings can be made on nitrogen fertilizers and pesticides whereas the costs for mechanical weed treatment and spreading of other fertilizers are likely to increase. Yields are likely to decrease by about 30-40% without nitrogen fertilizer. It is unclear if manure would be available for energy crops or used for food crops. Sewage sludge and waste water could be available and eligible for ecological energy crop production and in this case the effect may be lower specific costs if the value of avoided disposal and treatment costs is accounted for. Despite uncertainties, production cost for energy crops under an eco-scenario are calculated and presented in Appendix 4. These numbers are an input in the total cost calculations in the Renew project.

## 6.6 Comparison with other studies

A review of production cost studies is presented in ECBREC (2006). In the 22 previous studies that were reviewed, calculated production costs ranged from 0.5-8.0 EUR/GJ and assumed yields varied between 7 and 27 tDS/ha,yr. Most of the cost estimates are in the range of 2-6 EUR/GJ. The studies differ in terms of yield assumptions, cost items included, cost levels, subsidies and discount rates. In general, it is very difficult to compare results across different studies since methods, models, data and assumptions are not always explicitly described or stated. In general, other studies do not include overhead and brokerage costs. It is very uncommon to include the cost for risk as is done in this study where we emphasize the farmer’s perspective. Not all studies include the land costs. Optimistic yield assumptions is a major explanation for low production costs. In general, the less practical experience there is with an energy crop, the more optimistic are the future yield assumptions. Low land costs and low cost levels in general is the main reason why many studies calculate low production costs in Eastern Europe. The use of opportunity cost as a way of estimating land costs in this study is one way of doing the valuation. The effect is that land costs become relatively high in otherwise low-cost Eastern Europe and overall cost-differences are leveled out. The opportunity cost approach makes sense from a farmer’s perspective when assessing different crop options.

# 7. Discussion and implementation aspects

An analysis of implementation strategies for energy crop production is beyond the scope of this report. Nevertheless, a few observations can be made based on the preceding economic analysis.

## 7.1 Production costs and energy prices

Gasoline and diesel prices for final consumers are currently in the range of 30-35 EUR/GJ for most European countries. About two-thirds of the fuel price is taxes. For comparison, oil prices of 50 USD per barrel correspond to about 8 EUR/GJ. Production costs are typically much lower. World market coal prices tend to be about 2 EUR/GJ or below. Wood chip prices for large users was between 3.6 and 4.7 EUR/GJ during the heating season of 2002/2003 for Austria, Denmark, France and Sweden. This is relatively close to calculated current energy crop production costs in the range of 4 to 6 EUR/GJ. Assuming 33% to 50% conversion efficiencies in BtL production this corresponds to feedstock costs of 8 to 18 EUR/GJ of synthetic fuel. Whether biomass feedstock costs seem high or low depends on what the point of reference is. Furthermore, it is worth emphasising the frequently large difference between costs and prices.

With current wood chip prices, energy crops are competitive, or near competitive, when excluding the cost for risk compensation (Table 6.1). In the long term, total production costs can be below current wood chip prices (Table 6.2). At present, there is a 45 EUR/ha subsidy available for energy crop production, corresponding to about 0.4 EUR/GJ of energy crops produced. Some countries also have subsidies for establishing plantations. In Sweden, the subsidy is somewhat over 500 EUR/ha, which if annualised for a short rotation coppice plantation corresponds to about 0.3 EUR/GJ. Taken together, this increases the income for the farmer by 0.7 EUR/GJ, sufficient to make short rotation coppice cultivation profitable in some regions for some farms in the short run. Learning effects from increased areas of energy crop production may over time reduce total production costs for short rotation coppice by about 35%, making it profitable to a larger number of growers, with present wood chip prices.

Energy crops cannot compete with coal unless the price of coal, or coal derived energy carriers, is increased through environmental taxes or emissions trading schemes. Alternatively, the demand and willingness to pay for bioenergy can be increased through quota based systems, or the like. In addition, agricultural and energy policy goals must be better harmonised. If the goal is to remove land from food production, a hectare subsidy may be efficient. If the goal is to increase bioenergy production, a subsidy per unit of energy produced would be more efficient. For illustration, Table 7.1 shows the effect on production costs of 100 EUR/GJ given as an annual subsidy or as an establishment subsidy.

Table 7.1. Costs per GJ with a subsidy of 100 EUR/ha as a yearly subsidy and as a one time establishment subsidy. The calculation is done for 2005 yield levels.

| Crop | Yield | Region | Year | Yearly | Establishment |
|---|---|---|---|---|---|
| | | | | | |
| Willow | 9 | North | 22 | 0.90 | 0.07 |
| Reed canary grass | 7.5 | North | 10 | 1.07 | 0.14 |
| Triticale whole crop | 11 | North | 1 | 0.60 | 0.60 |
| | | | | | |
| Willow | 13 | UK, Ir | 22 | 0.63 | 0.05 |
| Miscanthus | 18 | UK, Ir | 21 | 0.46 | 0.04 |
| Triticale whole crop | 16 | UK, Ir | 1 | 0.41 | 0.41 |
| | | | | | |
| Willow | 10 | West | 22 | 0.81 | 0.06 |
| Miscanthus | 16 | West | 21 | 0.52 | 0.04 |
| Triticale whole crop | 12 | West | 1 | 0.55 | 0.55 |
| | | | | | |
| Willow | 10 | Alp | 22 | 0.81 | 0.06 |
| Miscanthus | 11 | Alp | 21 | 0.75 | 0.06 |
| Triticale whole crop | 11 | Alp | 1 | 0.60 | 0.60 |
| | | | | | |
| Eucalyptus | 12 | South | 22 | 0.68 | 0.05 |
| Switch grass | 13 | South | 10 | 0.61 | 0.08 |
| Triticale whole crop | 8 | South | 1 | 0.82 | 0.82 |
| | | | | | |
| Willow | 9 | East | 22 | 0.90 | 0.07 |
| Reed canary grass | 7.5 | East | 10 | 1.07 | 0.14 |
| Triticale whole crop | 9 | East | 1 | 0.73 | 0.73 |

As shown in Table 7.1, the resulting subsidy per GJ depends on both yield levels and when the energy crop will be harvested. A high yield per hectare means a lower subsidy per GJ when the subsidy is a fixed payment per hectare. Establishment subsidies have a relatively larger effect on the production of crops with shorter lifetimes. It should be noted that high area based subsidies can have negative effects in the sense that the subsidy becomes more important than the income from the energy crop. A high area subsidy with little incentive for energy crop productivity can result in plantations on poor soils with poor management. This was the case in Sweden in the early 1990s when a 10 000 SEK/ha (1100 EUR/ha) establishment subsidy was given to short rotation coppice plantations. During this time, 59% of the plantations were made on poorer than average soils and only 12% on better than average soils (Roos and Rosenqvist, 2001). As a result, actual yields were only in the range of 4-5 tDM/ha,yr.

In addition to improving the economics of energy crop production through demand pull and supply push policies, information, education, study visits, and advisory services are important. A detailed study of the reasons behind terminating willow plantations found that the most common reason was failed growth due to weeds. The second most common reason was failed growth due to dry soil (Helby et al, 2006). Both of the reasons can be addressed through better information.

## 7.2 Soil types and irrigation costs

It is generally assumed that energy crops should, or will, be grown on poor soils, less suited for food production. However, from an economic perspective, good soils also have the higher energy crop yields. The cultivation costs are lowest on the best soils and highest for the poorest soils when costs for land are excluded. But when the costs for land are included, assuming present cereals prices, the differences between soil types are small in the short run calculations. In the long run calculations, with present cereals prices, the production cost are lowest on the best soils. The reason is the relatively low profitability of cereals production with current grain prices. The farmer needs a very high grain yield in order to have a positive result from grain production when all costs are taken into consideration.

An increase in grain prices will produce a movement for energy crops in the direction of poorer soils. If the prices for energy crops increase more than cereal prices, this will cause a movement of energy crops to better soils. For example, in calculations at the 1995 price levels, willow was competitive with cereal production on medium quality soils, but not on the best soils in Sweden (Rosenqvist 1997). Ten years later, grain prices are lower and the cost of inputs for cereal production has increased, shifting the balance so that energy crop production on good soils has become relatively more attractive.  Hence, both cereal prices and bioenergy prices affect which soils are most profitable for cereals and bioenergy production, respectively.

It should be noted that the connection between soil and yield is not linear for different crops. For example, reed canary grass will sometimes grow well in places with low grain yields, like in northern Sweden. Willow will grow well on land which is too wet for grain production. In these cases bioenergy crops can be more profitable than cereal production even with high cereal prices.

The costs are 1 to 1.5 EUR/GJ higher for irrigated energy crops with relatively low irrigation intensity compared with non-irrigated energy crops in the calculations. With higher bioenergy prices compared with the situation today, it may become interesting to irrigate energy crops. In situations where irrigation costs are lower than assumed here, or even negative as in the case of waste water irrigation, irrigation may be an interesting option.

## 7.3 Who will grow energy crops, and where?

For the purpose of understanding possible strategies for implementation, it is interesting to reflect on some early experiences from energy crop cultivation in Sweden. Another important aspect is whether strong economic incentives for energy crop cultivation can be created in some niche areas, for the early stages of energy crop introduction.

Different farmers are in different situations and in that way they need different compensation levels for deciding to grow energy crops. Rosenqvist et al (1999) have compared willow growers with non-willow growers in Sweden. The study showed that willow growers are in high concentrations in central Sweden (around Lake Mälaren). One reason being active information and agricultural advisors in this region. Willow growers are more often in the age span of 50-65 years, and as compared with non-willow growers, have larger farms. They are less often focused on animal or milk production, and more often focused on cereal production, compared with other farmers. Thus, it is important to take into account factors such as farm size, age structure, specialisation, etc., when considering ways of supporting the introduction of energy crops.

Barriers to the introduction of energy crops also include:

- Lack of information and good examples
- Markets for bioenergy are not developed
- Technical and biological reasons
- Traditions of, and existing resources for, food and feed production
- Economies of scale in cereal production
- Energy crops require less labour
- Risks
- Land requirements to feed the animals.

Some of these barriers can be addressed. Few farmers will start with a production system they have no knowledge about. Information and advise give the farmer more knowledge and can reduce the farmer´s perception of risk. The market for solid biofuels is not as well developed as the market for food and feed. With a larger market for solid biofuels, and safer ways to sell these biofuels, the income will be less uncertain. One way to make incomes from solid biofuels less uncertain, is to use contracts that distributes risks. Helby et al (2003) show ways to develop contracts between buyers of the solid biofuels, who take most of the fuel price risk, and the producers of solid biofuels, who can take most of the cultivation risk.

A powerful way of creating niche areas for growing energy crops is to capitalise on environmental benefits, additional to the energy production. The potential for using energy plantations for protecting and restoring polluted water and land resources is considerable. Energy crops for producing additional environmental services is commonly denoted multi-functional energy plantations. They can be divided into two categories: those designed for dedicated environmental services (e.g., vegetation filters for waste water and sewage sludge treatment, and shelter belts against soil erosion), and those generating more general benefits (e.g., soil carbon accumulation, increased soil fertility, cadmium removal and increased hunting potential). For example, Rosenqvist and Dawson (2005), and Börjesson and Berndes (2005), have shown that vegetation filters with willow can be a cost effective way to treat waste water. Rosenqvist and Ness (2004) have shown lower costs for treatment of leachate water in vegetation filter compared with a traditional water treatment. The economic value of multi-functional plantations is normally highest for those designed for such dedicated environmental services. The greatest potentials are found in areas that are densely populated but dominated by farmland. Using multi-functional energy plantations as a prime mover for energy crops, requires, however, that the value of the environmental service is monetized and transferred to the energy crop producer.

**References**

ECBREC, 2006, “Review on existing production cost studies, energy crops in Europe”, Deliverable 5.3.3 in RENEW (Renewable fuels for advanced powertrains), EC 6FP Project SES6-CT-2003-502705 (prepared by EC Baltic Renewable Energy Center).

Energimyndigheten, 2005. Prisblad för biobränslen, torv m.m. Nr 4 / 2005 (Prices for biofuels, peat, etc), Eskilstuna Sweden. (In Swedish)

Börjesson P. & Berndes G. (2005). The Prospects for Willow Plantations for Wastewater Treatment in Sweden. *Biomass and Bioenergy* (in press).

Hall D. O. & Rosillo-Calle, F., 1998. 10 th European conference and technology exhibition, Wurzburg, German.

Helby, Peter (ed.), Pål Börjesson, Anders Christian Hansen, Anders Roos, Håkan Rosenqvist, Linn Takeuchi (2003) Market development problems for sustainable bio-energy systems in Sweden. (The BIOMARK project), IMES/EESS Report no. 38, Environmental and Energy Systems Studies, Lund University, Lund, Sweden.

