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ABBREVIATIONS

CEE	Central East Europe
CEEC	Central East European Countries
DM	Dry matter
dna	Data not available
FAO	Food and Agriculture Organization
LGP	Length of Available Growing Period
RES	Renewable energy sources
SRC	Short rotation coppice
SRF	Short rotation forestry

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1. Preface

The report has been developed in the framework of WP5.1, under the task 5.1.2 *Energy crops development potentials*. The target of the report is the first approach to energy crops potential assessment methodology. Report contains the review of regional conditions for the assessment of energy crops cultivation in Europe. Energy crops analysis is preceded with natural conditions and agricultural characteristics including description of agro-climatic, agricultural, and economical parameters relevant for energy crops cultivation. The energy crops experiences are presented in following sections:

- Field trials results;
- Energy crops development perspectives;
- And Economical feasibility.

Each partner was also invited to give the characteristics of the existing energy crops market in the respective country and give recommendations for species considered as the most promising in the region.

Specific requirements for energy crops development **break-down** in different EU regions and **barriers** were discussed and underlined. The following European regions were considered and analysis for the representative countries were performed in the report:

Region of Europe	Central and East	North	West	UK and Ireland	Alpine region	South
Representative country	Poland	Sweden	Germany	Ireland	Switzerland	Greece
Partner responsible	EC BREC	LU	IE	UCD	ESU services	CRES

2. EAST (POLAND)

Eastern region consist of following countries:

Poland	Estonia	Latvia	Lithuania	Czech Republic	Hungary	Slovakia	Slovenia

2.1 Natural conditions

The climate of CEEC countries is temperate and the dominant type is sub-continental. The climate is characterized by warm summers and cool to cold winters. The seasonality (the difference in mean temperature of the warmest and coldest month) averages 20-35^{o}C.

The available water capacity is sufficient for agricultural cultivation. Precipitation and temperature conditions allow that nearly all – except the typical tropical crops – can be grown. Natural vegetation is deciduous forest with oak, birch, hornbeam and beech, but it hardly exist any more.

Slovenia and western part of Czech Republic, Poland and Latvia characterize oceanic type of temperate climate. The seasonality is less than 20^{o}C and in general annual and daily variations of temperature are lower comparing to sub-continental.

The Length of Available Growing Period (LGP) averages from lest than 210 days (Estonia, Latvia, Lithuania, North-Eastern Poland, North part of Slovakia, Eastern part of Czech Republic), 210-240 days (Poland, Czech Republic, Slovakia, and North Hungary), 240-270 days for Western Hungary.

The soil formation in the region is connected with the formation, migration and accumulation of clay minerals, combined with a moderate liberation of iron (Luviosols, Cambisols) (Finke et.al., 2001). In Baltic States there are podzoluvisols soils dominant with combined with rendzinas in Estonia and gleysols in Lithuania.

2.2 Agricultural characteristic

Agriculture in Central and Eastern European countries has been under the process of economic transition and restructuring. In most countries agricultural contribution to GDP is significant at the level from 2,9% for Poland and Slovenia to 6,9% in Lithuania[1]. The proportion of crop and animal production are balanced in all courtiers, however the crop production structure is changing from north to south according to climate conditions. In all countries is observed significantly lower average cereal yield, which testify more extensive production system and natural conditions comparing to EU-15. The average yield level extent from 30% to 95% of referenced EU-15 yield level[2]. In all countries (except Slovenia) there is still a potential of yield increases, which is however linked to the use of advanced varieties, increased use of fertilizers inputs, availability of capital, and restructuring of farms .

Farm structure

In all countries the small and medium farm size is dominant. Most of agricultural holdings re farms smaller than 5 ha. The most of the cultivated land belong to group of farms 0-20 ha. The significant contribution to the land ownership have large (>50ha) farms, mainly arose from former national farms.

Employment

In most of countries, there is characteristically high rate of employment in agriculture. This labour indicator related to the share of agriculture incomes in GDP states on agricultural effectiveness, e.g. Poland: employment rate in agriculture is 18,8% and agriculture share in GDP is 2,9% (data for 2000), corresponding indicators for Hungary are respectively 6,0% and 3,9% or in Czech Republic 4,5% and 3,4%.

Future perspectives for agriculture sector for more countries are optimistic. The EU subsidies directed to farmers will increase agricultural production profitability. After the first year of accession the trade liberalisation has appeared as an additional export of food products incentive.

Table 1. General characteristic (EC DG Agri, reports, 2002)

	Poland	Estonia	Latvia	Lithuania	Czech Republic	Hungary	Slovakia	Slovenia
Population, 2000 [mln]	38	1,37	2,37	3,7	10,27	10,02	5,4	1,99
Land area [thous. km^2]	312	45,2	64,6	65,3	78,8	93	49	20,2
Agricultural land, 2001 [%]	60	21	40	56	55	64	51	25
Forests, 2001 [%]	27	46	39	26	33	18	35	51
GDP in PPS[(1)], 2000 [thous. Eur per capita]	8,7	8,4	6,6	6,6	15,4	11,7	10,8	16,1
Agriculture share of GDP, 2000 [%][(2)]	2,9	4,7	4,0	6,9	3,4	3,9	4,5	2,9
Share of agricultural employment in total	18,8	7,6	13,5	19,6	4,5	6,0	6,7	9,9

[1] The given figures refer to year 2000. It is necessary emphasize that agricultural production strongly dependant on whether conditions has a rough character in the context of the whole sector.

[2] The average yield of each crop species should be justified, the presented indicator is a rough approach (i.e. some species like maize which have high single yield significantly increase the average)

	Poland	Estonia	Latvia	Lithuania	Czech Republic	Hungary	Slovakia	Slovenia
employment, 2000 [%]								
Average size of agricultural holding [ha]	7,2 for individual farms	20,1	18 (1999)	6,17 (1998)	18	6,7 (2000)	36 for individual farms	
Crop production [% of total agricultural production]	51,6 (1999)	44,3 (2000)	49,6 (1999)	55,1 (1999)	46,6 (1998)	52,2 (1999)	44,2 (1999)	46,1 (2000)
Animal production [%of total agricultural production]	46 (1999)	49,1 (2000)	47,8 (1999)	43,7 (1999)	51,8 (1998)	43,7 (1999)	51,3 (1999)	52,6 (2000)
Average yield [t/ha]	3 (2000)	1,74 (2000)	2,2 (2000)	2,71 (2000)	3,9 (2000)	4,8 (1997)	4,5 (2001)	5,51 (2001)
	Main cereals products (1998-1999)							(99-00)
Cereals	18,0	8,3	16,5	16,9	20,11	17,6	15,6	7,4
Rapeseeds	1,8	1,4	0,3	1,6	4,97	1,0	2,0	
Sugar	2,9		4,2	3,2			1,8	1,8
Vegetables	7,4	3,4	4,4	9,3	1,90	11,2	9,4	5,1
Potatoes	6,9	9,6	9,0	10,4	4,01	3,7	3,1	2,5
Fruits	6,3	1,8	1,8	0,7	1,70	7,5	3,7	6,9
Other plant products		9,1			0,37	3,5	1,4	19,3

(1) PPS: Purchasing Power Standard, (2) Including Forestry, Hunting and Fishing sector

2.3 Experiences with energy crops

Ligno-cellulose energy crops, such as woody short-rotation crops as well as herbaceous perennial species have gained growing interest since 1990. This resulted from bottom-up interest in agriculture development and renewable energy technologies implementation. Several R&D institutions have conducted field trials with different energy crops.

Table 2. Predominant energy crops tested in CEE countries; based on literature review.

Czech Republic	Estonia	Hungary	Latvia	Lithuania	Poland	Slovakia	Slovenia
Willow, Poplar, Miscanthus	Willow, Aspen	Willow, Poplar, Robinia, Common reed	d.n.a.	Reed canary grass, Hemp, Sunflower	Willow, Miscanthus, Sida	Amaranthus	d.n.a.

d.n.a. – data not available

Poland

Most research fields with energy crops in Poland have been provided with willow (*Salix sp.*) cultivation. Willow has been grown for decades in Poland to serve several purposes. Traditionally, it was grown for wattle (8000 ha in 1960s then the acreage shrank). Another purpose of growing willow was to use the plantation as a vegetation filter. Due to this property, willow is being grown along rivers and lakes in Poland in order to strengthen the riverbanks and to decrease the leakage of nutrients and agro-chemicals into watercourses. Willow is also used for restoring contaminated land in areas of industrial land, landfills and mine dumps (Szczukowski, 2002).

Since 1990 various trials of willow have been carried on poor quality lands, medium and also good quality lands. Yields reported in review studies are between 5 – 25 t DM per ha*y^{-1}, however research results have not been proved yet in commercial production (Majtkowski, 2001). Density of planting of 10-60 thousand cuttings per hectare was tested. Recommendations for fertilization are 20-30 kg P_2O_5/ha, 40-90 kg K_2O/ha and 30-90 kg N/ha depending on crops growth year. There were more than 150 genotypes clones tested including development of 3 new Polish genotypes. Yields of 11-18 t DM per ha*y^{-1} were obtained in research fields when density of planting was 40.000 cuttings/ha on medium quality soil (Szczukowski et al., 2004).

Table 3. Yields of willow (*Salix viminalis* clones) achieved on experimental sides in Poland (Stolarski, 2004; Stolarski, 2003)

	Density of cuttings	18.000	32.000	40.000
		Yield DM t/ha*year		
Harvesting cycle	Every year	12.8	14.4	14.8
	Every 2 years	14.5	d.n.a.	16.1
	Every 3 years	21.5	d.n.a.	21.5

d.n.a. – data not available

Few R&D institutions investigated cultivation of *Miscanthus* in Poland (including *Miscanthus giganteus, Miscanthus sacchariflorus, Miscanthus sinensis)*. R&D tests showed great difficulties to take roots. This resulted from the two general planting options (i) in vitro method or (ii) by use of seedlings. The latter is more expensive while the first was assessed as a risky method (Majtkowski, 2001). Yields obtained in R&D tests based on experiments in western Poland may vary 13 – 20 t DM per ha*y_{-1} (Pude, 2001).

Sida (*Sida hermaphrodita) is* a herbaceous perennial crop that has been tested in Poland since 1950s in Lublin Agricultural University. It was based on research cultivation of *Sida* in the USA. The results of field trials showed that *Sida* is a very promising crop suitable for Polish agro-climatic conditions. In the field trials the plantation life span was 15-20 years. Research tests showed yields up to 15 t DM per ha*y^{-1}. The optimal fertilization doses are: 80-120 kg P_2O_5/ha, 100-150 kg K_2O/ha and 150-250 kg N/ha. *Sida* may be used for fodder, as a vegetation filter on contaminated land, as a raw material for pulp and paper industry and as an energy crop. Cellulose content tested was 53% DM of total mass (Borkowska and Styk, 2003). Dry matter content in the stems is 70%, which is very favourable for energy use of this crop. It is hardly possible to evaluate the opportunities for wider cultivation of *Sida* for energy purposes as none of the wider proven R&D programme has been developed yet.

Czech Republic

In the Czech Republic the first sets of experimental plots with poplar and willow were established in 1995-1996 and until now 21 small testing plots (0.1–0.3 ha) have been planted in diverse environmental conditions. Clones were densely planted with 13000-18000 ps/ha. In general some of the clones could reach yields of 10 t DM per ha*y^{-1} or more on sites that fit their adaptation. Some of these clones were then recommended as the assortment to be used to obtain the state subsidy for the "establishment of plantations of fast growing trees on agricultural soil" that started to work in the spring of 2001 (Weger & Havlickowa, 2002). In 1999 a new set of experimental plots was established with 13 poplars and 22 willows clones, see table 4. The main goal was to evaluate more precisely their production potential on agricultural soils [Weger, 2000]. It showed that the best growth conditions are on the Doubravice locality, where the average stem increment was more than 1.3 meters and yields were 3.9 t DM per ha*y^{-1} in the first rotation.

Table 4. Clones of willow and poplar tested and recommended for SRC in Czech Republic (Weger, Havlickowa, 2002)

Species, *taxa* (S=Salix)	Species, *taxa* (P= Populus; S=Salix)
S. alba L. + hybrids	P. x euroamericana Dode
S. viminalis L. + hybrids	P. nigra L.
S. caprea L. hybrids	P. deltoides March.
S. daphnoides Vill.	P. maximowiczii + hybrids
	P. trichocarpa + hybrids
	P. simonii + hybrids

The Czech Research Institute for Crops Production (VURV) also provided research in reeds and grasses. Various species were tested e.g. *Sorghum, Miscanthus, Cannabis* and others. Research cultivation was provided in different parts of the country including different soils and agriculture conditions. Some of the results obtained in the test are presented in *Table 43*. Research results showed that in the warmer areas of Czech higher yields were obtained by Sorghum and Reynoutria (during the 3rd year of cultivation), while in cooler areas higher yields of shoots were obtained by Reynoutria, Secale cereale, Triticosecale (Strasil, 2001).

Estonia

In Estonia willow and hybrid aspen (*Populus x wettsteinii*) were tested (Tullus, A. at al., 2004). In 1993 the first willow short-rotation experimental plantations, as energy forestry examples, were established. Despite high biomass production (about 14.7 t DM per ha*y^{-1} at fertilised sites) plantation forestry of willows has not gained popularity in Estonia.

In 1999 the first 14 hybrid aspen plantations, with a total area of 130 ha, were established in Estonia. The aim was to experiment with this relatively new species in Estonian climate and soil conditions. Very good growth rates and survival rates were achieved. Since then, approximately 600 ha of plantations have been established on abandoned agricultural lands. On the basis of the evaluation, it was recommended to the Estonian Ministry of the Environment to include hybrid aspen in the list of tree species that may be cultivated in Estonia (Tullus, A. at al., 2004).

Lithuania

In Lithuania a few species of ligno-cellulose energy crops were tested in the mid 90’ ties, including sunflower, hemp, corn and grasses; *Reed Canary Grass - Typhoides arundinacea*, *Reed fescue grass – Festuca arundinacea* and *Poa pratensis*. Hemp obtained the worse yields in research tests, not exceeding 3-4 t DM/ha*y, while grasses yields varied from 7-13 ton DM/ha*y. Sunflower yields obtained were between 8-13 ton DM/ha*y (Jasinskas, 1998).

Latvia

In Latvia there were not many research programmes in lingo-cellulose energy crops cultivation, thus the knowledge on perspectives and field results are not widely published yet.

Hungary

There were several energy crops tested in Hungary. The majority of tests were provided with woody crops – Willow, Poplar and Black-locust *(Robinia)* (Horvath, 2003). The research results showed good, promising results of the woody-species cultivation i.e. Salix yields of 11 t DM/ha*y (13,000 cuttings/ha) on wet-flood soils, Poplar yields of 7-20 t DM/ha*y (8-11.000 cuttings/ha) on medium-quality soils, and Robinia yields of 9 t DM/ha*y on poor-quality sandy soils (12,000 cuttings/ha). Also Sweet Sorghum and grasses species were tested, however results of cultivation have not been presented yet (Chrappan, 2003; Zanowszky, 2003).

Slovakia

In Slovakia research tests with the lingo-cellulose energy crops until now were limited, however some research is provided with amaranthus (*Amaranthus cruentus L.*) – annual C4 crop cultivated in South America (Viglasky & Huska, 2003).

2.3.1. Energy crops development perspectives

National agricultural systems have been affected by many changes in the CEE countries, which experienced political and economic transformation in the 1990s. Considerable large areas of formerly cultivated land have been abandoned. In 2002 total area of fallow land in CEE amounted to 3.0 million ha including 2.3 million ha of set-aside and fallow land in Poland The abandoned lands require alternative usage to generate income for the farmers. One option may be energy crops cultivation.

In the Table 5 there is a summary of energy crops potentials perspective in CEE countries based on agricultural land resources per capita, fallow and set-aside land areas and researches in energy cops carried out in these countries (Gańko et al. 2005). The most favour conditions for large-scale energy crops growing seem to be in the Czech Republic, Hungary, Latvia, Lithuania and Poland.

Table 5. Opportunities for energy crops in the CEE countries, based on data for 2002.

Country	Agricultural land per capita >0,4 ha	Share of fallow land and set-aside land in arable land >5%	Researches and field trials on energy crops	Potential for energy crops
Czech Rep.	✓		✓	good
Estonia	✓		✓	?
Hungary	✓	✓	✓	good
Latvia	✓✓	✓		good
Lithuania	✓✓	✓	✓	good
Poland	✓	✓✓	✓	good
Slovakia	✓			?
Slovenia	✓		✓	?

In Poland energy crops are receiving large interest among farmers and energy producers. Since 1997 there were established 1000 – 3000 ha of willow plantations, mainly small scale: 1–10 ha, larger do not exceed 50 ha. Majority of the willow plantations is in early phase of development and thus they are not operating commercially on a broader scale. Some plantations are used for stem cuttings production. Small plantations (1-5 ha) owned by conventional farmers are used for own heating purposes or sold to local biomass heating plants. There are also several single plantations of herbaceous energy crops such as Sida and Miscanthus, but their total area is less than 1000 ha. Most of the existing energy crops plantations in Poland, mainly willow, are located in western and northern part.

The Polish Ministry of Agriculture and Rural Development has assumed that the area covered by energy crops in 2010 will be 140-170 thousands of ha and then will grow up to 250-300 thousands of ha (Ministry of Agriculture, 2004). This is necessary to achieve the quantity targets resulting from the Polish document *Development Strategy of Renewable Energy* (Ministry of Environment, 2000).

In Estonia during the last decade 25-30% of agricultural land have been abandoned. At present the total area of former agricultural fields is considered to be more than 300 000 ha. Afforestation with fast growing deciduous species is one way to reemploy these lands. Beside domestic tree species (mainly birch, but also oak and alder species), establishment of hybrid aspen plantations has begun during the last years. Willow has not gained popularity in Estonia, whereas hybrid aspen has a high growth potential in Estonian conditions (Tullus, A. at al., 2004). The plantations are operating preliminarily as a source of raw material for the pulp and paper industry.

In the Czech Republic the utilization of agricultural land for the purpose of energy generation is regarded as a perspective trend in the National Development Plan (NDP Czech Republic, 2003). The area of fallow and set-aside land was 83 000 ha in 2002, which was 2.7% of arable land (EUROSTAT, 2002). The direct subsidy system for establishment of willow and poplar plantations has been started in 2000. However, even with these subsidies, the acreage of short rotation coppices is growing rather slowly (10-15 hectares per year, about 50 hectares in total) (Weger, Havlickova, 2002). This slow growth stems mainly from the non-profitability of the wood chips, the final SRC product, under the current economic conditions (Knapek, 2002). Other reasons are low public awareness and a limited stock of planting material.

There's no commercial cultivation of lingo-cellulose energy crops in Hungary yet. The area of fallow and set-aside land, which could be used for lingo-cellulose energy crops production, is at the level of 300,000 ha (EUROSTAT, 2002). However, currently biodiesel production in agriculture is supported.

In Latvia and Lithuania the ligno-cellulose energy crops production has not been commercial yet. The share of fallow and set-aside land in 2002 was at the level of 5-6% (140,000 ha in Lithuania and 83,000 in Latvia). In both countries biodiesel production from rapeseed is supported. In Latvia biodiesel production should amount to 40% of total diesel fuel used in agriculture in 2010 (Ecodoma & EREC, 2004). In Lithuania it was estimated that 230-290 thousand ha could be used for rapeseed growing (LEI & EREC, 2004).

In Slovakia and Slovenia the resources of agricultural land are relatively very small. Forestry residues are the major source of biomass. Energy crops plantations are not developed or promoted. The fallow and set-aside land in 2002 was 0,25% of arable land in Slovakia and 0,28% in Slovenia, which is very low (EUROSTAT, 2002).

2.3.2. Economical feasibility

There are limited economical studies of energy crops cultivation feasibility in East European countries. Several studies show results for willow - Salix, but there is limited cost assessment for herbaceous crops i.e. *Miscanthus* or reeds. Refereeing to polish conditions and research experiences of willow cultivation, we see Salix as most suitable energy crop in Central Europe.

There are some economical studies about energy crops profitability, based on experimental field cultivation of 1-50 ha, but not fully operated in a commercial way. Those studies presents establishment cost of 1500-2500 €/ha for willow (Szczukowski et al.,), (Kotowski & Dubas, 2004). Reported example of annual gross margin of willow is at the level 250-270 €/ha y^{-1}, assuming 9 €/MWh biomass market price and yields of 22-26 t DM/ha y^{-1} (Kotowski and Dubas, 2004). These studies seem to overestimate incomes because of possible yields of >20 tDM/ha y^{-1}.

Another study based on 10-year research experience shows costs level for Salix plantation establishment of € 1600/ha, and annual gross margin of 1400 PLN/ha y^{-1} (Szczukowski et al., 2004). However the calculation was made for much more intensive production, when assumed 30.000 cuttings/ha density of plantation, yields level of 30 t DM/ha y^{-1} and biomass price level of 8-9 €/MWh. The gross margin seems to be over-estimated, due to assumption of high cuttings density compared to typical conditions of commercial willow cultivation in Sweden, where density of 12-15.000 cuttings/ha is usually met.

Based on the calculation provided with several assumptions verified by Swedish scientists (Eriksson et al., 2004) several conclusions were drawn. The calculation was based on the price level of 2003, with the assumptions that field preparation, plantation establishment and harvesting are made by contractors. Salix plantation was defined to be as at least 50 ha with intensive production practices on medium quality soils. Economic parameters were compared with cost production of most common cereals – wheat and barley. Results showed the discounted annual production costs for Salix in Poland at the level of 235 €/ha y-1 are about half of the costs in Sweden or Ireland, which is of 500 – 558 €/ha y-1. Lower costs referred mainly to lower labour costs in Poland and to some extend lower costs of agriculture production means (fertilizers, pesticides etc.).

It was found that biomass market price has a larger impact on willow economics than the yield level. For the biomass market price of 8 €/MWh in 2003 it was generally found that willow production resulted in gross margin of 70 PLN/ha y-1, which is several times lower to 300 PLN/ha y-1 to wheat gross margin . However willow gross margin was at similar level to barley production of 50-60 PLN/ha y-1. It was also found that for higher biomass market price of 12-15 €/MWh, the annual gross margin of 600 PLN/ha exceeds both the level of gross margin of wheat and barley production.

Table 6. Annual cost distribution for willow cultivation in Poland.
The costs refer to a situation where an area of at least 10,000 ha is covered by willow plantations Land rental costs and common business overheads are excluded. The discount rate is 6%. The lifespan of the willow plantation is 22 years. First harvest is after 4 years and then every third year. Planting density is 12,240 cuttings per ha. Energy content of the willow crop is 4.5 MWh/tonne. Average exchange rates from 2003 are used: 1 € = 4.4 PLN.