Helby P., Rosenvist H., Roos A., 2006. Retreat from Salix – Swedish experience with energy crops in the 1990´s. Biomasss and Bioenergy Volume xx, (2006) xx-xx.

Håkansson, S. 1978. Fällor och fel i jordbrukspolitiken (Pitfalls and mistakes in agricultural policy), Ekonomisk Debatt 1978:7, Nationalekonomsiska föreningen, Stockholm, Sweden. (in Swedish)

Roos, A., 1996. The economics of forest ownership. Rapport nr 42, Inst. för Skog-Industri-Markand Studier. SLU, Uppsala, Sweden.

Roos A & Rosenqvist H. 2001. Experiences of commercial energy crop production - A study of willow growers in Sweden. In: 1st world conference on biomass for energy and industry, Seville, Spain, 5-9 June 2000. London: James & James; 2001. P. 222-225.

Rosenqvist H., 1997, Salixodling - Kalkylmetoder och lönsamhet (Salix cultivation – methods for calculation and profitability), Silvestria 24, SLU, Uppsala, Sweden. (In Swedish)

Rosenqvist, H. and Dawson, W. M. (2005) Economics of using wastewater irrigation of willow in Northern Ireland. Biomasss and Bioenergy Volume 29, (2005) 83-92.

Rosenqvist, H. and Ness, B. (2004) An economic analysis of leachate purification through willow-coppice vegetation filters. *Bioresource Technology* **94:** 321-329.

Rosenqvist, H., Roos, A., Ling, E., Hektor, B. 2000. Willow growers in Sweden. Biomass and Bioenergy 18(2):137-145.

Sharpe, W. F. 1964. Capaital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk. Journal of Finance Nr 19, Sept. 1964, pp 425-442.

# Appendix

## Appendix 1: Yield levels for poorer and better soils than average and yield levels for irrigated crops

## Appendix 2: Costs for different crops
**Appendix 2.1: Cost for different crops, small scale 2005**
**Appendix 2.1: Cost for different crops, large scale 2005**
**Appendix 2.3: Cost for different crops, large scale 2020**

## Appendix 3: Results from cost calculations for different yields and cost level
**Appendix 3.1: Cereals as opportunity value for land**
**Appendix 3.2: Cost for bioenergy 2005, small scale**
**Appendix 3.3: Cost for bioenergy 2005, large scale**
**Appendix 3.4: Cost for bioenergy, future situation, large scale**
**Appendix 3.5: Cost for bioenergy, future situation, large scale, irrigated crops**

## Appendix 4: Organic energy crop production

## Appendix 1: Yield levels for poorer and better soils than average

Table A.1.1. Commercial yields for non irrigated crops grown on the poorest third of arable land in terms of soil quality, tdm per hectare and year

| Crop | North | UK, IR | West | Alp | South | East |
|---|---|---|---|---|---|---|
| Willow | 7.5 tdm | 11 | 10 | 8 | --- | 7 |
| Poplar | 7.5 tdm | 11 | 10 | 8 | --- | 7 |
| Eucalyptus | ----------- | --------------- | | | 10 | |
| Miscantus | 8 tdm | 15 | 8 | 8 | --- | 9 |
| RCG | 6 tdm | -------------- | ------- | | --- | 7.5 |
| Switch grass | ----------- | -------------- | ----------- | ----------- | 11 | |
| Hemp (whole crop) | 8 tdm | ---------------- | 9 | 8 | --- | 8 |
| Triticale (whole crop) | 9 tdm | ----------------- | 10 | 9 | 6 | 7 |
| Sorghum (whole crop) | ----------- | --------------- | 8 | --------- | --- | |
| Barley (not energy) | 4.1 t wet | 5.6 | 5.1 | 5.8 | 1.5 | 3.5 |
| Winter wheat (not energy) | 5.2 t wet | 7.4 | 6.0 | 5.2 | 1.5 | 3.8 |

Table A.1.2. Commercial yields for non irrigated crops grown on the best third of arable land in terms of soil quality, tdm per hectare and year

| Crop | North | UK, IR | West | Alp | South | East |
|---|---|---|---|---|---|---|
| Willow | 11 tdm | 14 | 12 | 12 | --- | 12.5 |
| Poplar | 11 tdm | 14 | 15 | 13 | --- | 12.5 |
| Eucalyptus | ----------- | -------------- | | | 14 | |
| Miscantus | 13 tdm | 19.5 | 25 | 16 | --- | 17 |
| RCG | 10 tdm | --------------- | ------- | | --- | 10 |
| Switch grass | ------------ | ----------------- | ----------- | | 15 | |
| Hemp (whole crop) | 13 tdm | ---------------- | 13 | 13 | --- | 13 |
| Triticale (whole crop) | 14 tdm | --------------- | 15 | 14 | 10 | 12 |
| Sorghum (whole crop) | ------------ | ---------------- | 15 | | --- | |
| Barley (not energy) | 5.8 t wet | 8.8 | 6.2 | 6.8 | 2.5 | 5.8 |
| Winter wheat (not energy) | 8.0 t wet | 11.8 | 10.1 | 7 | 2.5 | 6.2 |

# Appendix 2. Costs for different crops

## Appendix 2.1: Cost for different crops, small scale 2005

North
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 9 | 4.1 | 0.0-0.5 | 0.9 | 5.0-5.5 |
| Poplar | 9 | 4.4 | 0.0-0.5 | 1.1 | 5.5-6.0 |
| Reed canary grass | 7.5 | 6.0 | 0.0-0.6 | 0.4 | 6.4-7.0 |
| Miscanthus | 10 | 7.1 | 0.0-0.5 | 0.8 | 7.9-8.4 |
| Hemp | 10 | 8.2 | 0.0-0.4 | 0.4 | 8.6-9.0 |
| Triticale whole crop | 11 | 6.5 | 0.0-0.4 | 0.2 | 6.7-7.1 |
| Straw | | 6.1 | 0 | 0.1 | 6.2 |

North
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 7.5 | 4.5 | 0.0-0.2 | 0.9 | 5.4-5.6 |
| Poplar | 7.5 | 4.9 | 0.0-0.2 | 1.1 | 6.0-6.2 |
| Reed canary grass | 6 | 6.6 | 0.0-0.3 | 0.4 | 7.0-7.3 |
| Miscanthus | 8 | 7.5 | 0.0-0.2 | 0.8 | 8.3-8.5 |
| Hemp | 8 | 9.0 | 0.0-0.2 | 0.4 | 9.4-9.6 |
| Triticale whole crop | 9 | 7.1 | 0.0-0.2 | 0.2 | 7.3-7.5 |

North
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 11 | 3.7 | 0.0-0.9 | 0.9 | 4.6-5.5 |
| Poplar | 11 | 3.9 | 0.0-0.9 | 1.1 | 5.0-5.9 |
| Reed canary grass | 10 | 5.5 | 0.0-1.0 | 0.4 | 5.9-6.9 |
| Miscanthus | 13 | 6.6 | 0.0-0.8 | 0.8 | 7.4-8.2 |
| Hemp | 13 | 7.5 | 0.0-0.6 | 0.4 | 7.9-8.5 |
| Triticale whole crop | 14 | 5.9 | 0.0-0.6 | 0.2 | 6.1-6.7 |

UK, IR
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 13 | 3.1 | 0.0-1.7 | 0.9 | 4.0-5.7 |
| Poplar | 13 | 3.3 | 0.0-1.7 | 1.1 | 4.4-6.1 |
| Miscanthus | 18 | 5.7 | 0.0-1.3 | 0.8 | 6.5-7.8 |
| Triticale whole crop | 16 | 5.3 | 0.0-1.1 | 0.2 | 5.5-6.6 |
| Straw | | 5.7 | 0 | 0.1 | 5.8 |

UK, IR
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 11 | 3.4 | 0.0-0.8 | 0.9 | 4.3-5.1 |
| Poplar | 11 | 3.6 | 0.0-0.8 | 1.1 | 4.7-5.5 |
| Miscanthus | 15 | 5.9 | 0.0-0.7 | 0.8 | 6.7-7.4 |
| Triticale whole crop | 13 | 5.7 | 0.0-0.6 | 0.2 | 5.9-6.5 |

UK, IR
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 14 | 3.0 | 0.0-1.9 | 0.9 | 3.9-5.8 |
| Poplar | 14 | 3.2 | 0.0-1.9 | 1.1 | 4.3-6.2 |
| Miscanthus | 19.5 | 5.6 | 0.0-1.5 | 0.8 | 6.4-7.9 |
| Triticale whole crop | 18 | 5.1 | 0.0-1.2 | 0.2 | 5.3-6.5 |

West
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 10 | 3.4 | 0.0-1.5 | 0.9 | 4.3-5.8 |
| Poplar | 10 | 3.7 | 0.0-1.5 | 1.1 | 4.8-6.3 |
| Miscanthus | 16 | 5.6 | 0.0-1.0 | 0.8 | 6.4-7.4 |
| Hemp | 11 | 7.0 | 0.0-1.1 | 0.4 | 7.4-8.5 |
| Triticale whole crop | 12 | 5.6 | 0.0-1.0 | 0.2 | 5.8-6.8 |
| Sorghum whole crop | 10 | 6.0 | 0.0-1.2 | 0.2 | 6.2-7.4 |
| Straw | | 5.4 | 0 | 0.1 | 5.5 |

West
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 10 | 3.4 | 0.0-0.9 | 0.9 | 4.3-5.2 |
| Poplar | 10 | 3.7 | 0.0-0.9 | 1.1 | 4.8-5.7 |
| Miscanthus | 8 | 6.7 | 0.0-1.1 | 0.8 | 7.5-8.6 |
| Hemp | 9 | 7.6 | 0.0-0.8 | 0.4 | 8.0-8.8 |
| Triticale whole crop | 10 | 6.0 | 0.0-0.7 | 0.2 | 6.2-6.9 |
| Sorghum whole crop | 8 | 6.7 | 0.0-0.9 | 0.2 | 6.9-7.8 |

West
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 12 | 3.1 | 0.0-1.9 | 0.9 | 4.0-5.9 |
| Poplar | 15 | 3.0 | 0.0-1.5 | 1.1 | 4.1-5.6 |
| Miscanthus | 25 | 5.4 | 0.0-0.8 | 0.8 | 6.2-7.0 |
| Hemp | 13 | 6.6 | 0.0-1.4 | 0.4 | 7.0-8.4 |
| Triticale whole crop | 15 | 5.1 | 0.0-1.3 | 0.2 | 5.3-6.6 |
| Sorghum whole crop | 15 | 5.1 | 0.0-1.3 | 0.2 | 5.3-6.6 |

Alp
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 10 | 3.2 | 0.0-1.1 | 0.9 | 4.1-5.2 |
| Poplar | 10 | 3.5 | 0.0-1.1 | 1.1 | 4.6-5.7 |
| Miscanthus | 11 | 5.8 | 0.0-0.8 | 0.8 | 6.6-7.4 |
| Hemp | 10 | 7.0 | 0.0-0.9 | 0.4 | 7.4-8.3 |
| Triticale whole crop | 11 | 5.6 | 0.0-0.8 | 0.2 | 5.8-6.6 |
| Straw | | 5.3 | 0 | 0.1 | 5.4 |

Alp
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 8 | 3.7 | 0.0-0.9 | 0.9 | 4.6-5.5 |
| Poplar | 8 | 4.0 | 0.0-0.9 | 1.1 | 5.1-6.0 |
| Miscanthus | 8 | 6.3 | 0.0-0.8 | 0.8 | 7.1-7.9 |
| Hemp | 8 | 7.7 | 0.0-0.7 | 0.4 | 8.1-8.8 |
| Triticale whole crop | 9 | 6.1 | 0.0-0.6 | 0.2 | 6.3-6.9 |

Alp
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 12 | 3.0 | 0.0-1.1 | 0.9 | 3.9-5.0 |
| Poplar | 13 | 3.0 | 0.0-1.1 | 1.1 | 4.1-5.2 |
| Miscanthus | 16 | 5.3 | 0.0-0.8 | 0.8 | 6.1-6.9 |
| Hemp | 13 | 6.4 | 0.0-0.8 | 0.4 | 6.8-7.6 |
| Triticale whole crop | 14 | 5.1 | 0.0-0.8 | 0.2 | 5.3-6.1 |

South
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Eucalyptus | 12 | 3.2 | 0-0-0.0 | 1.1 | 4.3-4.3 |
| Switch grass | 13 | 4.3 | 0.0-0.0 | 0.4 | 4.7-4.7 |
| Triticale whole crop | 8 | 6.2 | 0.0-0.0 | 0.2 | 6.4-6.4 |
| Straw | | 5.1 | 0 | 0.1 | 5.2 |