	Annual cost distribution (€/ha)
Cost structure	Poland
Establishment	64
Fertilization	38.6
Harvest	61.6
Field transport	12.5
Transport to thermal plant	28.2
Brokerage	22.5
Supervision, administration	0.23
Wind-up	2.04
Weed control after harvest	2.5
Total	235
Total (€/MWh)	7.0

[a] The annual willow yield is 5.25 tonne/ha until year 4 and 9 tonne/ha after that (Swedish energy Agency, 2003)
[b] The annual willow yield is 12 tonne/ha from year 5 and onwards. Farm labour cost is 4.5 £/h. Road transport distance is 20 km (Rosenqvist and Dawson, 2004).

2.4 Market development for products from energy crops

In the CEE countries the market for products from lingo-cellulose energy crops plantations is not established yet. The area of commercial energy crops plantations is growing in Poland, Czech Republic and Estonia, but they are still in very small. There is high technical energy crops potential resulting from relatively extensive agricultural production system and land availability in CEEC (van Dam, et. al., 2004). This potential can be exploited, but it is necessary to stimulate appropriate legislative and economic condition to enable market development. There are still significant barriers to overcome (Rogulska et. al., 2004):

- Lack of agricultural, energy and environment policies harmonization at national level;
- Need for appropriate agro-machinery development for SRC;
- Need for stable, long-term energy crops market development.

The conventional agricultural system in Europe is based on annual crops and especially cereals. Perennial crops with annual harvest cycle, such as Miscanthus, Sida and Reed canary grass give the possibility of usage the conventional agricultural machinery for plantation establishment, maintenance and harvesting, i.e. Miscanthus can be harvested with a corn-harvester. Harvesting of woody energy crops such as short rotation coppice (willow, poplar, *etc.*) requires harvesters specially design for cutting woody shoots. Such machines are not available yet either on the Polish market, nor other ECC markets, due to very small willow acreage. However, further growth of willow plantations will facilitate the development of contractors providing harvesting machinery services for at local and regional level.

The development of energy crops market in Poland is facilitated by the 'green electricity' regulation (Ministry of Economy, 2004), which is in line with the EU directive 2001/77/EC. Energy companies in Poland are obligated to prove a certain share of green electricity in the total amount of electricity sold to the final customer. The obligatory amount of green electricity is growing each year, e.g. for 2005 it is 3,1%. To fulfil the obligation Polish energy companies are very interested in purchasing woody biomass for co-combustion with coal in the existing energy boilers. Whereas the resources of forest fuel-wood are limited (due to restrictive forest management and strong competition from wood-board industry), the most relevant source of biomass for energy sector in Poland will be woody energy crops – SRCs. The obligation on 'green electricity' is regarded as a strong driving force for woody energy crops (SRCs) development in Poland.

For the farmer who is the potential producer of energy crops the most important issue is the profitability of energy crops cultivation and economic competitiveness with conventional crops. Currently only in the Czech Republic establishment subsidies are available. The direct subsidy for establishing a 1-hectare SRC is 1600–2500 EURO (50000-75000 CZK), which should cover most of the real expenses for soil preparation, purchasing cuttings and planting. One of the obligations for applicants is to use only clones recommended by the Ministry of Environment (Weger & Havlickova, 2002). In other CEE countries no such subsidies for the establishment of energy crops plantations are available.

Czech Republic, Poland and other CEE countries joint the European Community in 1st May 2004. Since then the support in the framework of Common Agricultural Policy is available for agricultural production. However, for the period of first 10 years (till 2013) the new member states of EU have accepted a simplified system of direct payments. Currently only conventional crops are supported. No direct payments for perennial energy crops are available from EU from the Common Agricultural Policy. Additionally to that the short rotation forestry such as willow or poplar is categorized as forestry production, not agricultural production. However, in order to support the development of energy crops in Poland the Polish Ministry of Agriculture established special area payments for energy crop. The payments are redistributed from Polish national budget and they area available for Willow and Rosa multiflora grown for energy purposes (Ministry of Agriculture and Rural Development, 2005). In 2005 the payment amounts to 54,46 EURO. The direct area payment will be growing with 5-10% each year until 2013, when the same support system will be available for agriculture in all EU-25 countries.

Support for establishment and utilization of energy crops is also potentially available in few of the CEE countries in the framework of structural founds. Sectoral operational programmes for agriculture are offering financial support for non-production functions of agriculture. Such programmes are in Poland and Czech Republic (Ministry of Agriculture CZ, 2004).

2.5 Regional recommendations for energy crops

Among different ligno-cellulose energy crops most trials with very positive results were done with willow. However, Miscanthus also seems to be a suitable energy crop. In Poland experimental cultivation of non-woody crop Sida gave very promising results, but Sida was not tested as an energy crops in other countries.

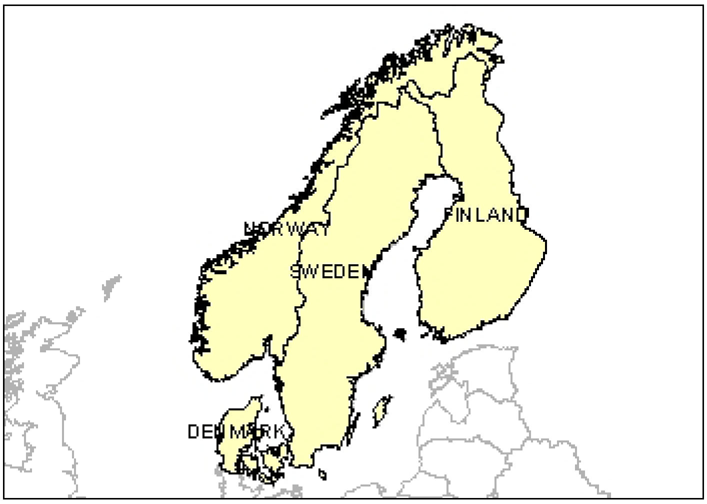
In most cases energy crops have been tested only on experimental fields. Only few demonstration plantations exists. Commercial production on a large-scale is not established in CEE countries. The development of energy crops plantation is expected to cover the low quality lands, which are now set-aside or fallow land. For this reason the expected yields will be considerably lower than in the trial fields.

Great interest is towards energy crop cultivation for production of heat and electricity (especially co-firing), a priority which is driven by energy directives.

3. NORTH (SWEDEN)

The Northern region consists of the following countries:

Sweden Finland Denmark Norway



3.1 Natural conditions

The climate of the Nordic countries is basically a temperate climate ranging from warm temperate in the south to cold temperate in the north. The length of the vegetation period ranges from more than 240 days in the very south to less than 120 days in the very north, but there are many hours of sun during the vegetation period. It may be noted that wheat yields on comparable soils in the north and in the south are almost the same. The north is dominated by coniferous forest, whereas mixed and deciduous forests dominate in the south. Annual average temperatures range from +8-10 C in the south to well below zero (-3-5 C) in the far north. Most areas are humid during the vegetation period, i.e., the precipitation is greater than the evaporation and transpiration. Annual average precipitation ranges from 600 mm per year in the eastern parts to 3000 mm in some parts west of the Scandinavian mountain ridge. Local climate can be both maritime and continental relative to what it would be based only on latitude and elevation. Soils are predominantly mineral soils (91% in Sweden) of which most are clay soils but also sandy soils in western Denmark and parts of Sweden. For energy crops, the main alternatives considered are miscanthus (in Denmark), willow (mainly in Denmark, the southern half of Sweden and southern parts of Finland), and reed canary grass in the northern parts. The use of willow in the north is mainly restricted by its sensitivity to frost. Plant breeding has made willow more resistant to frost and hence cultivation possible further north. Such breeding efforts continue.

3.2 Agricultural characteristic

Agricultural production in the Nordic countries is relatively intensive with, for example, wheat yields of 6.2 and 7.0 tons per hectare in Sweden and Denmark. The corresponding numbers are 3.3 and 4.3 for Finland and Norway, respectively, where the soils are poorer. Restructuring for many years has led to larger farm sizes but the majority of farms are still smaller than 30 ha: in Denmark about 50%, in Finland and Sweden 65%, and in Norway 90% of the farms. Employment in agriculture, forestry and fisheries has been decreasing for many years and now range from 3-6% of the employed. Arable land and permanent pasture accounts for roughly 85% and 15% of agricultural land, respectively, except in Finland where permanent pasture is only about 1% of agricultural land. Arable land is dominated by cereals, with a relatively high share of wheat and barley in Denmark and Sweden (60% and 30%, respectively), and barley and oats in Finland (44%). Norway is standing out with its high share of ley and other food crops (58%). The differences in production reflect differences in geographical and climatic conditions leading to somewhat poorer agricultural conditions in Norway and Finland. I may be noted that Denmark has a very intensive livestock production with about 13 million pigs (more than 2 per capita) and about 20 million fowls and chicken. Set aside or fallow land is about 10%, except for Norway where less than 1% is fallow. Finland, Sweden and Denmark belong to the EU. The agriculture in these countries is manged by the CAP. Norway, although not belonging to the EU is also striving to reduce price subsidies and replace it with non-product-specific support in order to reduce overproduction (Norway has relatively high subsidies). Agriculture in the Nordic EU member states is expected to be increasingly challenged by competition from other countries. Lower area support will mean that land with poor soils will be taken out of production.

3.3 Experiences with energy crops

3.3.1. Field trials

Field trial cultivation of energy crops took off in the 1970's although experiments were also made before then, often with the purpose of producing fibre for paper production. Research in Sweden soon focused on willow and reed canary grass although there has also been interest in *Miscanthus and Poplar*. In Denmark, research has focused on *Miscanthus* and *Willow*, whereas canary reed grass and to some extent willow has attracted interest in Finland.

Studies of *Reed Canary Grass* started in the 1980's, first in Sweden and later also in Finland. It can be grown on most soil types but is particularly suited for wet organic soils that are more common in the northern parts of the region. Trials in Finland have identified reed canary grass as the most promising option for Finnish conditions. Swedish trials have generated yields in the range between 6.4 and 12.5 tDS/ha. It has been estimated that possible yields under commercial conditions are 5-8 tDS/ha in Sweden and Finland. *Reed Canary Grass* has the advantage of high dry matter contents at harvest in early spring (>85%), low establishment cost, there is no need for special agricultural machinery and the land can be easily returned to food crops. Recommended fertilization for Swedish conditions has been 80, 30 and 10 kg/ha of N, P, and K, respectively, after the first year. We estimate that at least 50-100 ha has been established for R&D projects over the years. About 4000 ha of commercial plantations were established in Sweden in the early 1990's due to an establishment support of 10,000 SEK/ha.

The first experiments for *Miscanthus* were carried out in Denmark in the late 1960's. Estimated mean yields under commercial conditions in Denmark are 7-8 tDS/ha on sandy soils and 8-9 tDS/ha on clay soils although higher yields have been reported (~15 tDS/ha). Higher than 20 tDS/ha has been reported for northern Germany, and above 30 tDS/ha in southern Europe. *Miscanthus* is sensitive to late spring frost and hard winter conditions which is a problem in northern Europe. There is much more experience with *Miscanthus* than reed canary grass through various field tests across Europe. One disadvantage of *Miscanthus* is the high cost of establishment but like other perennial crops it can be produced with low environmental impacts. It has relatively high water-efficiency and growth should not be water-limited in, for example, Denmark. Late harvest reduces water and mineral content, but at the price of lower biomass yield, and is usually carried out in the early spring. Fertilization need is relatively low due to the translocation of nutrients to the rhizomes at the end of the growing season. Overall nutrient requirement for N, P, and K has been reported to be 2-5, 0.3-1.1, and 4-8 kg/tDS, hence the potassium requirement is relatively high. Field trials in the Nordic countries are concentrated to Denmark but overall we estimate that the field trial experience in Europe to be several hundreds of ha. Although existing farm equipment has been used for harvesting, machinery will have to be adapted to the height (2.5-3.5 m) and stiffness of *Miscanthus*. Drying is necessary to allow storage of *Miscanthus*. Moisture should be less than 15% for long-term storage or less than 25% in ventilated storage.