South
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Eucalyptus | 10 | 3.5 | 0.0-0.0 | 1.1 | 4.6-4.6 |
| Switch grass | 11 | 4.5 | 0.0-0.0 | 0.4 | 4.9-4.9 |
| Triticale whole crop | 6 | 7.2 | 0.0-0.0 | 0.2 | 7.3-7.5 |

South
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Eucalyptus | 14 | 3.0 | 0.0-0.0 | 1.1 | 4.1-4.1 |
| Switch grass | 15 | 4.1 | 0.0-0.0 | 0.4 | 4.5-4.5 |
| Triticale whole crop | 10 | 5.6 | 0.0-0.0 | 0.2 | 5.8-5.8 |

East
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 9 | 1.7 | 1.1-2.7 | 0.9 | 3.7-5.3 |
| Poplar | 9 | 1.9 | 1.1-2.7 | 1.1 | 4.1-5.7 |
| Reed canary grass | 7.5 | 2.3 | 1.5-3.4 | 0.4 | 4.2-6.1 |
| Miscanthus | 11 | 2.7 | 1.1-2.4 | 0.8 | 4.6-5.9 |
| Hemp | 10 | 3.3 | 0.9-2.0 | 0.4 | 4.6-5.7 |
| Triticale whole crop | 9 | 2.8 | 1.0-2.3 | 0.2 | 4.0-5.3 |
| Straw | | 2.5 | 0 | 0.1 | 2.6 |

East
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 7 | 1.8 | 0.6-2.3 | 0.9 | 3.3-5.0 |
| Poplar | 7 | 2.1 | 0.6-2.3 | 1.1 | 3.8-5.5 |
| Reed canary grass | 7.5 | 2.4 | 0.5-2.1 | 0.4 | 3.3-4.9 |
| Miscanthus | 9 | 2.8 | 0.5-1.9 | 0.8 | 4.1-5.5 |
| Hemp | 8 | 3.6 | 0.4-1.6 | 0.4 | 4.4-5.6 |
| Triticale whole crop | 7 | 3.2 | 0.5-1.8 | 0.2 | 3.9-5.2 |

East
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 12.5 | 1.5 | 1.3-2.2 | 0.9 | 3.7-4.6 |
| Poplar | 12.5 | 1.6 | 1.3-2.2 | 1.1 | 4.0-4.9 |
| Reed canary grass | 10 | 2.1 | 1.8-2.9 | 0.4 | 4.3-5.4 |
| Miscanthus | 17 | 2.5 | 1.0-1.7 | 0.8 | 4.3-5.0 |
| Hemp | 13 | 3.0 | 1.0-1.8 | 0.4 | 4.4-5.2 |
| Triticale whole crop | 12 | 2.5 | 1.2-2.0 | 0.2 | 3.9-4.7 |

**South irrigated crops**

Average soils

Few irrigations, unrealistic few compared with the yield.

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Poplar, irr. 3 tim. | 17.5 | 4.4 | 0.0-0.0 | 1.1 | 5.5 |
| Eucalyptus, irr 3 tim. | 15 | 4.9 | 0-0-0.0 | 1.1 | 6.0 |
| Miscanthus, irr 3 | 15 | 7.4 | 0.0-0.0 | 0.8 | 8.2 |
| Switch grass, irr 3 tim. | 18 | 5.7 | 0.0-0.0 | 0.4 | 6.1 |
| Hemp, irr 3 tim. | 18.5 | 6.9 | 0.0-0.0 | 0.4 | 7.3 |
| Triticale whole crop, 3 tim | 15 | 6.4 | 0.0-0.0 | 0.2 | 6.6 |
| Sorghum, irr. 3 tim. | 37.5 | 4.5 | 0.0-0.0 | 0.2 | 4.0 |
| Straw | | | 0 | 0.1 | |

Average soils

Higher irrigation level

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Poplar, irr. 4 tim. | 17.5 | 4.9 | 0.0-0.0 | 1.1 | 5.9 |
| Eucalyptus, irr 4 tim. | 15 | 5.6 | 0-0-0.0 | 1.1 | 6.7 |
| Miscanthus, irr 5 | 15 | 8.8 | 0.0-0.0 | 0.8 | 9.6 |
| Switch grass, irr 5 tim. | 18 | 6.8 | 0.0-0.0 | 0.4 | 7.2 |
| Hemp, irr 7 tim. | 18.5 | 8.7 | 0.0-0.0 | 0.4 | 9.1 |
| Triticale whole crop,7tim | 15 | 8.7 | 0.0-0.0 | 0.2 | 8.9 |
| Sorghum, irr. 7 tim. | 37.5 | 5.4 | 0.0-0.0 | 0.2 | 5.6 |
| Straw | | | 0 | 0.1 | |

**Appendix 2.1: Cost for different crops, large scale 2005**

North
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 9 | 3.7 | 0.0-0.5 | 0.7 | 4.4-4.9 |
| Poplar | 9 | 3.9 | 0.0-0.5 | 0.8 | 4.7-5.2 |
| Reed canary grass | 7.5 | 5.7 | 0.0-0.7 | 0.3 | 6.0-6.7 |
| Miscanthus | 10 | 6.5 | 0.0-0.5 | 0.6 | 7.1-7.6 |
| Hemp | 10 | 7.9 | 0.0-0.4 | 0.3 | 8.2-8.6 |
| Triticale whole crop | 11 | 6.3 | 0.0-0.3 | 0.1 | 6.4-6.7 |
| Straw | | 5.8 | 0 | 0.1 | 5.9 |

North
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 7.5 | 4.0 | 0.0-0.3 | 0.7 | 4.7-5.0 |
| Poplar | 7.5 | 4.3 | 0.0-0.3 | 0.8 | 5.1-5.4 |
| Reed canary grass | 6 | 6.3 | 0.0-0.3 | 0.3 | 6.6-6.9 |
| Miscanthus | 8 | 6.9 | 0.0-0.2 | 0.6 | 7.5-7.7 |
| Hemp | 8 | 8.7 | 0.0-0.2 | 0.3 | 9.0-9.2 |
| Triticale whole crop | 9 | 6.9 | 0.0-0.2 | 0.1 | 7.0-7.2 |

North
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 11 | 3.3 | 0.0-0.9 | 0.7 | 4.0-4.9 |
| Poplar | 11 | 3.5 | 0.0-0.9 | 0.8 | 4.3-5.2 |
| Reed canary grass | 10 | 5.3 | 0.0-0.9 | 0.3 | 5.6-5.5 |
| Miscanthus | 13 | 6.1 | 0.0-0.8 | 0.6 | 6.7-7.5 |
| Hemp | 13 | 7.2 | 0.0-0.6 | 0.3 | 7.5-8.1 |
| Triticale whole crop | 14 | 5.7 | 0.0-0.6 | 0.1 | 5.8-6.4 |

UK, IR
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 13 | 3.1 | 0.0-1.2 | 0.7 | 3.8-5.0 |
| Poplar | 13 | 3.2 | 0.0-1.2 | 0.8 | 4.0-5.2 |
| Miscanthus | 18 | 5.8 | 0.0-0.9 | 0.6 | 6.4-7.3 |
| Triticale whole crop | 16 | 5.5 | 0.0-0.8 | 0.1 | 5.6-6.4 |
| Straw | | 5.8 | 0 | 0.1 | 5.9 |

UK, IR
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 11 | 3.3 | 0.0-0.8 | 0.7 | 4.0-4.8 |
| Poplar | 11 | 3.5 | 0.0-0.8 | 0.8 | 4.3-5.1 |
| Miscanthus | 15 | 6.0 | 0.0-0.5 | 0.6 | 6.6-7.1 |
| Triticale whole crop | 13 | 5.9 | 0.0-0.5 | 0.1 | 6.0-6.5 |

UK, IR
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 14 | 3.0 | 0.0-1.5 | 0.7 | 3.7-5.2 |
| Poplar | 14 | 3.1 | 0.0-1.5 | 0.8 | 3.9-5.4 |
| Miscanthus | 19.5 | 5.5 | 0.0-1.3 | 0.6 | 6.1-7.4 |
| Triticale whole crop | 18 | 5.3 | 0.0-0.9 | 0.1 | 5.4-6.3 |

West
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 10 | 3.1 | 0.0-1.4 | 0.7 | 3.8-5.2 |
| Poplar | 10 | 3.3 | 0.0-1.4 | 0.8 | 4.1-5.5 |
| Miscanthus | 16 | 5.8 | 0.0-0.7 | 0.6 | 6.4-7.1 |
| Hemp | 11 | 7.6 | 0.0-0.7 | 0.3 | 7.9-8.6 |
| Triticale whole crop | 12 | 6.1 | 0.0-0.6 | 0.1 | 6.2-6.8 |
| Straw | | 5.8 | 0 | 0.1 | 5.9 |

West
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 10 | 3.5 | 0.0-0.4 | 0.7 | 4.2-4.6 |
| Poplar | 10 | 3.7 | 0.0-0.4 | 0.8 | 4.5-4.9 |
| Miscanthus | 8 | 6.9 | 0.0-0.5 | 0.6 | 7.5-8.0 |
| Hemp | 9 | 8.3 | 0.0-0.3 | 0.3 | 8.6-9.1 |
| Triticale whole crop | 10 | 6.6 | 0.0-0.3 | 0.1 | 6.7-7.0 |
| Sorghum whole crop | 8 | 7.3 | 0.0-0.4 | 0.1 | 7.4-7.8 |

West
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 12 | 3.2 | 0.0-1.3 | 0.7 | 3.9-5.2 |
| Poplar | 15 | 3.0 | 0.0-1.0 | 0.8 | 3.8-4.8 |
| Miscanthus | 25 | 5.5 | 0.0-0.7 | 0.6 | 6.1-6.8 |
| Hemp | 13 | 7.2 | 0.0-1.0 | 0.3 | 7.5-8.5 |
| Triticale whole crop | 15 | 5.6 | 0.0-0.9 | 0.1 | 5.7-6.6 |

Alp
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 10 | 3.5 | 0.0-0.5 | 0.7 | 4.2-4.7 |
| Poplar | 10 | 3.7 | 0.0-0.5 | 0.8 | 4.5-5.0 |
| Miscanthus | 11 | 6.4 | 0.0-0.4 | 0.6 | 7.0-7.4 |
| Hemp | 10 | 7.9 | 0.0-0.3 | 0.3 | 8.2-8.5 |
| Triticale whole crop | 11 | 6.3 | 0.0-0.3 | 0.1 | 6.4-6.7 |
| Straw | | 5.8 | 0 | 0.1 | 5.9 |

Alp
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 8 | 3.9 | 0.0-0.2 | 0.7 | 4.6-4.8 |
| Poplar | 8 | 4.2 | 0.0-0.2 | 0.8 | 5.0-5.2 |
| Miscanthus | 8 | 6.9 | 0.0-0.2 | 0.6 | 7.5-7.7 |
| Hemp | 8 | 8.7 | 0.0-0.1 | 0.3 | 9.0-9.1 |
| Triticale whole crop | 9 | 6.9 | 0.0-0.1 | 0.1 | 7.0-7.1 |

Alp
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 12 | 3.2 | 0.0-0.6 | 0.7 | 3.9-4.5 |
| Poplar | 13 | 3.2 | 0.0-0.5 | 0.8 | 4.0-4.5 |
| Miscanthus | 16 | 5.8 | 0.0-0.5 | 0.6 | 6.4-6.4 |
| Hemp | 13 | 7.2 | 0.0-0.4 | 0.3 | 7.5-7.9 |
| Triticale whole crop | 14 | 5.7 | 0.0-0.4 | 0.1 | 5.4-5.8 |

South
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Eucalyptus | 12 | 3.5 | 0.0-0.0 | 0.8 | 4.3-4.3 |
| Switch grass | 13 | 4.9 | 0.0-0.0 | 0.3 | 5.2-5.2 |
| Triticale whole crop | 8 | 7.3 | 0.0-0.0 | 0.1 | 7.4-7.4 |
| Straw | | 5.8 | 0 | 0.1 | 5.9 |

South
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Eucalyptus | 10 | 3.8 | 0.0-0.0 | 0.8 | 4.6-4.6 |
| Switch grass | 11 | 5.1 | 0.0-0.0 | 0.3 | 5.4-5.4 |
| Triticale whole crop | 6 | 8.5 | 0.0-0.0 | 0.1 | 8.6-8.6 |

South
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Eucalyptus | 14 | 3.3 | 0.0-0.0 | 0.8 | 4.1-4.1 |
| Switch grass | 15 | 4.7 | 0.0-0.0 | 0.3 | 5.0-5.0 |
| Triticale whole crop | 10 | 6.6 | 0.0-0.0 | 0.1 | 6.7-6.7 |