Willow was identified as a promising species in the first Swedish energy research programme starting in 1975 and has been subject to relatively intensive research since then. *Willow* has clearly received the greatest attention in terms of R&D spending. In the past 5-10 years, government funded R&D has been scaled back and more attention has been given to the need for increased market support. In contrast to grasses, *Willow* is harvested every 3-4 years. Estimated annual yields under commercial conditions with new clones are expected to be about 10 tDS/ha. Well above 15 tDS/ha has been achieved in field trials with optimized water and nutrient supply. Lower actual yields in commercial plantations (~4 tDS/ha) during the 1990's are explained mainly by poor management and establishment on poor soils. The highest yields are achieved on good and medium mineral soils. For optimal conditions, the soils should be well drained, rootable in a depth of at least 1 m, and highly supplied with water and nutrients. According to Swedish recommendations P and K are applied after each harvest at quantities of 22 and 73 kg/ha, respectively. Nitrogen (N) is applied twice as often, (14 times in all assuming a 22-year life span), at alternating quantities of 80 and 120 kg/ha. Due to the high water and nutrient needs, willow is also well suited as a biofilter for water from sewage treatment or landfill leachate. The main company involved in plant breeding is the Swedish company Agrobränsle AB which also has the license rights from Svalöf-Weibull. One important goal is to develop clones that are suitable for different regions, not least frost-resistant clones for the northern parts of Sweden and Finland. There is currently about 15,000 ha in Sweden. We estimate there is 1,000 ha at most in Denmark, and perhaps 50-100 ha in Finland. There may be 10-20 ha of trial plantations in Norway.

3.3.2. Energy crops development perspectives

Energy crops have been considered an important option for the agricultural sector for the past 20-30 years, mainly in Denmark and Sweden. Interest in Finland came later, and it seems only very recently in Norway. The oil crises and later the surplus food production have provided motivation for pursuing this option. Sweden has been a leader through an ambitious R&D effort and the introduction in of an economic support for establishing energy crop plantations, namely reed canary grass and willow.

Statistics on willow in Sweden indicate that annual planting has been greatly influenced by the level of establishment support (see Figure 1). The establishment support was introduced in 1989 at 6500 SEK/ha. One year later the support was raised to 10,000 SEK/ha, which roughly equals the establishment cost in Sweden. This support lead to a rapid increase, notably in the area of willow plantations, up until the support was scaled back due to restrictions imposed by the accession of Sweden to the European Union in 1995. In addition, accession to the EU raised the Swedish farmers' expectations on profitability in cereal crop cultivation, something which also decreased the planting of willow. After some years of relatively low interest in willow in Sweden this crop is now receiving more attention again. A factor which has probably contributed to that is that the establishment support was raised again to 5000 SEK/ha. According to Agrobränsle AB, about 1000 ha of willow will be established in Sweden in 2005, and perhaps 2,000 ha in 2006. No, or slow, development is expected in the other Nordic countries since they do not have establishment support.

The relatively high cost for establishing a plantation and the long time before harvest, which together cause a negative liquidity for the farmer, is generally seen as the main barrier to energy crops, and willow in particular. In addition, the farmer cannot know what the fuel price will be 4-5 years down the road. As a remedy it has been suggested that contracts should be constructed so that the energy company carries the fuel price risk and the farmer carries the production risk. Other barriers include the fact that it is a relatively unknown crop, it commits the land for many years, farmers may be locked in to other strategies for farming through investments, etc.

It may be noted that Agrobränsle AB has a very dominant position in the market although there are also small companies such as Henriksson Salix AB. Agrobränsle AB is owned by “Lantmännen Energi AB” and is part of the Swedish farmers co-operatives “Lantmännen”. The stable ownership has probably been an important factor behind the sustained effort, over decades, to develop willow into a business.

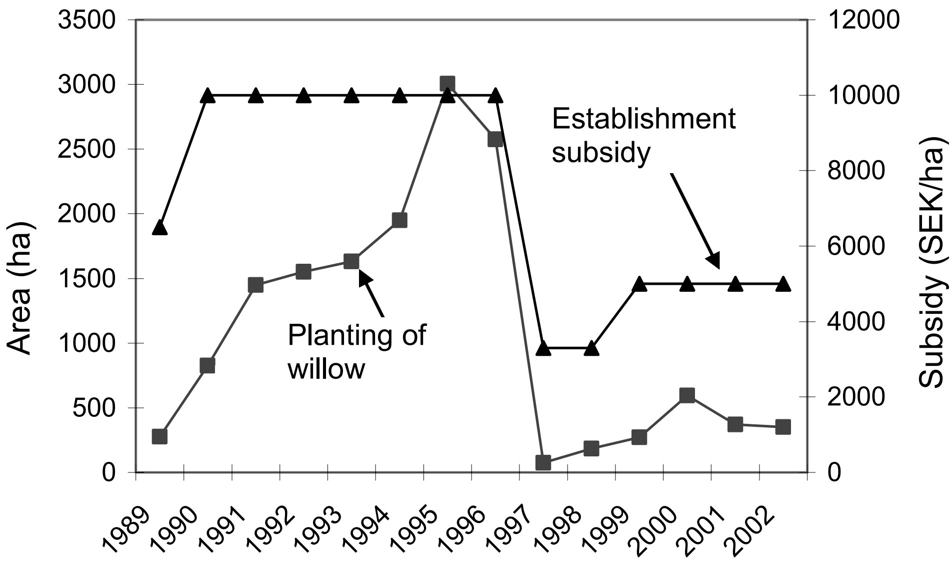


Figure 1. Establishment support and area planted with willow in Sweden. 1 SEK=0.11 € (Stem-rapport)

3.3.3. Economical feasibility

The economics of growing willow in the Nordic countries has to our knowledge only been studied for Sweden and Denmark. These calculations were based on the same model developed by H. Rosenqvist. The calculations show that the total costs of growing willow is similar in Sweden and Denmark being equivalent to a wood chip price of about 15 €/MWh (Table 7). The Danish study also includes *Miscanthus* and reed canary grass, whose economics are relatively similar to that of willow but slightly worse on the good soils. Since the relative economics of energy crops to food crops is so important in the farmer’s choice of crop, these two studies also included the economics of growing wheat and barley. These studies indicate that on very good soils (good clay soils) wheat and barley are definitely more viable crops than the energy crops (no subsidies included). *Willow, Miscanthus* and *Reed Canary Grass* could, however, be equally viable on medium to poor soils despite harvests being lower there. Since willow wood chips account for such a small share of the biofuel markets in Sweden and Finland the fuel price is mainly set by the price of wood chips from forestry residues.

Establishment costs are generally high for perennial crops, accounting for about 20% of the total costs of willow production. The establishment costs have a significant effect on farmers' liquidity since they are incurred during the first and second years of the plantation lifespan whereas the first income is not obtained until the fourth year. Poor liquidity may, however, be reduced by granting farmers an establishment subsidy, which has and is being done only in Sweden.

In Sweden, Denmark and Finland, where agricultural policy is set by the CAP, energy crops such as willow enjoy the same area subsidy as cereal crops. In contrast to cereals, however, energy crops may be grown on the mandatory set-aside areas. When energy crops are grown on agricultural land that is not part of the set-aside area they are, in addition to the area aid, also eligible for a so-called carbon credit, which is an annual subsidy of 45 €/ha. Assuming a yield of 10 tDS/ha this translates to a subsidy of about 1 €/MWh. The development in Sweden clearly illustrates that an establishment support is needed for tipping the scale.

Table 7. Annual cost distribution for willow cultivation in Sweden and Denmark.
The costs refer to a situation where an area of at least 10,000 ha is covered by willow plantations in each country. Land rental costs and common business overheads are excluded. The discount rate is 6%. The lifespan of the willow plantation is 22 years. First harvest is after 4 years and then every third year. Planting density is 12,240 cuttings per ha. Energy content of the willow crop is 4.5 MWh/tonne. Average exchange rates from 2003 are used, which implies that the costs presented here may differ from those presented in the studies: 1 € = 9.1 SEK and 1€ = 7.4 DKK. (STEM-rapport, 2003; Parsby and Rosenqvist, 1999)

	Annual cost distribution (€/ha)	
	Sweden[a]	Denmark[b]
Establishment	86	86
Fertilization	93	88
Harvest	106	84
Field transport	33	51
Transport to thermal plant	116	97
Brokerage	39	
Supervision, administration	17	15
Wind-up	5	14
Weed control after harvest	4	1
Total	499	436
Total (€/MWh)	15	15

a The annual willow yield is 5.25 tonne/ha until year 4 and 9 tonne/ha after that.

b The economics refer to clay soils. The annual willow yield is 6.25 tonne/ha until year 4 and then 9 tonne/ha after that. Costs refer to 1997/98 price levels.

3.4 Energy crops market development

Willow plantations are established with stem cuttings, typically 20 cm pieces, planted in rows with about 15,000 cuttings per ha. Site preparation starts in the autumn prior to planting. Vegetation is then killed by application of glyphosate, a herbicide. In the following spring the soil is harrowed and rolled, after which planting is carried out. During the next couple of years, only mechanical weed control is applied. During the winter after planting the shoots are pruned, i.e. cut back in order to promote the growth of several vigorous shoots from each plant during the following spring. The first harvest is after 3-4 years and then periodically again every 3-4 years. Harvest is carried out in winter, which is preferable since that is when heat demand is highest. Two types of harvesters are used, one slightly modified maize harvester and one based on a sugar cane harvester. The willow is typically chipped at harvest for road-side short-term storage or for direct transport to a district heating or CHP plant. District heating is widely used in Sweden, Denmark and Finland, accounting for about 50% of the demand for space heating and tap water. Since the 1990's the use of biofuels in general has been growing in these large-scale applications in Sweden, Denmark and Finland. During this period relatively strong incentives for using renewable energy were introduced in these countries, e.g. a carbon dioxide tax on fossil fuels. For Sweden it is clear that the established use of forest-based biofuels have greatly facilitated the use of willow for energy purposes. Wood chips from willow are very similar to those from forestry residues, thus enabling combustion in the same type of boiler without retrofitting. In Sweden there were at least 20 district heating plants burning willow in 2002-2003. The willow wood chips were normally co-fired with other biofuels and accounted for some 15-20% of the fuel supply (mainly due to the limited willow production). In recent years there has been considerable interest in linking willow production with wastewater treatment as a way of increasing profitability (the farmer is paid twice, once for taking wastewater or sludge, and again for selling wood chips). The interest in conventional willow plantations is increasing again motivated by the establishment support, the carbon credit, and a couple of heating seasons with high wood fuel prices.