East
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 9 | 3.7 | 0.0-0.3 | 0.7 | 4.4-4.7 |
| Poplar | 9 | 3.9 | 0.0-0.3 | 0.8 | 4.7-5.0 |
| Reed canary grass | 7.5 | 5.7 | 0.0-0.4 | 0.3 | 6.0-6.4 |
| Miscanthus | 11 | 6.4 | 0.0-0.2 | 0.6 | 7.0-7.2 |
| Hemp | 10 | 7.9 | 0.0-0.2 | 0.3 | 8.2-8.4 |
| Triticale whole crop | 9 | 6.9 | 0.0-0.2 | 0.1 | 7.0-7.2 |
| Straw | | 5.8 | 0 | 0.1 | 5.9 |

East
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 7 | 4.2 | 0.0-0.0 | 0.7 | 4.9-4.9 |
| Poplar | 7 | 4.5 | 0.0-0.0 | 0.8 | 5.3-5.3 |
| Reed canary grass | 7.5 | 5.7 | 0.0-0.0 | 0.3 | 6.0-6.0 |
| Miscanthus | 9 | 6.7 | 0.0-0.0 | 0.6 | 7.3-7.3 |
| Hemp | 8 | 8.7 | 0.0-0.0 | 0.3 | 9.0-9.0 |
| Triticale whole crop | 7 | 7.8 | 0.0-0.0 | 0.1 | 7.9-7.9 |

East
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 12.5 | 3.2 | 0.0-0.3 | 0.7 | 3.9-4.2 |
| Poplar | 12.5 | 3.3 | 0.0-0.3 | 0.8 | 4.1-4.4 |
| Reed canary grass | 10 | 5.3 | 0.0-0.4 | 0.3 | 5.6-6.0 |
| Miscanthus | 17 | 5.8 | 0.0-0.3 | 0.6 | 6.4-6.7 |
| Hemp | 13 | 7.2 | 0.0-0.3 | 0.3 | 7.5-7.8 |
| Triticale whole crop | 12 | 6.1 | 0.0-0.3 | 0.1 | 6.2-6.5 |

**Appendix 2.3: Cost for different crops, large scale 2020**

North
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 12.6 | 2.8 | 0.0-0.4 | 0.4 | 3.2-3.6 |
| Poplar | 11.25 | 3.1 | 0.0-0.4 | 0.4 | 3.5-3.9 |
| Reed canary grass | 10.5 | 5.1 | 0.0-0.5 | 0.2 | 5.3-5.8 |
| Miscanthus | 16 | 5.8 | 0.0-0.3 | 0.3 | 6.1-6.4 |
| Hemp | 12.5 | 7.2 | 0.0-0.4 | 0.2 | 7.4-7.8 |
| Triticale whole crop | 11.55 | 6.1 | 0.0-0.4 | 0.1 | 6.2-6.6 |
| Straw | | 5.8 | 0 | 0.1 | 5.9 |

Cost for different crops
North
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 10.5 | 3.1 | 0.0-0.1 | 0.4 | 3.5-3.6 |
| Poplar | 9.4 | 3.4 | 0.0-0.2 | 0.4 | 3.8-4.0 |
| Reed canary grass | 8.4 | 5.5 | 0.0-0.2 | 0.2 | 5.7-5.9 |
| Miscanthus | 12.8 | 6.0 | 0.0-0.1 | 0.3 | 6.3-6.4 |
| Hemp | 10 | 7.9 | 0.0-0.1 | 0.2 | 8.1-8.2 |
| Triticale whole crop | 9.5 | 6.7 | 0.0-0.1 | 0.1 | 6.8-6.9 |

Cost for different crops
North
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 15.4 | 2.6 | 0.0-0.6 | 0.4 | 3.0-3.6 |
| Poplar | 13.8 | 2.8 | 0.0-0.7 | 0.4 | 3.2-3.9 |
| Reed canary grass | 14 | 4.8 | 0.0-0.7 | 0.2 | 5.0-5.7 |
| Miscanthus | 20.8 | 5.6 | 0.0-0.4 | 0.3 | 5.9-6.3 |
| Hemp | 16.2 | 6.7 | 0.0-0.5 | 0.2 | 6.9-7.4 |
| Triticale whole crop | 14.7 | 5.6 | 0.0-0.6 | 0.1 | 5.7-6.3 |

Cost for different crops, large scale 2020

UK, IR
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 18.2 | 2.4 | 0.0-0.9 | 0.4 | 2.8-3.7 |
| Poplar | 16.2 | 2.6 | 0.0-1.0 | 0.4 | 3.0-4.0 |
| Miscanthus | 28.8 | 5.4 | 0.0-0.5 | 0.3 | 5.7-6.2 |
| Triticale whole crop | 16.8 | 5.4 | 0.0-0.8 | 0.1 | 5.5-6.3 |
| Straw | | 5.8 | 0 | 0.1 | 5.9 |

Cost for different crops

UK, IR
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 15.4 | 2.6 | 0.0-0.5 | 0.4 | 3.0-3.5 |
| Poplar | 13.8 | 2.8 | 0.0-0.6 | 0.4 | 3.2-3.8 |
| Miscanthus | 24 | 5.5 | 0.0-0.3 | 0.3 | 5.8-6.1 |
| Triticale whole crop | 13.6 | 5.8 | 0.0-0.5 | 0.1 | 5.9-6.4 |

Cost for different crops

UK, IR
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 19.6 | 2.4 | 0.0-1.0 | 0.4 | 2.8-3.8 |
| Poplar | 17.5 | 2.6 | 0.0-1.2 | 0.4 | 3.0-4.2 |
| Miscanthus | 31.2 | 5.3 | 0.0-0.7 | 0.3 | 5.6-6.3 |
| Triticale whole crop | 18.9 | 5.2 | 0.0-0.9 | 0.1 | 5.3-6.2 |

Cost for different crops, large scale 2020
West
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 14 | 2.7 | 0.0-0.7 | 0.4 | 3.1-3.8 |
| Poplar | 12.5 | 3.0 | 0.0-0.8 | 0.4 | 3.4-4.2 |
| Miscanthus | 25.6 | 5.4 | 0.0-0.4 | 0.3 | 5.7-6.1 |
| Hemp | 13.8 | 7.0 | 0.0-0.6 | 0.2 | 7.2-7.8 |
| Triticale whole crop | 12.6 | 5.9 | 0.0-0.6 | 0.1 | 6.0-6.6 |
| Straw | | 5.8 | 0 | 0.1 | 5.9 |

Cost for different crops

West
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 14 | 2.7 | 0.0-0.3 | 0.4 | 3.1-3.4 |
| Poplar | 12.5 | 3.0 | 0.0-0.3 | 0.4 | 3.4-3.7 |
| Reed canary grass | 8.4 | 5.5 | 0.0-0.5 | 0.2 | 5.7-6.2 |
| Miscanthus | 12.8 | 6.0 | 0.0-0.3 | 0.3 | 6.3-6.6 |
| Hemp | 11.2 | 7.5 | 0.0-0.3 | 0.2 | 7.7-8.0 |
| Triticale whole crop | 10.5 | 6.4 | 0.0-0.3 | 0.1 | 6.5-6.8 |

Cost for different crops

West
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 16.8 | 2.5 | 0.0-1.0 | 0.4 | 2.9-3.9 |
| Poplar | 18.8 | 2.5 | 0.0-0.9 | 0.4 | 2.9-3.8 |
| Miscanthus | 40 | 5.2 | 0.0-0.4 | 0.3 | 5.5-5.9 |
| Hemp | 16.2 | 6.7 | 0.0-0.8 | 0.2 | 6.9-7.7 |
| Triticale whole crop | 15.8 | 5.5 | 0.0-0.8 | 0.1 | 5.6-6.4 |
| Sorghum whole crop | 15.8 | 5.5 | 0.0-0.8 | 0.1 | 5.6-6.4 |

Cost for different crops, large scale 2020

Alp
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 14 | 2.7 | 0.0-0.3 | 0.4 | 3.1-3.5 |
| Poplar | 12.5 | 3.0 | 0.0-0.3 | 0.4 | 3.4-3.7 |
| Miscanthus | 17.6 | 5.7 | 0.0-0.2 | 0.3 | 6.0-6.2 |
| Hemp | 12.5 | 7.2 | 0.0-0.3 | 0.2 | 7.4-7.7 |
| Triticale whole crop | 11.6 | 6.1 | 0.0-0.3 | 0.1 | 6.2-6.5 |
| Straw | | 5.8 | 0 | 0.1 | 5.9 |

Cost for different crops

Alp
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 11.2 | 3.0 | 0.0-0.1 | 0.4 | 3.4-3.5 |
| Poplar | 10 | 3.3 | 0.0-0.2 | 0.4 | 3.7-3.9 |
| Miscanthus | 12.8 | 6.0 | 0.0-0.1 | 0.3 | 6.3-6.4 |
| Hemp | 10 | 7.9 | 0.0-0.1 | 0.2 | 8.1-8.2 |
| Triticale whole crop | 9.5 | 6.7 | 0.0-0.1 | 0.1 | 6.8-6.9 |

Cost for different crops

Alp
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 16.8 | 2.5 | 0.0-0.4 | 0.4 | 2.9-3.3 |
| Poplar | 16.2 | 2.7 | 0.0-0.4 | 0.4 | 3.1-3.5 |
| Miscanthus | 25.6 | 5.4 | 0.0-0.3 | 0.3 | 5.9-6.2 |
| Hemp | 16.2 | 6.7 | 0.0-0.3 | 0.2 | 6.9-7.2 |
| Triticale whole crop | 14.7 | 5.6 | 0.0-0.4 | 0.1 | 5.7-6.1 |

Cost for different crops, large scale 2020

South
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Eucalyptus | 15 | 2.9 | 0.0-0.0 | 0.4 | 3.3-3.3 |
| Switch grass | 18.2 | 4.5 | 0.0-0.0 | 0.2 | 4.7-4.7 |
| Triticale whole crop | 8.4 | 7.1 | 0.0-0.0 | 0.1 | 7.2-7.2 |
| Straw | | 5.8 | 0 | 0.1 | 5.9 |

Cost for different crops

South
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Eucalyptus | 12.5 | 3.1 | 0.0-0.0 | 0.4 | 3.5-3.5 |
| Switch grass | 15.4 | 4.7 | 0.0-0.0 | 0.2 | 4.9-4.9 |
| Triticale whole crop | 6.3 | 8.2 | 0.0-0.0 | 0.1 | 8.3-8.3 |

Cost for different crops

South
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Eucalyptus | 17.5 | 2.7 | 0.0-0-0 | 0.4 | 3.1-3.1 |
| Switch grass | 21 | 4.4 | 0.0-0.0 | 0.2 | 4.6-4.6 |
| Triticale whole crop | 10.5 | 6.4 | 0.0-0.0 | 0.1 | 6.5-6.5 |

Cost for different crops, large scale 2020
East
Average soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 12.6 | 2.8 | 0.0-0.2 | 0.4 | 3.2-3.4 |
| Poplar | 11.2 | 3.1 | 0.0-0.2 | 0.4 | 3.5-3.7 |
| Reed canary grass | 10.5 | 5.2 | 0.0-0.2 | 0.2 | 5.4-5.6 |
| Miscanthus | 17.6 | 5.7 | 0.0-0.2 | 0.3 | 6.0-6.2 |
| Hemp | 12.5 | 7.2 | 0.0-0.2 | 0.2 | 7.4-7.6 |
| Triticale whole crop | 9.5 | 6.7 | 0.0-0.2 | 0.1 | 6.8-7.0 |
| Straw | | 5.8 | 0 | 0.1 | 5.9 |

Cost for different crops
East
Poor soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 9.8 | 3.2 | 0.0-0.0 | 0.4 | 3.6-3.6 |
| Poplar | 8.8 | 3.6 | 0.0-0.0 | 0.4 | 4.0-4.0 |
| Reed canary grass | 10.5 | 5.2 | 0.0-0.0 | 0.2 | 5.4-5.4 |
| Miscanthus | 14.4 | 5.9 | 0.0-0.0 | 0.3 | 6.2-6.2 |
| Hemp | 10 | 7.9 | 0.0-0.0 | 0.2 | 8.1-8.1 |
| Triticale whole crop | 7.4 | 7.6 | 0.0-0.0 | 0.1 | 7.7-7.7 |

Cost for different crops

East
Good soils

| Crop | Yield Tdm | Growing cost EUR/GJ | Costs for land EUR/GJ | Cost for risk and new crop | Sum |
|---|---|---|---|---|---|
| Willow | 17.5 | 2.5 | 0.0-0.2 | 0.4 | 2.9-3.1 |
| Poplar | 15.6 | 2.7 | 0.0-0.3 | 0.4 | 3.1-3.4 |
| Reed canary grass | 14 | 4.8 | 0.0-0.3 | 0.2 | 5.0-5.3 |
| Miscanthus | 27.2 | 5.4 | 0.0-0.2 | 0.3 | 5.9-6.1 |
| Hemp | 16.2 | 6.7 | 0.0-0.2 | 0.2 | 6.9-7.1 |
| Triticale whole crop | 12.6 | 5.9 | 0.0-0.3 | 0.1 | 6.0-6.3 |

# Appendix 3: Results from cost calculations for different yields and cost level

## Appendix 3.1: Cereals as opportunity value for land

Calculations for cereals are done for conditions 2005.