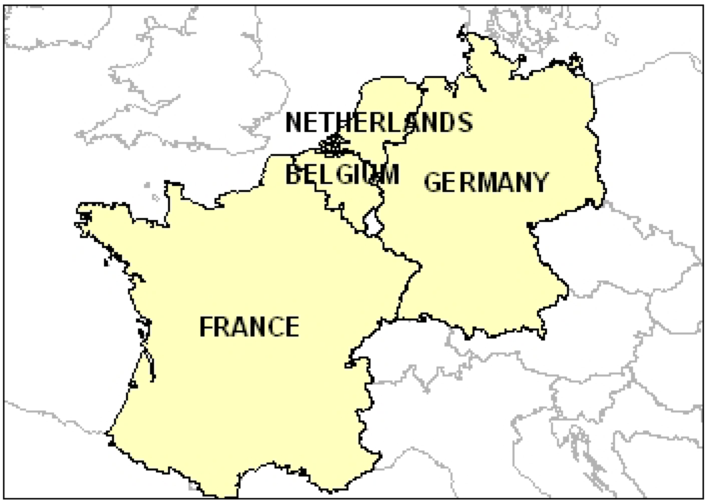
3.5 Regional recommendations for energy crops

Besides the fact that willow and reed canary grass (and partly miscanthus) are well-suited crops for the climate conditions in Northern Europe, these crops have also attracted interest due to their high biomass yields and relatively low needs for inputs of energy and fertilizers. So far the cultivation of these crops has not been intended for the production of transportation fuels. Instead they have been destined for production of heat and electricity, a priority which is partly the result of the extensive use of district heating in Sweden, Denmark and Finland.

4. WEST

The Western region consist of following countries:

Germany France Netherlands Belgium



4.1 Natural conditions

In the examined Western European countries in RENEW 4 ecological zones predominates the area:

- Temperate oceanic forest (includes parts of Germany, France, total Netherlands and Belgium
- Temperate continental forest (includes parts of south-east Germany)
- Temperate mountain system (includes the French Pyrenees, Massif Central, Jura and Alps)
- Subtropical dry forest (includes parts of south-east France and the French islands of the Mediterranean Sea)

The following definition was reported by the FAO. And describes the ecological conditions in all 4 relevant zones.

Temperate Oceanic Forest

The climate is influenced by the Gulf Stream and the proximity to the ocean. The influence decreases inland and is replaced in the Po plain by a different climatic parameter with similar effects. The average annual temperature ranges from 7° to 13°C and annual rainfall varies from 600 to 1700 mm. While in coastal areas the temperature of the coldest month does not fall below 0°C, inland mean temperature is locally below 0°C.

Temperate Mountain System

As the highest altitudinal belt of the temperate domain the mountain region is characterized by generally greater precipitation and lower temperature, the climate is extremely varied.

Precipitation varies from less than 500 mm to more than 3000 mm. The average annual temperature ranges from -4° to 8°C (locally 12°C) and the average January temperature at the highest altitudes fluctuates between -10° and -4°C.

Subtropical Dry Forest

In Europe, subtropical dry forests are found in the Mediterranean region below 800 m altitude, as well as all the European islands of the Mediterranean Sea. The distribution of olives and holm oaks roughly defines their boundary.

The Mediterranean climate provides dry, warm summers and cool, moist winters without severe frosts. Precipitation maxima are normally in November/December and February/March. Pronounced elevational relief produces substantial local differentiation. Average annual precipitation is between 400 and 900 mm, rarely above 1200 mm (e.g. Kerkira) or below 400 mm (e.g. southeastern Crete). The amount of precipitation decreases slightly to the east. The average temperature of the warmest month is between 25° and 28°C, that of the coldest month between 6° and 13°C.

4.2 Agricultural characteristic

The pattern and diversity of agriculture reflects Europe's geography and political history. North-west Europe is generally associated with large-scale, highly productive arable or livestock production, while mixed and fragmented patterns of production are typical of southern Germany, France and northern-central Italy (Potter, 1997).

In western Europe (WE), the common agricultural policy (CAP) and several national policies encouraged intensification. This took various forms, including the sustained use of chemical inputs, increasing field size and higher stocking densities. Intensified farm management led to discontinuation of traditional fallowing practices and crop rotations resulting in a displacement of leguminous fodder crops with increased use of silage and maize. Specialisation and intensification have resulted in a decrease in the number of farm holdings and numbers employed, as well as a regionalisation of production leading to less diversity of local agricultural habitats. (EEA, 2003)

Energy crops are CO_2-neutral which means that they only produce the same amount of CO_2 that is burned in the thermo-chemical conversion process as the plant could ingest during its lifetime. Generally, economically useful energy crop cultivation is signed by high biomass outputs with a high percentage of dry mass (>80%), a few amount of nutrients and the plant material is free of pest management residues. (BLV, 1998)

Livestock numbers and energy crops

Apart from cattle, overall numbers of pigs, poultry, sheep and goats have increased, but the total agricultural area used by these types of farms has fallen. This reflects the trend towards specialisation and intensification. Recent food scares, concern about farm-animal welfare and the risks associated with feedstuffs fed to farm animals have raised questions about some modern farming systems.

High densities of animal populations are associated with excessive concentrations of manure and an increased risk of water pollution. The contribution of livestock to gaseous emissions is also significant — about 80-90 % of total EU ammonia emissions (from animal housing) and 45 % of total methane emissions arise from animal husbandry. (EEA, 2000)

Fertiliser use

The downward trend in the use of inorganic fertiliser (nitrogen and phosphorus) has recently been reversed (Figure 2). The use of manure to supplement or replace inorganic fertilisers may explain some of the initial decrease. However, agriculture continues to be the main source of nitrate pollution in Europe. (EEA, 2000)

Table 8. Total nitrogen and phosphorus fertilizers used in the Western European countries and the EU

kg/ha	1980	1985	1990	1995	1996
Belgium + Luxembourg	191,6	188,6	177,9	145,8	145,8
France	123,5	123,2	125,5	113,9	119,2
Germany	.	.	132,9	125,2	125,4
Netherlands	280,0	287,8	231,4	229,7	233,8
EU	109,3	112,7	105,3	98,1	98,0

Irrigated land

Agriculture is a major consumer of water (at an average 30 % of total water use in EU15 countries) compared with other sectors. Between 1980 and 1996, the area of irrigated land expanded significantly (by about 15 %), particularly in southern Europe. For example, the irrigated area in France more than tripled from 870 thousand hectare to 2.5 million hectares between 1980 and 1995.

The main irrigated crop in terms of area is maize. In Western Europe irrigation is also used on other annual or permanent crops to boost or stabilise yields as well as to ensure high-quality produce. The expansion of irrigated area has increased the demand and use of non-farm resources, thus exerting other burdens on the environment besides water stress. More efficient ways of irrigating land such as drip irrigation have reduced dosage rates, but this improvement has often been offset by an increase in the irrigated area. (EEA, 2000)

Organic farming

Across the EU countries, organic farming area increased between 1997 and 2003, to 5.6 million hectares from 2.4 million. This constituted 3.4 % of agricultural area and 142.000 organic farms. In 2003, the organic area in Germany comprised 734.027 ha (about 4.3 %), in France 550.000 ha (about 1.8 %), in the Netherlands 41.865 ha (2.2 %) and in Belgium 24.163 ha (about 1.7 %). (FiBL, 2005)

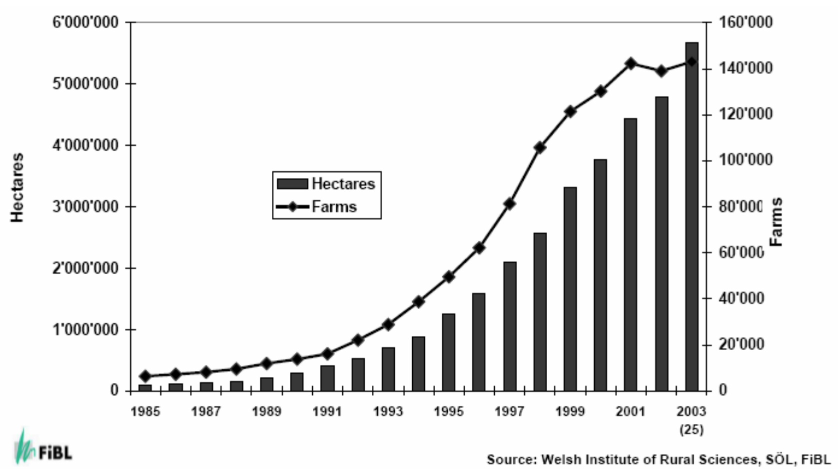


Figure 2. Development of organic farming in the European Commision between 1988-2003

4.3 Experiences with energy crops

The following tables give an overview of practical experiences and expectation with lignocellulose energy crop species in Western European countries (GER, NL, BEL, partly FR). Generally, the cultivation of lignocelluslose energy crops is no typical kind of agriculture in West Europe so far. In Germany the most common specie is Miscanthus which is used for different kinds of isolation, in the textile industry and somewhere else since years. However, several R&D project were run during the last two decades and also presently on hundreds and more hectares in the specific countries to get practical experiences with the planting, cultivation, harvest and techniques of energy crops. The improvement of the seedlings/rhizomes, fertilisation, constant high harvest results as well as environmental & combustion technical requirements of energy crops are main research objectives.

The following tables describe common perspectives of energy crop developments, existing farming practices and economical results of cultivation tests in West European countries.

4.3.1. Energy crops development perspectives in West Europe

Driving forces	Barriers and limitations
increase of agriculture value added independency of fossil fuels tax exemptions of biofuels, subsidies for ecologically produced bio-materials (e.g. isolation in GER) the permanent soil cover in perennial crops can reduce surface run-off of soil, nutrients and organic material perennial crops are usually efficient at taking up nitrate due to their long growing season and the permanent root system energy plants are usually harvested when the nutrients have been retranslocated or leached from the crop (woody crops and C_4 grasses have the highest nutrient value depending on length of harvest cycle) nutrient use efficiency of energy crops (NUE about 20) is higher (N, P and K) than of common agricultural crops with high lignocellulose content and low ahs content High water use of willow and poplar makes the crops suitable for planting on sanitary landfills or in vegetation filters for wastewater management to minimize leachate discharge along with an uptake of surplus nutrients. From all energy crop species poplar and willow causes the minimize emissions during cultivation and conversion process and they convince with a high accumulation capacity of cadmium and other heavy metals.	inflexibility of farmers for new cultivation methods long growing period of perennial crops (income breaks) introduction of new (expensive) technology to farmers temporary legal uncertainties risk of increased problems with pest, diseases (especially valuable for young willow plants) and frost resistant (especially for young Miscanthus plants) shortage of water is under practical conditions the most important yield-limiting factor due to high crop water consumption of energy crops in comparison to agriculture plants, under optimum temperature conditions the WUE (water use efficiency) of C_4-plants like willow is twice as high than of C_3-plants (e.g. weed, barley, potatoes, sugar beets); thus perennial crops may limit aquifer recharge (however there are alternatively annual crops with lower water use, e.g. Miscanthus) but have a high WUE