Table A.3.1: Gross margin per hectare for spring barley with different cost level and yield level.

Cost level % — Yield level tons (14% water content) per hectare

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| 60 | -193 | -131 | -69 | -7 | 55 | 117 | 179 | 241 | 304 |
| 70 | -255 | -197 | -139 | -82 | -24 | 34 | 92 | 150 | 208 |
| 80 | -317 | -263 | -209 | -156 | -102 | -49 | 5 | 58 | 112 |
| 90 | -378 | -329 | -280 | -230 | -181 | -132 | -83 | -33 | 16 |
| 100 | -440 | -395 | -350 | -305 | -260 | -215 | -170 | -125 | -80 |
| 110 | -501 | -461 | -420 | -379 | -339 | -298 | -257 | -217 | -178 |
| 120 | -563 | -526 | -490 | -454 | -417 | -381 | -345 | -308 | -272 |
| 130 | -624 | -592 | -560 | -528 | -496 | -464 | -432 | -400 | -368 |

Table A.3.2: Gross margin per hectare for winter wheat with different cost level and yield level.

Cost level % — Yield level tons (14% water content) per hectare

| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | -92 | -33 | 25 | 84 | 143 | 202 | 261 | 320 | 378 | 437 |
| 70 | -157 | -105 | -53 | -1 | 52 | 104 | 156 | 208 | 260 | 312 |
| 80 | -222 | -176 | -131 | -85 | -40 | 5 | 51 | 96 | 142 | 187 |
| 90 | -287 | -248 | -209 | -170 | -132 | -93 | -54 | -15 | 24 | 62 |
| 100 | -352 | -319 | -287 | -255 | -223 | -191 | -159 | -127 | -95 | -62 |
| 110 | -416 | -391 | -365 | -340 | -315 | -289 | -264 | -238 | -213 | -187 |
| 120 | -481 | -462 | -444 | -425 | -406 | -387 | -369 | -350 | -331 | -312 |
| 130 | -546 | -534 | -522 | -510 | -498 | -486 | -473 | -461 | -449 | -437 |

Table A.3.3: Gross margin per hectare for winter wheat with different cost level and yield level. Cost reduction for machineries, workforce and OH with 50 percent. A short run calculation.

Cost level % — Yield level tons (14% water content) per hectare

| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 54 | 115 | 176 | 237 | 298 | 360 | 421 | 482 | 543 | 605 |
| 70 | 13 | 68 | 123 | 178 | 233 | 288 | 343 | 398 | 453 | 507 |
| 80 | -27 | 21 | 70 | 119 | 167 | 216 | 264 | 313 | 362 | 410 |
| 90 | -68 | -26 | 17 | 59 | 102 | 144 | 186 | 229 | 271 | 313 |
| 100 | -108 | -72 | -36 | 0 | 36 | 72 | 108 | 144 | 180 | 216 |
| 110 | -149 | -119 | -89 | -60 | -30 | 0 | 30 | 60 | 90 | 119 |
| 120 | -190 | -166 | -142 | -119 | -95 | -72 | -48 | -25 | -1 | 22 |
| 130 | -230 | -213 | -196 | -178 | -161 | -144 | -127 | -109 | -92 | -75 |

Table A.3.4: Gross margin per hectare for winter wheat with different cost level and yield level. Reduced soil cultivation.

Cost level % — Yield level tons (14% water content) per hectare

| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | -32 | 27 | 86 | 145 | 204 | 263 | 321 | 380 | 439 | 498 |
| 70 | -86 | -34 | 18 | 70 | 122 | 174 | 227 | 279 | 331 | 383 |
| 80 | -141 | -96 | -50 | -5 | 41 | 86 | 132 | 177 | 223 | 268 |
| 90 | -196 | -157 | -118 | -79 | -41 | -2 | 37 | 75 | 115 | 153 |
| 100 | -250 | -218 | -186 | -154 | -122 | -90 | -58 | -26 | 7 | 38 |
| 110 | -305 | -278 | -254 | -229 | -203 | -178 | -152 | -127 | -102 | -76 |
| 120 | -360 | -341 | -322 | -304 | -285 | -266 | -247 | -228 | -210 | -191 |
| 130 | -415 | -403 | -390 | -378 | -366 | -354 | -342 | -330 | -318 | -306 |

Table A.3.5: Gross margin per hectare for winter wheat with different cost level and yield level. Reduced soil cultivation. Cost reduction for machineries, workforce and OH with 50 percent. A short run calculation.

Cost level % — Yield level tons (14% water content) per hectare

| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 84 | 145 | 206 | 268 | 329 | 390 | 451 | 512 | 574 | 635 |
| 70 | 48 | 103 | 158 | 213 | 268 | 323 | 378 | 433 | 488 | 543 |
| 80 | 13 | 62 | 110 | 159 | 208 | 256 | 304 | 354 | 402 | 451 |
| 90 | -22 | 20 | 62 | 105 | 147 | 189 | 232 | 274 | 317 | 359 |
| 100 | -58 | -22 | 14 | 50 | 86 | 123 | 159 | 195 | 231 | 267 |
| 110 | -93 | -64 | -34 | -4 | 26 | 56 | 85 | 115 | 145 | 175 |
| 120 | -129 | -105 | -82 | -58 | -35 | -11 | 12 | 36 | 59 | 83 |
| 130 | -164 | -147 | -130 | -113 | -95 | -78 | -61 | -44 | -26 | -9 |

Table A.3.6: Gross margin per hectare for spring barley with different cost level and yield level. Cost reduction for machineries, workforce and OH with 50 percent. A short run calculation.

Cost level % — Yield level tons (14% water content) per hectare

| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | -208 | -160 | -113 | -65 | -17 | 30 | 78 | 125 | 173 | 220 |
| 70 | -254 | -208 | -161 | -114 | -67 | -20 | 27 | 74 | 121 | 168 |
| 80 | -301 | -255 | -209 | -162 | -116 | -70 | -24 | 23 | 69 | 115 |
| 90 | -348 | -302 | -257 | -211 | -166 | -120 | -74 | -29 | 17 | 62 |
| 100 | -395 | -350 | -305 | -260 | -215 | -170 | -125 | -80 | -35 | 10 |
| 110 | -442 | -397 | -353 | -309 | -264 | -220 | -176 | -131 | -87 | -43 |
| 120 | -488 | -445 | -401 | -357 | -314 | -270 | -226 | -183 | -139 | -95 |
| 130 | -535 | -492 | -449 | -406 | -363 | -320 | -277 | -234 | -191 | -148 |

Table A.3.7: Gross margin per hectare for spring barley with different cost level and yield level.
Costs are reduced with 100 EUR per hectare.

Cost level % — Yield level tons (14 % water content) per hectare

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| 60 | -93 | -31 | 31 | 93 | 155 | 217 | 279 | 341 | 404 |
| 70 | -155 | -97 | -39 | 18 | 76 | 134 | 192 | 250 | 308 |
| 80 | -217 | -163 | -109 | -56 | -2 | 51 | 105 | 158 | 212 |
| 90 | -278 | -229 | -180 | -130 | -81 | -32 | 17 | 67 | 116 |
| 100 | -340 | -295 | -250 | -205 | -160 | -115 | -70 | -25 | 20 |
| 110 | -401 | -361 | -320 | -279 | -239 | -198 | -157 | -117 | -78 |
| 120 | -463 | -426 | -390 | -354 | -317 | -281 | -245 | -208 | -172 |
| 130 | -524 | -492 | -460 | -428 | -396 | -364 | -332 | -300 | -268 |

Table A.3.8: Gross margin per hectare for winter wheat with different cost level and yield level. Costs are reduced with 100 EUR per hectare.

Cost level % — Yield level tons (14% water content) per hectare

| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 8 | 67 | 125 | 184 | 243 | 302 | 361 | 420 | 478 | 537 |
| 70 | -57 | -5 | 47 | 99 | 152 | 204 | 256 | 308 | 360 | 412 |
| 80 | -122 | -76 | -31 | 15 | 60 | 105 | 151 | 196 | 242 | 287 |
| 90 | -187 | -148 | -109 | -70 | -32 | 7 | 46 | 85 | 124 | 162 |
| 100 | -252 | -219 | -187 | -155 | -123 | -91 | -59 | -27 | 5 | 38 |
| 110 | -316 | -291 | -265 | -240 | -215 | -189 | -164 | -138 | -113 | -87 |
| 120 | -381 | -362 | -344 | -325 | -306 | -287 | -269 | -250 | -231 | -212 |
| 130 | -446 | -434 | -422 | -410 | -398 | -386 | -373 | -361 | -349 | -337 |

**Appendix 3.2: Cost for bioenergy 2005, small scale**

Table A.3.9: Costs per GJ with 100 EUR risk compensation or land compensation with different yield levels for willow.

Cost level % — Yield level tDM per hectare

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 5,0 | 4,3 | 3,9 | 3,5 | 3,3 | 3,0 | 2,9 | 2,7 | 2,6 | 2,5 |
| 70 | 5,6 | 4,9 | 4,4 | 4,0 | 3,7 | 3,4 | 3,2 | 3,1 | 2,9 | 2,8 |
| 80 | 6,2 | 5,4 | 4,9 | 4,4 | 4,1 | 3,8 | 3,6 | 3,4 | 3,3 | 3,2 |
| 90 | 6,8 | 6,0 | 5,4 | 4,9 | 4,5 | 4,3 | 4,0 | 3,8 | 3,7 | 3,5 |
| 100 | 7,5 | 6,6 | 5,9 | 5,4 | 5,0 | 4,7 | 4,4 | 4,2 | 4,0 | 3,9 |
| 110 | 8,1 | 7,1 | 6,4 | 5,8 | 5,4 | 5,1 | 4,8 | 4,6 | 4,4 | 4,2 |
| 120 | 8,7 | 7,7 | 6,9 | 6,3 | 5,9 | 5,5 | 5,2 | 5,0 | 4,8 | 4,6 |
| 130 | 9,4 | 8,2 | 7,4 | 6,8 | 6,3 | 5,9 | 5,6 | 5,4 | 5,1 | 4,9 |

Table A.3.10: Costs per GJ for willow with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 3.4 | 3.0 | 2.7 | 2.5 | 2.4 | 2.3 | 2.1 | 2.1 | 2.0 | 1.9 |
| 70 | 4.0 | 3.6 | 3.2 | 3.0 | 2.8 | 2.6 | 2.5 | 2.4 | 2.3 | 2.3 |
| 80 | 4.6 | 4.1 | 3.7 | 3.4 | 3.2 | 3.0 | 2.9 | 2.8 | 2.7 | 2.6 |
| 90 | 5.2 | 4.6 | 4.2 | 3.9 | 3.6 | 3.4 | 3.3 | 3.1 | 3.0 | 2.9 |
| 100 | 5.8 | 5.2 | 4.7 | 4.3 | 4.1 | 3.9 | 3.7 | 3.5 | 3.4 | 3.3 |
| 110 | 6.5 | 5.7 | 5.2 | 4.8 | 4.5 | 4.3 | 4.1 | 3.9 | 3.7 | 3.6 |
| 120 | 7.1 | 6.3 | 5.7 | 5.3 | 4.9 | 4.7 | 4.5 | 4.3 | 4.1 | 4.0 |
| 130 | 7.7 | 6.9 | 6.2 | 5.8 | 5.4 | 5.1 | 4.9 | 4.7 | 4.5 | 4.4 |

Table A.3.11: Increased costs per GJ with 100 EUR risk compensation or land compensation with different yield levels for willow.

Cost level % — Yield level tDM per hectare

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 1,6 | 1,3 | 1,2 | 1 | 0,9 | 0,8 | 0,7 | 0,7 | 0,6 | 0,6 |
| 70 | 1,6 | 1,3 | 1,2 | 1 | 0,9 | 0,8 | 0,7 | 0,7 | 0,6 | 0,6 |
| 80 | 1,6 | 1,3 | 1,2 | 1 | 0,9 | 0,8 | 0,7 | 0,7 | 0,6 | 0,6 |
| 90 | 1,6 | 1,3 | 1,2 | 1 | 0,9 | 0,8 | 0,7 | 0,7 | 0,6 | 0,6 |
| 100 | 1,6 | 1,3 | 1,2 | 1 | 0,9 | 0,8 | 0,7 | 0,7 | 0,6 | 0,6 |
| 110 | 1,6 | 1,3 | 1,2 | 1 | 0,9 | 0,8 | 0,7 | 0,7 | 0,6 | 0,6 |
| 120 | 1,6 | 1,3 | 1,2 | 1 | 0,9 | 0,8 | 0,7 | 0,7 | 0,6 | 0,6 |
| 130 | 1,6 | 1,3 | 1,2 | 1 | 0,9 | 0,8 | 0,7 | 0,7 | 0,6 | 0,6 |

Table A.3.12: Costs per GJ for poplar with different cost level and yield level.

| Cost level % | Yield level tDM per hectare | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 60 | 3,7 | 3,3 | 3,0 | 2,7 | 2,6 | 2,4 | 2,3 | 2,2 | 2,1 | 2,0 |
| 70 | 4,4 | 3,9 | 3,5 | 3,2 | 3,0 | 2,8 | 2,7 | 2,6 | 2,5 | 2,4 |
| 80 | 5,0 | 4,4 | 4,0 | 3,7 | 3,4 | 3,2 | 3,1 | 3,0 | 2,8 | 2,7 |
| 90 | 5,7 | 5,0 | 4,5 | 4,2 | 3,9 | 3,7 | 3,5 | 3,3 | 3,2 | 3,1 |
| 100 | 6,4 | 5,5 | 5,1 | 4,7 | 4,4 | 4,1 | 3,9 | 3,7 | 3,6 | 3,5 |
| 110 | 7,0 | 6,2 | 5,6 | 5,2 | 4,8 | 4,6 | 4,3 | 4,1 | 4,0 | 3,8 |
| 120 | 7,7 | 6,9 | 6,2 | 5,7 | 5,3 | 5,0 | 4,7 | 4,5 | 4,4 | 4,2 |
| 130 | 8,4 | 7,4 | 6,7 | 6,2 | 5,8 | 5,4 | 5,2 | 5,0 | 4,8 | 4,6 |

Table A.3.13: Costs per GJ for eucalyptus with different cost level and yield level.

| Cost level % | Yield level tDM per hectare | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 60 | 3.8 | 3.4 | 3.1 | 2.8 | 2.6 | 2.5 | 2.4 | 2.3 | 2.2 | 2.1 |
| 70 | 4.5 | 4.0 | 3.6 | 3.3 | 3.1 | 2.9 | 2.8 | 2.7 | 2.6 | 2.5 |
| 80 | 5.2 | 4.6 | 4.1 | 3.8 | 3.6 | 3.4 | 3.2 | 3.1 | 3.0 | 2.9 |
| 90 | 5.8 | 5.2 | 4.7 | 4.3 | 4.0 | 3.8 | 3.6 | 3.5 | 3.3 | 3.2 |
| 100 | 6.5 | 5.8 | 5.2 | 4.8 | 4.5 | 4.3 | 4.1 | 3.9 | 3.7 | 3.6 |
| 110 | 7.2 | 6.4 | 5.8 | 5.3 | 5.0 | 4.7 | 4.5 | 4.3 | 4.1 | 4.0 |
| 120 | 7.9 | 7.0 | 6.4 | 5.9 | 5.5 | 5.2 | 4.9 | 4.7 | 4.5 | 4.4 |
| 130 | 8.6 | 7.6 | 6.9 | 6.4 | 6.0 | 5.6 | 5.4 | 5.1 | 5.0 | 4.8 |

Table A.3.14: Costs per GJ for red canary grass and switch grass with different cost level and yield level.

| Cost level % | Yield level tDM per hectare | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 60 | 4.1 | 3.8 | 3.6 | 3.5 | 3.3 | 3.2 | 3.1 | 3.1 | 3.0 | 3.0 |
| 70 | 4.9 | 4.5 | 4.2 | 4.1 | 3.9 | 3.8 | 3.7 | 3.6 | 3.5 | 3.5 |
| 80 | 5.6 | 5.2 | 4.9 | 4.7 | 4.5 | 4.4 | 4.3 | 4.2 | 4.1 | 4.0 |
| 90 | 6.3 | 5.9 | 5.5 | 5.3 | 5.1 | 4.9 | 4.8 | 4.7 | 4.6 | 4.5 |
| 100 | 7.1 | 6.6 | 6.2 | 5.9 | 5.7 | 5.5 | 5.4 | 5.3 | 5.2 | 5.1 |
| 110 | 7.8 | 7.3 | 6.8 | 6.5 | 6.3 | 6.1 | 6.0 | 5.8 | 5.7 | 5.6 |
| 120 | 8.6 | 8.0 | 7.2 | 7.2 | 6.9 | 6.7 | 6.5 | 6.4 | 6.3 | 6.2 |
| 130 | 9.4 | 8.7 | 8.2 | 7.8 | 7.5 | 7.3 | 7.1 | 7.0 | 6.8 | 6.7 |

Table A.3.15: Costs per GJ for hemp with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 6.6 | 6.0 | 5.6 | 5.3 | 5.0 | 4.8 | 4.6 | 4.5 | 4.4 | 4.3 |
| 70 | 7.8 | 7.1 | 6.5 | 6.2 | 5.9 | 5.6 | 5.4 | 5.3 | 5.1 | 5.0 |
| 80 | 8.9 | 8.1 | 7.5 | 7.1 | 6.7 | 6.5 | 6.3 | 6.1 | 5.9 | 5.8 |
| 90 | 10.1 | 9.2 | 8.5 | 8.0 | 7.6 | 7.3 | 7.1 | 6.9 | 6.7 | 6.5 |
| 100 | 11.3 | 10.3 | 9.5 | 9.0 | 8.5 | 8.2 | 7.9 | 7.7 | 7.5 | 7.3 |
| 110 | 12.5 | 11.4 | 10.6 | 9.9 | 9.5 | 9.1 | 8.8 | 8.5 | 8.3 | 8.1 |
| 120 | 13.8 | 12.5 | 11.6 | 10.9 | 10.4 | 10.0 | 9.6 | 9.3 | 9.1 | 8.9 |
| 130 | 15.0 | 13.6 | 12.7 | 11.9 | 11.3 | 10.9 | 10.5 | 10.2 | 9.9 | 9.7 |

Table A.3.16: Costs per GJ for triticale as whole crop with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 5.7 | 5.1 | 4.7 | 4.4 | 4.2 | 4.0 | 3.8 | 3.7 | 3.6 | 3.5 |
| 70 | 6.7 | 6.0 | 5.5 | 5.2 | 4.9 | 4.7 | 4.5 | 4.3 | 4.2 | 4.1 |
| 80 | 7.7 | 6.9 | 6.4 | 6.0 | 5.6 | 5.4 | 5.2 | 5.0 | 4.8 | 4.7 |
| 90 | 8.7 | 7.8 | 7.2 | 6.7 | 6.4 | 6.1 | 5.8 | 5.6 | 5.5 | 5.3 |
| 100 | 9.8 | 8.8 | 8.1 | 7.5 | 7.1 | 6.8 | 6.5 | 6.3 | 6.1 | 5.9 |
| 110 | 10.8 | 9.7 | 8.9 | 8.3 | 7.9 | 7.5 | 7.2 | 7.0 | 6.8 | 6.6 |
| 120 | 11.9 | 10.7 | 9.8 | 9.2 | 8.7 | 8.3 | 7.9 | 7.7 | 7.4 | 7.2 |
| 130 | 13.0 | 11.6 | 10.7 | 10.0 | 9.5 | 9.0 | 8.7 | 8.4 | 8.1 | 7.9 |

Table A.3.17: Costs per GJ for sorghum as whole crop with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 5.7 | 5.1 | 4.7 | 4.4 | 4.2 | 4.0 | 3.8 | 3.7 | 3.6 | 3.5 |
| 70 | 6.7 | 6.0 | 5.5 | 5.2 | 4.9 | 4.7 | 4.5 | 4.3 | 4.2 | 4.1 |
| 80 | 7.7 | 6.9 | 6.3 | 5.9 | 5.6 | 5.4 | 5.1 | 5.0 | 4.8 | 4.7 |
| 90 | 8.7 | 7.8 | 7.2 | 6.7 | 6.4 | 6.1 | 5.8 | 5.6 | 5.5 | 5.3 |
| 100 | 9.7 | 8.7 | 8.0 | 7.5 | 7.1 | 6.8 | 6.5 | 6.3 | 6.1 | 5.9 |
| 110 | 10.7 | 9.7 | 8.9 | 8.3 | 7.9 | 7.5 | 7.2 | 7.0 | 6.8 | 6.6 |
| 120 | 11.8 | 10.6 | 9.8 | 9.1 | 8.6 | 8.2 | 7.9 | 7.7 | 7.4 | 7.2 |
| 130 | 12.9 | 11.6 | 10.7 | 10.0 | 9.4 | 9.0 | 8.6 | 8.4 | 8.1 | 7.9 |

Table A.3.18: Costs per GJ for Miscanthus with different cost level and yield level.

| Cost level % | Yield level tDM per hectare | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 60 | 5.2 | 4.8 | 4.6 | 4.4 | 4.2 | 4.1 | 4.0 | 3.9 | 3.9 | 3.8 |
| 70 | 6.1 | 5.7 | 5.4 | 5.2 | 5.0 | 4.8 | 4.7 | 4.6 | 4.6 | 4.5 |
| 80 | 7.0 | 6.5 | 6.2 | 5.9 | 5.7 | 5.6 | 5.4 | 5.3 | 5.2 | 5.2 |
| 90 | 7.9 | 7.4 | 7.0 | 6.7 | 6.5 | 6.3 | 6.2 | 6.0 | 5.9 | 5.8 |
| 100 | 8.9 | 8.3 | 7.8 | 7.5 | 7.3 | 7.1 | 6.9 | 6.8 | 6.6 | 6.5 |
| 110 | 9.8 | 9.2 | 8.7 | 8.3 | 8.0 | 7.8 | 7.6 | 7.5 | 7.4 | 7.2 |
| 120 | 10.8 | 10.1 | 9.5 | 9.1 | 8.8 | 8.6 | 8.4 | 8.2 | 8.1 | 8.0 |
| 130 | 11.8 | 11.0 | 10.4 | 10.0 | 9.6 | 9.4 | 9.1 | 9.0 | 8.8 | 8.7 |

## Appendix 3.3: Cost for bioenergy 2005, large scale

Table A.3.20: Costs per GJ for willow with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 4.2 | 3.7 | 3.4 | 3.1 | 2.9 | 2.8 | 2.6 | 2.5 | 2.4 | 2.4 |
| 90 | 4.7 | 4.2 | 3.8 | 3.5 | 3.3 | 3.1 | 3.0 | 2.9 | 2.8 | 2.7 |
| 100 | 5.3 | 4.7 | 4.2 | 3.9 | 3.7 | 3.5 | 3.3 | 3.2 | 3.1 | 3.0 |
| 110 | 5.8 | 5.2 | 4.7 | 4.3 | 4.1 | 3.9 | 3.7 | 3.5 | 3.4 | 3.3 |
| 120 | 6.4 | 5.7 | 5.1 | 4.8 | 4.5 | 4.2 | 4.0 | 3.9 | 3.7 | 3.6 |

Table A.3.21: Costs per GJ for poplar with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 4.5 | 4.0 | 3.6 | 3.3 | 3.1 | 2.9 | 2.8 | 2.7 | 2.6 | 2.5 |
| 90 | 5.1 | 4.5 | 4.1 | 3.7 | 3.5 | 3.3 | 3.1 | 3.0 | 2.9 | 2.8 |
| 100 | 5.7 | 5.0 | 4.5 | 4.2 | 3.9 | 3.7 | 3.5 | 3.4 | 3.2 | 3.1 |
| 110 | 6.3 | 5.6 | 5.0 | 4.6 | 4.3 | 4.1 | 3.9 | 3.7 | 3.6 | 3.4 |
| 120 | 6.9 | 6.1 | 5.5 | 5.1 | 4.7 | 4.5 | 4.3 | 4.1 | 3.9 | 3.8 |

Table A.3.22: Costs per GJ for eucalyptus with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 4.6 | 4.1 | 3.7 | 3.4 | 3.2 | 3.0 | 2.9 | 2.8 | 2.7 | 2.6 |
| 90 | 5.2 | 4.6 | 4.2 | 3.9 | 3.6 | 3.4 | 3.3 | 3.1 | 3.0 | 2.9 |
| 100 | 5.9 | 5.2 | 4.7 | 4.3 | 4.1 | 3.8 | 3.7 | 3.5 | 3.4 | 3.3 |
| 110 | 6.5 | 5.7 | 5.2 | 4.8 | 4.5 | 4.2 | 4.0 | 3.9 | 3.7 | 3.6 |
| 120 | 7.1 | 6.3 | 5.7 | 5.3 | 4.9 | 4.7 | 4.4 | 4.2 | 4.1 | 4.0 |