4.3.2. Energy crops and existing farming practices

Ligno-cellulose energy crop species for Western European countries	General issues	Cultivation			Harvest		Storage	Delivery	Conversion or Use
		Soil condition	Establishment & Maintenance	Technology	Time & Yields	Technology		Transport Form	
Miscanthus (GER, NL, BEL, FR) Nordh, 2003; www.miscanthus.de; Luger, 2002	herbaceous crop, C_4-perennial grass, lifetime: 20 years; grows up to 4m; cultivation altitude max. 700m; warmer climates; crop establishment is expensive and an environmentally critical phase;	soils with good water supply, but no permanent water accumulation;	planting of seedlings after last frost in May/June (rhizomes can be plant in autumn or spring) requires special machines; irrigation necessary by dry weather until seedling is accrued; high plant density (4 plants/m²) minimizes the winter losses (e.g. up to 30% in GER) in the first year but comprises a risk of profit cuts in the following years, thus 2 plants/m² is recommended; in the winter period the sprouts/tips die off; balance fertilization after each harvest;	ploughing and harrowing with standard equipment; plantation with special machines, low-cost-method with adapted potato harvester and planter to collect and plant the rhizomes (70-95% emergence rate, depending on time between harvest and planting); irrigation and mechanical weed control during the first two growing seasons requires only standard equipment; fertilization and maybe irrigation with standard technology as well as for mowing followed by swathing, pick-up, compacting and baling	annual harvest possible after the 2nd year but harvest window is limited: autumn (higher yields) or spring (mineral content is lower); harvesting of stalks and to some extent leaves; average harvest result after 3rd year of establishment without irrigation and average air temperatures 15-25 odt/ha and year, nitrate leaching is low	so far no special harvest equipment has been used; two method can be distinguished: *multi-phase* using several existing farmer machines (e.g. forage harvester like for silage maize or grass, choppers pulled by tractors, a self-propelled baler which decreases the transport amount) involving mowing, swathing, pick-up, compacting and balling or *single phase* (=> saving labor time) using only one machine which does moving followed by chopping, baling, bundling or pelleting in one step	storage like dry straw; water content of raw material 12-15%, if moisture content higher (winter harvest) outdoor storage in piles with plastic foils covered or drying in inside-storage must be feasible	bundles, bales or pellets	used in the geotextile and automobile industry, pulp & paper industry, in the building material branch (isulation material, plaster, light-weight-concrete, screed), gardening (peat compensation); for energy purposes (burning, gasification, liquefaction)

Poplar (GER, NL, BEL, FR) Deimling, 2000 Luger, 2002 Nordh, 2003	short rotation forestry (SRF); lifetime: 25-30 years; tolerates warmer climates than willow; crop establishment costs are high, but poplar is more resistant to environmental influences than willow (e.g. pest, diseases, water shortage);	soil quality >30 points (regarding German soil quality classification system); dry and light soils are unsuitable, a root penetration up to 60cm must be possible; soil preparation with lime by acid soil conditions; crop water requirements for willow are high; generally have woody energy crops a relatively high water consumption in comparison to other lignocellulose plants due to mass cultivation; thus a good water holding capacity is especially required for willow	Cultivation through cutting of 20cm; 2 plants/m² is recommended (about 18000 plants per ha; it can be calculate with an outfall of 15%); only in the 1st year an intensive pest reduction is required (chemically/mechanically); risk of game-muck by willow in the 1st year, thus eventually fences necessary; balance fertilization each year (nutrient removal of soil per produced odt biomass: 4-7 kg N; 0,8-1,8 kg P; 2,5-4 kg K) but no N-fertilizer in the 1st year (encourages pest plants); from the 2nd year of establishment fertilization is recommended with 60 kg N per ha every year and 30 kg P, 36 kg lime and 6 kg Mg per ha every 2nd year; energy crop water efficiency (WUE) vary between 0.3-14.2g biomass per kg water used (impact of environmental conditions and genotypic variations)	planting in double row design with alternating inter-row distances of 0,75-1,25/1,50m and a spacing of 50cm between cuttings (adopted to fit the machinery); a sugar cane planting machine is e.g. suitable for chopped willow material which is laid horizontally in the ground or a hand-planting-machine can be used; heterogeneity of field has strong influence on yields; fertilization of older crops with special machines	rotation period: 3-4 year intervals; harvest between October-April; from the 3rd year annual increment by low yield level: 6-7 odt/ha, medium yield level: 8-9 odt/ha; high yield level: 10-18 odt/ha; first yield is often not so profitable than the ensuing yields; water content by harvesting is always about 50-60%	harvest mass after 3-5 year cycle about 70-100 t/ha fresh biomass; kinds of harvester: *cut-only harvester* (cuts the stems and leaves them in the field for later collection and chipping), *cut-and-bundle harvester* (cuts and collects the stems in bundles and drop them in the field for later collection and chipping), *cut-and- extract harvester* (cuts, collects, loads the stems on a deck and unloads them at the field edge for later chipping) or *cut-and-chip harvester* (cuts, collects and chips the stems and loads the chips in containers); harvesters can be towed or carried by a tractor or self-propelled, based on the way they are connected to their prime mover; the recommended stem harvest level is 5-10cm over the ground, due to the largest proportion of woody biomass is in the thick end of the stems;	transport of chips directly to the users or suppliers without additional drying or storage or interim storage in the wood or on another outside stock ground leaves by the harvest increase the humidity of the chips and causes in fungal decay during the storage	wood chips, structure depending on chipper (15-100mm), bulk density 260-440 kg/m³ (fresh matter)	used for heat and electricity production so far
Willow salix. (GER, FR, NL, BEL) Deimling, 2000 Luger, 2002 Nordh, 2003 Jorgensen, 2001	Short rotation forestry (SRF); lifetime: 25-30 years; suitable for northern parts of EU; crop establishment is good, cheap and seems to be environmentally friendly; high water availability necessary; risk of pest problems;				rotation period: 3-5 year intervals depending on development; maximum stem diameter at harvest level about 60-70cm, about 7m high; harvest between Nov.-March (when the shoots have dropped the leaves and the ground is likely to be frozen); from the 3rd year annual increment by low yield level: 4-6 odt/ha, medium yield level: 7-9 odt/ha; high yield level: 10-18 odt/ha; first yield is often not so profitable than the ensuing yields; water content by harvesting is always about 48-55%				

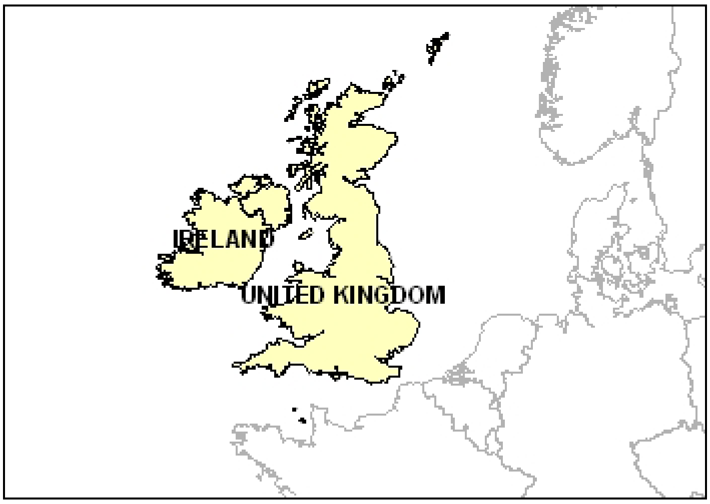
4.3.3. Economical feasibility of lingo-cellulose Energy Crops

<table>
<tr><th>Energy crop species</th><th>Cultivation areas in West Europe</th><th>Production Costs incl. cultivation & harvesting</th><th>Production Costs incl. cultivation, harvesting, storage & delivery</th></tr>
<tr><td>Miscanthus
(GER, NL, BEL, FR)</td><td>1998:
163 ha in GER, 20 ha in NL, Small research plots have been established as part of the European Miscanthus Network</td><td>2500-5000 ECU/ha; GER, 1996 (Luger, 2002)
1000 ECU/ha; DK, 1996, low-cost-method with adapted potato harvester and planter; similar experiences in NL with this technology (Luger, 2002)</td><td>34-75 ECU for 50km delivery odt; 1996 (Luger, 2002)
reduced cost experiences from 76 to 44 ECU per odt in DK by changing harvesting period from spring to winter, because of yield increases and reduced storage costs (Luger, 2002)</td></tr>
<tr><td>Poplar
(GER, NL, BEL, FR)</td><td></td><td rowspan="2">550-1550 €/ha including recultivation of soil, 30 €/odt (Hofmann, 1998)
20-200 €/odt depending on manual or machinable harvesting (Burger, 2001)
25-69 €/odt with full-automated harvester, 43-66 €/odt with semi-automated harvester (Summer, 2003)
44-60 €/odt or rather 421-579 €/ha for poplar, 55-56 €/odt or rather 330-494 €/ha for willow (Scholz, 2004)</td><td></td></tr>
<tr><td>Willow
(GER, NL, BEL, FR)</td><td>2003:
100 ha in GER, 100 ha in NL, 150 ha in FR</td><td>38-86 ECU for 50km delivery odt; 1996 (Luger, 2002)</td></tr>
<tr><td>Hemp
(GER, NL)</td><td></td><td>76-80 €/odt or rather 711-883 €/ha for willow (Scholz, 2004)</td><td>84 ECU per odt in NL; 1996, high storage costs (Luger, 2002)</td></tr>
<tr><td>Eucalypt
(FR)</td><td></td><td></td><td>46 ECU per odt in FR; 1996 (Luger, 2002)</td></tr>
<tr><td>Sorghum
(FR)</td><td></td><td></td><td>between 48 ECU in Spain and 65 ECU in FR per odt; 1996 (Luger, 2002)</td></tr>
</table>

5. UK AND IRELAND (IRELAND)

The region consist of following countries:

England Ireland



5.1 Natural conditions

<u>Ireland</u>

Climatically, Ireland is better suited to grassland than crop production. The dominant influence on Ireland's climate is the Atlantic Ocean. Average annual temperature is about 9 °C. In the middle and east of the country temperatures tend to be better than in other parts of the country. Summer mean daily maximum is about 19 °C and winter mean daily minimum is about 2.5 °C in these areas. Ireland normally gets between 1400 and 1700 hours of sunshine each year. With southwesterly winds from the Atlantic dominating, rainfall figures are highest in the northwest, west and southwest of the country, especially over the higher ground. Rainfall accumulation tends to be highest in winter and lowest in early summer. The annual number of days with more than 1 mm of rain varies between about 150 in the drier parts and over 200 in the wetter parts of the country. Most of the eastern half of the country has between 750 and 1000 millimetres (mm) of rainfall in the year. Rainfall in the west generally averages between 1000 and 1250 mm. In many mountainous districts rainfall exceeds 2000mm per year. The wettest months, almost everywhere are December and January. April is the driest month generally but in many southern parts, June is the driest (Met Eireann, 2005). Over 50% of Irish grasslands have a growing season of 270 days, the remainder having 300 days, with some of the southern and western coastal areas having up to 330 days. This is a significantly longer growing period compared with most of the rest of temperate Europe (Cullenton and Dillon, 2004).

Typical Irish soils include the following:

1. Podzols- low in humus (not fertile). Found in west Cork.
2. Brown soils- high in humus content (fertile). Found in the South East and Midlands.

3. Peat soils- very acidic and therefore not very fertile, but suitable for coniferous trees.
4. Grey soils- often badly drained, and usually not fertile. Found in Ulster.

UK

The climate and topography of the UK lends itself to two distinct types of farming. Pastoral farming (the use of grass pasture for livestock rearing) is found in areas of higher rainfall and among the hills, predominantly to the north and west of the UK. Arable farming (land that can be ploughed to grow crops) is concentrated in the south and east of the UK where the climate is drier and soils are deeper (www.metoffice.com).

England

The sunniest parts of the United Kingdom are along the south coast of England. Many places along this south coast achieve annual average figures of around 1,750 hours of sunshine. Rainfall in England varies widely. The Lake District is the wettest part, with average annual totals exceeding 2,000 mm. All of East Anglia, much of the Midlands, eastern and north-eastern England, and parts of the south-east receive less than 700 mm a year. July is normally the warmest month in England, and the highest temperatures of all have occurred in central districts. Over England the mean annual temperature at low altitudes varies from about 8.5 °C to 11 °C, with the highest values occurring in Cornwall. Around the coasts February is thus normally the coldest month, but inland there is little to choose between January and February as the coldest month (www.metoffice.com).