Table A.3.23: Costs per GJ for red canary grass and switch grass with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 5.4 | 5.0 | 4.7 | 4.5 | 4.3 | 4.2 | 4.0 | 4.0 | 3.9 | 3.8 |
| 90 | 6.1 | 5.6 | 5.3 | 5.0 | 4.9 | 4.7 | 4.6 | 4.5 | 4.4 | 4.3 |
| 100 | 6.8 | 6.3 | 5.9 | 5.6 | 5.4 | 5.3 | 5.1 | 5.0 | 4.9 | 4.8 |
| 110 | 7.5 | 6.9 | 6.5 | 6.2 | 6.0 | 5.8 | 5.7 | 5.5 | 5.4 | 5.3 |
| 120 | 8.2 | 7.6 | 7.2 | 6.8 | 6.6 | 6.4 | 6.2 | 6.1 | 5.9 | 5.8 |

Table A.3.24: Costs per GJ for hemp with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 8.7 | 7.9 | 7.3 | 6.9 | 6.5 | 6.3 | 6.0 | 5.8 | 5.7 | 5.6 |
| 90 | 9.8 | 8.9 | 8.3 | 7.8 | 7.4 | 7.1 | 6.8 | 6.6 | 6.4 | 6.3 |
| 100 | 11.0 | 10.0 | 9.2 | 8.7 | 8.3 | 7.9 | 7.6 | 7.4 | 7.2 | 7.0 |
| 110 | 12.2 | 11.0 | 10.2 | 9.6 | 9.1 | 8.7 | 8.4 | 8.2 | 8.0 | 7.8 |
| 120 | 13.3 | 12.1 | 11.2 | 10.5 | 10.0 | 9.6 | 9.3 | 9.0 | 8.7 | 8.5 |

Table A.3.25: Costs per GJ for triticale as whole crop with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 7.5 | 6.8 | 6.2 | 5.8 | 5.5 | 5.2 | 5.0 | 4.8 | 4.7 | 4.5 |
| 90 | 8.5 | 7.6 | 7.0 | 6.5 | 6.2 | 5.9 | 5.6 | 5.4 | 5.3 | 5.1 |
| 100 | 9.5 | 8.5 | 7.8 | 7.3 | 6.9 | 6.6 | 6.3 | 6.1 | 5.9 | 5.7 |
| 110 | 10.5 | 9.4 | 8.7 | 8.1 | 7.6 | 7.3 | 7.0 | 6.7 | 6.5 | 6.3 |
| 120 | 11.6 | 10.4 | 9.5 | 8.9 | 8.4 | 8.0 | 7.7 | 7.4 | 7.2 | 7.0 |

Table A.3.26: Costs per GJ for sorghum as whole crop with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 7.5 | 6.7 | 6.2 | 5.8 | 5.4 | 5.2 | 5.0 | 4.8 | 4.7 | 4.5 |
| 90 | 8.5 | 7.6 | 7.0 | 6.5 | 6.2 | 5.9 | 5.6 | 5.4 | 5.3 | 5.1 |
| 100 | 9.4 | 8.5 | 7.8 | 7.3 | 6.9 | 6.6 | 6.3 | 6.1 | 5.9 | 5.7 |
| 110 | 10.5 | 9.4 | 8.6 | 8.1 | 7.6 | 7.3 | 7.0 | 6.7 | 6.5 | 6.3 |
| 120 | 11.5 | 10.3 | 9.5 | 8.8 | 8.4 | 8.0 | 7.6 | 7.4 | 7.2 | 7.0 |

Table A.3.27: Costs per GJ for Miscanthus with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 6.4 | 6.0 | 5.7 | 5.5 | 5.3 | 5.1 | 5.0 | 4.9 | 4.9 | 4.8 |
| 90 | 7.3 | 6.8 | 6.4 | 6.2 | 6.0 | 5.8 | 5.7 | 5.6 | 5.5 | 5.4 |
| 100 | 8.1 | 7.6 | 7.2 | 6.9 | 6.7 | 6.5 | 6.4 | 6.2 | 6.1 | 6.0 |
| 110 | 9.0 | 8.4 | 8.0 | 7.6 | 7.4 | 7.2 | 7.0 | 6.9 | 6.8 | 6.7 |
| 120 | 9.9 | 9.2 | 8.7 | 8.4 | 8.1 | 7.9 | 7.7 | 7.6 | 7.4 | 7.3 |

## Appendix 3.4: Cost for bioenergy, future situation, large scale

Table A.3.28: Costs per GJ for willow with different cost level and yield level.

| Cost level % | Yield level tDM per hectare | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 80 | 3.3 | 3.0 | 2.8 | 2.6 | 2.5 | 2.4 | 2.3 | 2.2 | 2.1 | 2.1 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 |
| 90 | 3.8 | 3.4 | 3.2 | 3.0 | 2.8 | 2.7 | 2.6 | 2.5 | 2.4 | 2.4 | 2.3 | 2.2 | 2.2 | 2.2 | 2.1 |
| 100 | 4.2 | 3.8 | 3.5 | 3.3 | 3.2 | 3.0 | 2.9 | 2.8 | 2.7 | 2.6 | 2.6 | 2.5 | 2.5 | 2.4 | 2.4 |
| 110 | 4.6 | 4.2 | 3.9 | 3.7 | 3.5 | 3.3 | 3.2 | 3.1 | 3.0 | 2.9 | 2.8 | 2.8 | 2.7 | 2.7 | 2.6 |
| 120 | 5.1 | 4.6 | 4.3 | 4.0 | 3.8 | 3.6 | 3.5 | 3.4 | 3.3 | 3.2 | 3.1 | 3.0 | 3.0 | 2.9 | 2.9 |

Table A.3.29: Costs per GJ for poplar with different cost level and yield level.

| Cost level % | Yield level tDM per hectare | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 80 | 3.6 | 3.2 | 3.0 | 2.8 | 2.6 | 2.5 | 2.4 | 2.3 | 2.2 | 2.2 | 2.1 | 2.1 | 2.0 | 2.0 | 1.9 |
| 90 | 4.0 | 3.7 | 3.4 | 3.2 | 3.0 | 2.8 | 2.7 | 2.6 | 2.5 | 2.5 | 2.4 | 2.3 | 2.3 | 2.2 | 2.2 |
| 100 | 4.5 | 4.1 | 3.8 | 3.5 | 3.3 | 3.2 | 3.0 | 2.9 | 2.8 | 2.7 | 2.7 | 2.6 | 2.5 | 2.5 | 2.4 |
| 110 | 5.0 | 4.5 | 4.2 | 3.9 | 3.7 | 3.5 | 3.4 | 3.2 | 3.1 | 3.0 | 2.9 | 2.9 | 2.8 | 2.7 | 2.7 |
| 120 | 5.5 | 5.0 | 4.6 | 4.3 | 4.0 | 3.8 | 3.7 | 3.5 | 3.4 | 3.3 | 3.2 | 3.1 | 3.1 | 3.0 | 3.0 |

Table A.3.30: Costs per GJ for eucalyptus with different cost level and yield level.

| Cost level % | Yield level tDM per hectare | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 80 | 3.7 | 3.4 | 3.1 | 2.9 | 2.8 | 2.6 | 2.5 | 2.4 | 2.3 | 2.3 | 2.2 | 2.2 | 2.1 | 2.1 | 2.0 |
| 90 | 4.2 | 3.8 | 3.5 | 3.3 | 3.1 | 3.0 | 2.8 | 2.7 | 2.7 | 2.6 | 2.5 | 2.4 | 2.4 | 2.3 | 2.3 |
| 100 | 4.7 | 4.3 | 3.9 | 3.7 | 3.5 | 3.3 | 3.2 | 3.1 | 3.0 | 2.9 | 2.8 | 2.7 | 2.7 | 2.6 | 2.6 |
| 110 | 5.2 | 4.7 | 4.3 | 4.1 | 3.8 | 3.7 | 3.5 | 3.4 | 3.3 | 3.2 | 3.1 | 3.0 | 3.0 | 2.9 | 2.8 |
| 120 | 5.7 | 5.1 | 4.8 | 4.5 | 4.2 | 4.0 | 3.8 | 3.7 | 3.6 | 3.5 | 3.4 | 3.3 | 3.2 | 3.2 | 3.1 |

Table A.3.31: Costs per GJ for red canary grass and switch grass with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 4.9 | 4.7 | 4.4 | 4.3 | 4.1 | 4.0 | 3.9 | 3.9 | 3.8 | 3.7 | 3.7 | 3.6 | 3.6 | 3.6 | 3.5 |
| 90 | 5.6 | 5.3 | 5.0 | 4.8 | 4.7 | 4.6 | 4.5 | 4.4 | 4.3 | 4.2 | 4.2 | 4.1 | 4.1 | 4.0 | 4.0 |
| 100 | 6.2 | 5.9 | 5.6 | 5.4 | 5.2 | 5.1 | 5.0 | 4.9 | 4.8 | 4.7 | 4.7 | 4.6 | 4.5 | 4.5 | 4.5 |
| 110 | 6.9 | 6.5 | 6.2 | 6.0 | 5.8 | 5.6 | 5.5 | 5.4 | 5.3 | 5.2 | 5.1 | 5.1 | 5.0 | 5.0 | 4.9 |
| 120 | 7.6 | 7.1 | 6.8 | 6.5 | 6.3 | 6.2 | 6.0 | 5.9 | 5.8 | 5.7 | 5.6 | 5.6 | 5.5 | 5.5 | 5.4 |

Table A.3.32: Costs per GJ for hemp with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 7.8 | 7.2 | 6.8 | 6.5 | 6.2 | 6.0 | 5.8 | 5.7 | 5.5 | 5.4 | 5.3 | 5.2 | 5.1 | 5.1 | 5.0 |
| 90 | 8.9 | 8.2 | 7.7 | 7.3 | 7.0 | 6.8 | 6.6 | 6.4 | 6.2 | 6.1 | 6.0 | 5.9 | 5.8 | 5.7 | 5.7 |
| 100 | 9.9 | 9.2 | 8.6 | 8.2 | 7.9 | 7.6 | 7.3 | 7.1 | 7.0 | 6.8 | 6.7 | 6.6 | 6.5 | 6.4 | 6.3 |
| 110 | 10.9 | 10.1 | 9.5 | 9.1 | 8.7 | 8.4 | 8.1 | 7.9 | 7.7 | 7.6 | 7.4 | 7.3 | 7.2 | 7.1 | 7.0 |
| 120 | 12.0 | 11.1 | 10.5 | 9.9 | 9.5 | 9.2 | 8.9 | 8.7 | 8.5 | 8.3 | 8.1 | 8.0 | 7.9 | 7.8 | 7.7 |

Table A.3.33: Costs per GJ for triticale as whole crop with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 6.7 | 6.2 | 5.8 | 5.4 | 5.2 | 5.0 | 4.8 | 4.6 | 4.5 | 4.4 | 4.3 | 4.2 | 4.1 | 4.1 | 4.0 |
| 90 | 7.6 | 7.0 | 6.5 | 6.1 | 5.9 | 5.6 | 5.4 | 5.3 | 5.1 | 5.0 | 4.9 | 4.8 | 4.7 | 4.6 | 4.5 |
| 100 | 8.5 | 7.8 | 7.3 | 6.9 | 6.5 | 6.3 | 6.0 | 5.9 | 5.7 | 5.6 | 5.4 | 5.3 | 5.2 | 5.2 | 5.1 |
| 110 | 9.4 | 8.6 | 8.0 | 7.6 | 7.2 | 6.9 | 6.7 | 6.5 | 6.3 | 6.1 | 6.0 | 5.9 | 5.8 | 5.7 | 5.6 |
| 120 | 10.3 | 9.4 | 8.8 | 8.3 | 7.9 | 7.6 | 7.3 | 7.1 | 6.9 | 6.7 | 6.6 | 6.5 | 6.3 | 6.2 | 6.1 |

Table A.3.34: Costs per GJ for sorghum as whole crop with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 80 | 6.7 | 6.1 | 5.7 | 5.4 | 5.2 | 5.0 | 4.8 | 4.6 | 4.5 | 4.4 | 4.3 | 4.2 | 4.2 | 4.1 | 4.0 |
| 90 | 7.6 | 6.9 | 6.5 | 6.1 | 5.8 | 5.6 | 5.4 | 5.2 | 5.1 | 5.0 | 4.9 | 4.8 | 4.7 | 4.6 | 4.6 |
| 100 | 8.4 | 7.7 | 7.2 | 6.8 | 6.5 | 6.3 | 6.0 | 5.9 | 5.7 | 5.6 | 5.4 | 5.3 | 5.2 | 5.2 | 5.1 |
| 110 | 9.3 | 8.6 | 8.0 | 7.6 | 7.2 | 6.9 | 6.7 | 6.5 | 6.3 | 6.1 | 6.0 | 5.9 | 5.8 | 5.7 | 5.6 |
| 120 | 10.2 | 9.4 | 8.8 | 8.3 | 7.9 | 7.6 | 7.3 | 7.1 | 6.9 | 6.7 | 6.6 | 6.5 | 6.4 | 6.3 | 6.2 |