Scotland

Scotland is more cloudy than England, due mainly to the hilly nature of the terrain and the proximity of low-pressure systems from the Atlantic. Parts of Angus, Fife, the Lothians, Ayrshire, and Dumfries and Galloway average over 1,400 hours of sunshine per year. Mountainous areas have annual average of less than 1,100 hours of sunshine in the Highland region. Mean daily sunshine figures reach a maximum in May or June, and are at their lowest in December. Typically, measurable rainfall (an amount of 0.2 mm or more) occurs on over 250 days per year over much of the Highlands, decreasing to around 175 days per year on the Angus, Fife and East Lothian coasts. Over Scotland the mean annual air temperature at low altitude ranges from about 7 °C on Shetland, in the far north, to 9 °C on the coasts of Ayrshire and Dumfries and Galloway in the southwest. In general, January and February are the coldest months. The daytime maximum temperatures over low ground in Scotland in January and February average around 5 to 7 °C. The lowest temperatures occur inland, July and August are normally the warmest months in Scotland. The highest temperatures normally occur inland (www.metoffice.com).

Wales

Wales is cloudier than England, because of the hilly nature of the terrain and the proximity to the Atlantic. Even so, the south-western coastal strip of Dyfed manages an annual average total of over 1,700 hours of sunshine. The dullest parts of Wales are the mountainous areas, with annual average totals of less than 1,100 hours. Mean daily sunshine figures reach a maximum in May or June, and are at their lowest in December. Rainfall in Wales varies widely, with the highest average annual totals being recorded in the mountainous areas of Snowdonia and the Brecon Beacons. Snowdonia is the wettest part of Wales with average annual totals exceeding 3,000 mm, but coastal areas and the east receive less than 1,000 mm a year. Throughout Wales, the months from October to January are significantly wetter than those between February and September, unlike places in south-east Scotland or in the English Midlands where July and August are often the wettest months of the year. Over Wales the mean annual temperature at low altitudes varies from about 9.5 °C to 10.5 °C, with the higher values occurring around or near to the coasts. In winter, temperatures reach their lowest values in late February or early March. Around the coasts February is thus normally the coldest month, but inland there is little to choose between January and February as the coldest month. July is normally the warmest month in Wales (www.metoffice.com).

Northern Ireland

The coastal strip of County Down in Northern Ireland manages an annual average total of over 1,400 hours of sunshine. Mean daily sunshine figures reach a maximum in May or June, and are at their lowest in December. Rainfall in Northern Ireland varies widely, with the highest average annual totals being recorded in the Sperrin, Antrim and Mourne Mountains, where the yearly fall of around 1,600. The wettest months are between August and January. Over Northern Ireland the mean annual temperature at low altitudes varies from about 8.5 °C to 9.5 °C, with the higher values occurring around or near to the coasts. In winter, temperatures are at their lowest values in late February or early March. July is normally the warmest month in Northern Ireland (www.metoffice.com).

5.2 Agricultural characteristic

Ireland

The total area of land in Ireland is 6.9 Mha of which 4.4 Mha is devoted to agricultural land. 0.9% of the total agriculture land is currently used for arable crops; the remaining 91% is used as grassland or for rough grazing. Cereals account for approximately 80% of arable land of which four arable crops are produced in significant quantities: cereals (0.3 Mha), sugar beet (0.032 Mha), potatoes (0.014 Mha) and forage maize (0.015-0.020 Mha) (SEI, 2004.; CSO, 2004). 0.6 Mha is in forestry. There is circa 0.029 Mha of seta-side annually and 0.016 Mha of fallow land. Grassland areas are devoted predominantly for milk, beef and mutton production (Rice, B., 2004).

In Ireland cereal production is mainly located in the south and east of the country. This is due to a number of factors but principle because of climate and soil type. Cork is the largest county in Ireland thus is the most farmed land at approx 534,000 ha which is 363,000 ha above the national average. The five counties with the lowest agricultural production are Leitrim, Longford, Sligo, Dublin and Monaghan. Dublin is an urbanised county and this explains its low value. The other counties are all located in the north and west and would not be expected to be ideal locations for energy or tillage crops.

The employment figures in agriculture fell from 330,000 in 1960 to 110,000 in 2003. There were around 136,500 individual farms in 2002. Their average size in terms of land area is 32 hectares although there is considerable variation around this average. The average area farmed is large compared to the EU average, but because of the relatively low intensity of land use the average size of farm business in Ireland is relatively small in EU terms. There is an important regional dimension to differences in farm size, with a predominance of smaller farms in the West and the North-West, and a greater proportion of larger farms in the South and East. Small farm size is frequently associated with a low-margin farming system (mainly drystock) and a predominance of older farmers. The number of farms is falling over time, at a rate of about 2 per cent per annum. A more disaggregated analysis shows that all of the decline is concentrated among smaller farms (less than 20 ha) whose number fell from 85,000 to 59,000 between 1992 and 2002, while the number of larger farms is stable at around 77,000 (www.tcd.ie).

United Kingdom

In June 2004, the total agricultural area in the UK was 18.4 Mha, some 77% of the total land area. There was 4.5 Mha of arable land (25% of agricultural land) and cereals accounted for approximately 70% of this. The main cereal crops grown were barley (1Mha), wheat (2Mha) and oats (0.1Mha). Total area under set-aside was 0.56Mha, an 18% drop from the previous year. (DEFRA, 2004). In the same year the U.K. had 0.037 Mha of fallow land.

In the U.K the vast majority of cereal production is concentrated in the east and south of the county. Ranking the regions in order of magnitude reveals that West Midlands, London region, Merseyside, Tyne and Wear, and Greater Manchester are the five lowest crop-producing counties. All of these regions are all highly urbanised and have little agricultural land. The highest agriculture producing counties are Lincolnshire, North Yorkshire, Norfolk, Devon and Humberside. These are large counties with a tradition of agricultural and good land. There are all located in the east of the country expect Devon which is in the southwest. The counties in the east already have a lot of land in arable agriculture. Devon has a large pool of permanent pasture. At almost 300,000 ha, it has the largest permanent pasture area in England and Scotland only surpassed by Dyfed in Wales.

In the UK there are approximately 300,000 active farms with an average size of around 57 hectares. However the UK's high average size is swelled by the impact of Scotland where the average farm size is over 100 hectares. In England average size is around 50 hectares. For Wales and Northern Ireland, sizes are smaller at around 40 hectares. Despite the relatively large number of farms in the UK, the majority of the agricultural area is farmed by a much smaller number of farmers. Some 41,000 farms (~14% of the total) are larger than 100 hectares and account for over 65% of the agricultural area. In 2003 the UK farming workforce (full-time, part-time and casual) amounted to 184,000 persons. There were 160,000 full time farmers with a further 190,000 part-timer owners engaged in some capacity in the farm business. The total farming labour force of 533,000 in 2003 was down by 100,000 on a decade earlier (www.ukagriculture.com).

5.3 Experiences with energy crops

5.3.1. Field trials

Willow *salix*

Willow is considered to be the most suitable energy crop in Ireland in the short term (Bulfin *et al.,* 1995). Willow is easy to propagate from cuttings, shows excellent sprouting and coppice abilities, and thrives on wetland unsuitable for other crops. *Willow* SRC is the most researched energy crop in Ireland, and the most likely to achieve commercial exploitation (Van den Broek *et al*., 1997). The production of willows varies considerably depending on site conditions and management. Yields of willow at first harvest are 30 odt/ha (Nix, 2003).

Poplar

This is a fast growing broadleaf tree that grows best on good agricultural land. A study of the potential of poplar growing as an alternative to other agricultural systems by Teagasc proved that it was as viable as willow. It was recognised that fertilisation would be required on soils of poor nutrient status. Research concentrated on *Populus* clones, which was mainly on arable agricultural land produced yields for poplar of up to 13 oven-dry tonnes per hectare per annum on experimental plots, on a rotation of 5 years. The midlands and south-east are most suitable for growing short-rotation forestry, though sites can be found in all parts of the country. In Ireland Teagasc concluded that approximately 40.7% of the total land area, which corresponds to 55.8% of the agricultural area of Ireland, is suitable for growing poplars (Rice, 2004).

Miscanthus

Current R&D suggests the *Miscanthus* crops appears to be a very promising energy crop in Ireland and the U.K. *Miscanthus* productivity trials have been conducted for more than ten years in Ireland. The high yield, low dry matter and ease of establishment are useful advantages. Fields trials throughout Europe have confirmed the potential for high biomass production from *Miscanthus*. Productivity models from field trials have been scaled up to provide yield estimates at regional, national and continental areas. Model predictions suggest that *Miscanthus* yield in Ireland ranges from 16 t ha^{-1} in the north east of the country to a maximum of 26 t ha^{-1} in the south west. In the UK Miscanthus peak yields reached 18.6 t ha^{-1} yr^{-1} (Clifton-Brown *et al*., 2000). Rainfall in Ireland is not limiting to yield but the length of the frost-free period will determine the length of the growing season and so will account for some of the inter-annular variation in yield (IENICA, 2003). So far in most cases no specific machinery has been designed for the harvesting of *Miscanthus* but the existing machinery for other crops has been used. There are usually two methods of harvesting. Multi-phase using several machines, mowing followed by swathing, pick-up and baling or single phase using both self-propelled and trailed choppers. For direct harvesting, row-independent maize headers will be suitable. In general, self-propelled machines have the highest extraction capacities.

5.3.2. Energy crops development perspectives

UK policies have helped stimulate capital investment in major biofuel production plants. The total sales of biofuels in the UK in 2004 were some 13,606,400 litres, whilst total road fuel sales were approximately 48,000 million litres. As a percentage of total road fuel sales, biofuels contributed about 0.03%. Energy crops are deemed to play an important role in the future agricultural sector. The constantly increasing oil per barrel price and surplus food production, development of a biofuel industry is essential. However, the growth of energy crops in Ireland and the UK will incur problems with land competition and traditional farming practices. Of the 6.9 Mha area of Ireland, only 10% of the agricultural land is devoted to arable crops. This area of land remains relatively constant each year. Arable land is ideally suited for producing energy crops, but traditional food crops impose significant competition. Cereal production was worth €214.8 million in exports to the Irish economy in 2003. Any reduction in arable land for energy crop production will affect export income.

Enlarging the tillage area for energy crop production by converting permanent pastureland into arable land will prove difficult. Ireland and the UK have circa 2.8 and 5.5 million hectares respectively of permanent pasture each year. Ireland depends too heavily on livestock exports and its by-products to consider converting land from pastureland for energy crops. Even though Ireland is over sufficient in beef (820%), sheep-meat (303%), total livestock related exports were worth €3076.5 million to the economy in 2003 (Teagasc, 2004). Additionally some areas of permanent pasture are unsuited for cultivation. The possibility of pastureland supporting high yielding energy crops will depend on the lands physical and chemical makeup as well as field topography and geology. The anticipated high energy crops yields will in turn require the use of large machines and heavy traffic through the field at harvesting. The movement of such machines is facilitated if the fields are level. Pasturelands in various regions, i.e. Leitrim, Donegal, are unsuitable to be cultivated. In Leitrim for example, the total agricultural area used is 91,477ha. Of that 40ha is used in cereals and 48,363ha is permanent pasture, the rest of the area is made up of rough grazing, hay, silage etc. Such areas have limited potential of cultivation to the steepness of slopes, high erosion hazards, slow water permeation, alkalinity or salinity, unstable soil structure. Since these soils are less productive when cultivated they remain as pastureland and are unsuitable for energy crops or any arable conditions.