Table A.3.35: Costs per GJ for Miscanthus with different cost level and yield level.

| Cost level % | Yield level tDM per hectare | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 80 | 5.8 | 5.5 | 5.3 | 5.1 | 5.0 | 4.9 | 4.8 | 4.7 | 4.7 | 4.6 | 4.6 | 4.5 | 4.5 | 4.4 | 4.4 |
| 90 | 6.5 | 6.2 | 6.0 | 5.8 | 5.6 | 5.5 | 5.4 | 5.3 | 5.3 | 5.2 | 5.2 | 5.1 | 5.1 | 5.0 | 5.0 |
| 100 | 7.3 | 6.9 | 6.7 | 6.5 | 6.3 | 6.2 | 6.1 | 6.0 | 5.9 | 5.8 | 5.8 | 5.7 | 5.7 | 5.6 | 5.6 |
| 110 | 8.0 | 7.7 | 7.4 | 7.1 | 7.0 | 6.8 | 6.7 | 6.6 | 6.5 | 6.4 | 6.4 | 6.3 | 6.3 | 6.2 | 6.2 |
| 120 | 8.8 | 8.4 | 8.1 | 7.8 | 7.6 | 7.5 | 7.3 | 7.2 | 7.1 | 7.1 | 7.0 | 6.9 | 6.9 | 6.8 | 6.8 |

**Appendix 3.5: Cost for bioenergy, future situation, large scale, irrigated crops**

The calculation is done for the future perspective.

Table A.3.36: Costs per GJ for irrigated eucalyptus (3 times) with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 12.0 | 10.6 | 9.5 | 8.7 | 8.0 | 7.5 | 7.0 | 6.6 | 6.3 | 6.0 | 5.8 | 5.5 | 5.3 | 5.2 | 5.0 |

Cost level % — Yield level tDM per hectare

| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 4.9 | 4.7 | 4.6 | 4.5 | 4.4 | 4.3 | 4.2 | 4.1 | 4.1 | 4.0 | 3.7 | 3.5 | 3.3 | 3.2 |

Table A.3.37: Costs per GJ for irrigated Miscanthus (5 times) with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 18.9 | 16.9 | 15.5 | 14.3 | 13.4 | 12.7 | 12.1 | 11.5 | 11.1 | 10.7 | 10.4 | 10.1 | 9.8 | 9.5 | 9.3 |

Cost level % — Yield level tDM per hectare

| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 9.1 | 9.0 | 8.8 | 8.7 | 8.5 | 8.4 | 8.3 | 8.2 | 8.1 | 8.0 | 7.6 | 7.3 | 7.1 | 6.9 |

Table A.3.38: Costs per GJ for irrigated sorghum (10 times) with different cost level and yield level.

Cost level % — Yield level tDM per hectare

| | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 25.6 | 22.5 | 20.2 | 18.4 | 16.9 | 16.7 | 14.7 | 13.9 | 13.2 | 12.6 | 12.0 | 11.5 | 11.1 | 10.7 | 10.4 |

Cost level % — Yield level tDM per hectare

| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 10.1 | 9.8 | 9.5 | 9.3 | 9.1 | 8.9 | 8.7 | 8.5 | 8.4 | 8.2 | 7.6 | 7.1 | 6.8 | 6.5 |

## Appendix 4: Organic energy crop production

For scenario 2 in the Renew project it is assumed that energy crops will be grown with a "minimum of fertilisers and pesticides," reflecting a more ecological approach to energy crop production and to agriculture in general. These assumptions introduce considerable uncertainty for the calculation of production costs since there is very little practical experience of organic or ecological energy crop production. Organic food production on a large scale could also impact the cost of land. The calculations require some "heroic" assumptions that are described in more detail below. Consequently the results should be interpreted and used with great care.

The opportunity value of land and area of available land are dependent on conditions for food production. Organic food production will change the opportunity value of land but how it will change is determined by agricultural and trade policies. Since it is beyond the scope of this report to attempt to quantify these effects, we have assumed the same opportunity value (land cost) as in scenario 1 (i.e., future large-scale production with cost-levelling). Hence, land costs are the same per hectare, but they increase by 50% per GJ due to the assumed 33% lower yields assumed, see below

The value of risk will also change with organically produced energy crops. For example, it is possible that the risk of insect and fungus attacks will increase. However, the extent to which the risk will change has not been studied here. In the calculations here we have assumed the same value for risk per hectare that was used in scenario 1 (i.e., future large-scale production with cost-levelling). These values are expert "guesstimates" based on the authors´ long experience in agricultural economics.

The calculations for organically produced energy crops are done with the future large-scale perspective assuming cost-levelling across the EU. The calculations are done only for three energy crops for all regions: willow, miscantus and triticale. In some regions, there are crops with lower costs in scenario 1 than these three.

### 4.1 Willow

Some guidance concerning yield levels for low/no fertilization can be obtained based on field trials, see Table A4.1 and A4.2.

Table A4.1: Annual yields (tdm per hectare) of 3 years old shoots in trials with fertilization in willow at five different locations in central and southern Sweden during 1990-1992.

| Test sites | 0 kg N per hectare | 165 kg N per hectare | 330 kg N per hectare | 480 kg N per hectare |
|---|---|---|---|---|
| Bennebo | 3,9 | 5,7 | 7,4 | 4,4 |
| Borgeby | 8,8 | 10,6 | 11,1 | 11,7 |
| Grimstad | 6,7 | 8,5 | 9,7 | 10,5 |
| Korrvike | 7,4 | 9,3 | 9,8 | 9,9 |
| Logården | 3,7 | 5,7 | 6,8 | 7,5 |
| Mean | 6,1 | 8,0 | 9,0 | 8,8 |
| Yield increase % | 0 | 31 | 47 | 44 |

Source: Own calculations from Rosenqvist 1997.

Table A4.2: N-level in the RENEW calculations model and data with the yield levels as in the fertilizer trials.

| Tdm | kg N per hectare |
|---|---|
| 6,1 | 157 |
| 8,0 | 185 |
| 9,0 | 200 |
| 8,8 | 197 |

The fertilizer level of 185 kg in the RENEW calculations and 165 kg in the trials are closest to each other. From this we estimate a difference in yield of about 33% between the cases with and without nitrogen fertiliser. As a consequence, costs for nitrogen fertiliser are zero. In the other willow cases, nitrogen accounts for 15-20% of production costs. As a rule-of-thumb, it is often said that nitrogen fertilises the plant whereas phosphorous (P) and potassium (K) fertilises the soil. Bertilsson et al (2005) show that in the long run, P and K must be returned if yields should not decrease further. For that reason, we have kept the same P and K costs in the organic calculation. P and K could become more expensive if derived from new sources that would qualify in organic cultivation schemes. Without chemical weed control the cost will decrease, but the cost increases for mechanical weed control. The difference is limited and these costs account for a relatively small share of total production costs. It should be noted that some costs (e.g., for harvest and transport) do not scale with yields.

### 4.2 Miscantus and triticale (whole crop)

Yield reductions due to a switch to organic cultivation depend on several factors and vary between crops. Rosenqvist (2003) compares yield reductions in areas with generally high yields with those in areas with generally low yields. Yield reductions are smaller on farms with animals compared to farms without animals. There are also differences between different cereals. For example, winter wheat will suffer a greater yield reduction than oats. Triticale is somewhere between winter wheat and rye and would probably have a lower yield reduction than winter wheat. Our assumption here, based on this scant evidence, is that the yield reduction for triticale and miscanthus will be 33%, the same as for willow. The cost for nitrogen disappears but it should be noted that nitrogen accounts for a relatively small share of total costs, approximately 8-12%. In both cases the cost for chemical weed control decreases whereas the cost for mechanical weed control increases. As in the case of willow, we assume that costs for P and K remain in amounts equivalent to what is removed at harvest. In the case of triticale we assume that the amount of seed increases by 30 kg per hectare. It may be noted that various handling costs account for a large share of total costs for these low-density crops. For miscanthus, nearly 80% of total costs are associated with handling. With lower yields, these costs remain essentially the same in EUR/GJ.

Table A4.3: Assumed yield reduction for different crops in organic growing for farms without animal production for different districts in Sweden in Rosenqvist 2003.

| Crop | Region | Yield reduction |
|---|---|---|
| Winter wheat | Gss | 45% |
| Spring wheat | Gss | 36% |
| Sugar beets | Gss | 23% |
| Peas | Gss | 16% |
| Winter wheat | Ss | 45% |
| Peas | Ss | 15% |
| Spring barley | Gsk | 34% |
| Oats | Gsk | 28% |
| Peas | Gsk | 17% |

## 4.3 Results

Table A4.4: Costs for different organically grown energy crops. The calculation is done for the future perspective, 2020. The calculations are done assuming that the cost level for the northern region applies to all regions.

| Crop | Yield | Region | EUR/GJ | EUR/GJ | EUR/GJ | EUR/GJ |
|---|---|---|---|---|---|---|
| | | | Growing | Land | Risk and | Total |
| | | | | | New crop | |
| Willow | 8.4 | North | 2.9 | 0.0-0.6 | 0.6 | 3.5-4.1 |
| Miscanthus | 10.7 | North | 5.5 | 0.0-0.4 | 0,4 | 5.9-6.3 |
| Triticale whole crop | 7.7 | North | 6.4 | 0.0-0.6 | 0.1 | 6.5-7.1 |
| | | | | | | |
| Willow | 12.2 | UK, Ir | 2.4 | 0.0-1.4 | 0.6 | 3.0-4.4 |
| Miscanthus | 19.3 | UK, Ir | 5.0 | 0.0-0.8 | 0.3 | 5.3-6.1 |
| Triticale whole crop | 11.3 | UK, Ir | 5.4 | 0.0-1.2 | 0.1 | 5.5-6.7 |
| | | | | | | |
| Willow | 9.4 | West | 2.8 | 0.0-1.0 | 0.6 | 3.4-4.4 |
| Miscanthus | 17.2 | West | 5.0 | 0.0-0.6 | 0.4 | 5.4-6.0 |
| Triticale whole crop | 8.4 | West | 6.1 | 0.0-0.9 | 0.1 | 6.2-7.1 |
| | | | | | | |
| Willow | 9.4 | Alp | 2.8 | 0.0-0.4 | 0.6 | 3.4-3.8 |
| Miscanthus | 12.3 | Alp | 5.4 | 0.0-0.3 | 0.4 | 5.8-6.1 |
| Triticale whole crop | 7.8 | Alp | 6.4 | 0.0-0.4 | 0.1 | 6.5-6.9 |
| | | | | | | |
| Willow | 6.7* | South | 3.3 | 0.0-0.0 | 0.7 | 4.0-4.0 |
| Miscanthus | 8.0* | South | 5.8 | 0.0-0.0 | 0.5 | 6.3-6.3 |
| Triticale whole crop | 5.6 | South | 7.6 | 0.0-0.0 | 0.1 | 7.7-7.7 |
| | | | | | | |
| Willow | 8.4 | East | 2.9 | 0.0-0.3 | 0.6 | 3.5-3.8 |
| Miscanthus | 11.8 | East | 5.4 | 0.0-0.3 | 0.4 | 5.8-6.1 |
| Triticale whole crop | 6.4 | East | 7.1 | 0.0-0.4 | 0.1 | 7.2-7.6 |

* Estimated value. This crop is not used in the main calculation for southern Europe.

**References, Appendix 4**

Bertilsson G., Rosenqvist H. and Mattsson L. 2005. Fosforgödsling och odlingsekonomi med perspektiv på miljömål (Phosphor fertilisation and cultivation economics in the perspective of environmental goals). Swedish Environmental Protection Agency, Rapport 5518. Stockholm, 58 sidor. (In Swedish)

Rosenqvist H., 1997, Salixodling - Kalkylmetoder och lönsamhet (Salix cultivation – methods for calculation and profitability), Silvestria 24, SLU, Uppsala, Sweden. (In Swedish)

Rosenqvist H., 2003. Ekologiskt jordbruk – lönsamt för jordbrukaren? (Organic farming – profitable for the farmer?), SLI skrift 2003:5. Swedish Institute for Food and Agricultural Economics. Lund. Sweden. (In Swedish)