Figure 5 shows the distribution of land suitable for arable production (land use types A1, A2, A3 and B2) (Lee, 1996). This land is mainly in the southeast of the country and amounts to roughly 1 Mha (SEI, 2004).

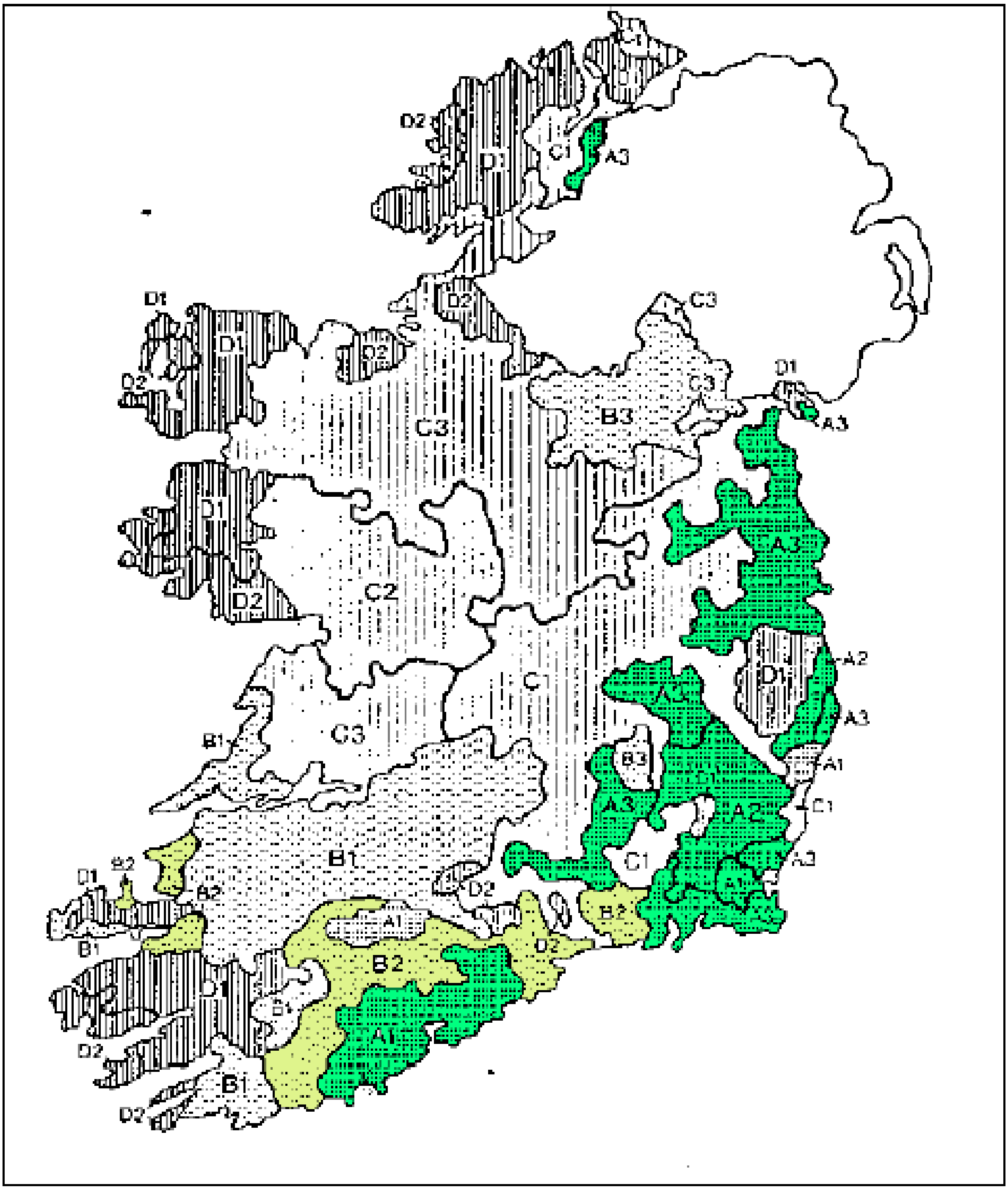


Figure 5. Distribution of land suitable for arable production in Ireland (Lee, 1996).

A1: Arable, dairying, dry stock
A2: Arable, sheep, dry stock
A3 Arable, dry stock
C1: Dry stock, arable, dairying (low)
C2: Dry stock

B1: Dairying (high), dry stock (average)
B2: Dairying, dry stock (low), arable (high)
B3: Dairying, dry stock
D1: Hill sheep (high), hill cattle (low)
D2: Hill cattle (high), hill sheep (low)

In England the cereal production is concentrated mainly in the south, East Anglia, Yorkshire and the East Midlands (Defra, 2004).

At present, there is no commercial production of energy crops, e.g. *Short Rotation Coppice/Miscanthus*, in Ireland. Although seta-side land is available for energy crops, this land is relatively small and is mainly used as forage. This land, like fallow land, is often in very smallholdings and largely fragmented leaving it difficult to manage

Historically the tilled area was much bigger than at present. However, the tilled area has remained fairly stable for the past half-century, and a big increase at this stage would have to overcome obstacles including a large investment in tillage machinery and some re-training of farmers (SEI, 2004).

5.3.3. Economical feasibility

The most appropriate species for perennial energy crops in Ireland are willow and poplar managed as short-rotation forestry or the C4 grass species, *Miscanthus* (Rice, 2004). Teagasc research on short-rotation began with an investigation into the biological and economic aspects of short-rotation forestry production on land marginal for agriculture (Neenan and Lyons, 1980). Of the broadleaf species selected for the trials, *Salix spp*. (willow) and *Populus* spp. (poplar) proved the most viable (Rice, 2004).

Most economic analyses conclude that energy coppice is not viable without a subsidy. Two types of subsidy are already available in the UK: a payment to the grower in the form of either Set aside payments or a WGS planting grant; and the tariffs offered under NFFO contracts. Despite these, there are indications that growing energy coppice for electricity generation is only marginally profitable, if at all. Subsidies for energy coppice are justified, primarily, in terms of longer term saving of CAP budget costs and reductions in emissions of greenhouse gases. Solid fuel crops represent the most immediate alternative (or complement) to energy coppice, offering several advantages. The main options are whole-crop cereals and *Miscanthus*. Advantages of the former over energy coppice include: reliance on existing, well established species, production systems and machinery; annual production and, hence, flexibility; a drier feedstock at harvest (approximately 18% moisture as compared with 55%); and a more immediate return on investments. Claimed advantages of *Miscanthus* over energy coppice include: higher yields; drier feedstock at harvest; annual production; fewer weeds, pests and diseases and relative ease of weed control using C3 specific herbicides. *Miscanthus* is, however, similar to energy coppice in requiring a longer term commitment and leaving rhizomes in the ground which would require removal, as would coppice stools. The technology to grow whole crop cereals is well established. Harvesting and storage would be as developed for large scale industrial use of straw. *Miscanthus* is at a very early stage of development. In common with other biofuels, solid fuel cropping would not be viable without a subsidy. At present Set aside payments and NFFO tariffs are theoretically available. Estimated product costs and Gross Margins from solid fuel crops are comparable or better than those from energy coppice. Solid fuel crops have the advantage of providing more immediate and annual returns. Combined production with other biofuels (eg ethanol from wheat grain, electricity from wheat straw) looks promising (Biomat, 2004)

5.4 Energy crops market development

Conventional agricultural in Ireland and the UK is based on annual crops (cereal production). *Miscanthus* which has an annual harvest cycle, will prove to be the most viable energy crop, due to the fact that conventional agricultural machinery can be used for plantation establishment, maintenance and harvesting. *Willow* and *Poplar* requires special machines for planting and harvesting, which will require large establishment investments for farmers. From a farmers perspective, immediate profitability and minimum start-up investment or little changes to traditional farming practices is required for the successful implementation of energy crops in Ireland and the UK.

In Ireland, optimum production for energy crops is mainly located in the south and east of the country. Kilkenny would stand out as the most appropriate collection point. This could draw from the Cork and Wexford and also from Tipperary, Laois and Waterford.

5.5 Regional recommendations for energy crops

The most advanced energy crop in the UK is currently short rotation coppice willow (*Salix* spp.). However, *Miscanthus* also seems to be a suitable energy crop in both Ireland and the UK. Due the national dependence on livestock exports and its by-products, converting large amounts of pastureland for energy crops will be difficult. Immediate development of energy crop production in the short term in Ireland and the UK is most likely to come from fallow and set-aside land.

6. ALPINE REGION (SWITZERLAND)

The region consists of following countries:

Switzerland Austria

6.1 Natural conditions

Switzerland

The alpine arch has a length of 800 km and a broadness of ca. 200 km as well as an average altitude of 2500 m over sea and acts as a climate barrier. Climate in the Swiss Alpine region is divided in the North and the South region. In the Northern part of the Alps maritime climate is dominating. The Southern part of the Alps is dominated by Mediterranean climate, which mean milder winters. Some valleys are protected again Northern and Southern precipitation activities. Consequence is a dry climate: typical for this kind of climate are Unterwallis and Engadin valleys. (source: Meteoschweiz, www.meteoschweiz.ch). In Davos (1590 m o. s.), the sunshine duration was 2083 h in 2003 with a precipitation quantity of 849 mm and an year average temperature of air of 4.3 °C[3]. Length of growing period is 115-180 day in the Subalpine zone (1700-2400 m.o.s.) and 180-245 days in the montane zone (1000-1700 m.o.s.).

Typical soils in the Alps are silica rocks with little humus. The classification system of the soils in Switzerland is based on a system from H. Pallmann. The FAO classification system is also increasingly used (http://www.geo.unizh.ch/bodenkunde/download/VorlesKap4_5.pdf, 30.05.2005).

[3] (Source: http://www.bfs.admin.ch/bfs/portal/de/index/themen/raum_und_umwelt/naturraum_schweiz/witterung/kennzahlen0/witterung.html, downloaded 30.4.2005)

Austria

About 60% of Austria are mountainous and have a part of the Eastern Alps (mostly Tyrol Central Alps, Hohe Tauern and Niedere Tauern, Nördliche Kalkalpen, Südliche Kalkalpen und Wienerwald). The great plains are situated in the Eastern part along the Donau.

The climate is temperate middle European and gets from West to East dryer (precipitation ca. 100 to 50 cm). Temperature and precipitation are depending strongly from the part of the country and of the altitude. It attains at the frontier to Slowakei and Hungary the pannonical continental climate. The winters are snowy. The sunshine duration is about 10-20% longer as in Germany, especially in the Southern part of Austria (source: http://www.austria.info.at/geographie_und_klima/).

Soils in Austria are about 6'000 years old. They are very different on small scale, as relief and climate is also changing in small areas. To make coarse generalizations they are in the forest areas mostly silicate brown earth, podzol brown earth and podzol, in the Northern Alp foreland "Parabraunerde", "vergleyte Parabraunerde", "Pseudogleye" and in the Southern Alpine foreland "Pseudogleye". "Rendsinen" cover big areas of the Nothern and Southern limestone Alps. The central alps are covered mostly with podzol brown earth and semipodzol (http://www.aeiou.at/aeiou.encyclop.b/b596398.htm).

Austria has its own classification of soils which is described in Nestroy et al. 2000.

6.2 Agricultural characteristic

Switzerland

Switzerland has mostly small sized farms with an average of 16.2 ha (19.9 ha when considering only full-time farmers). Intensity of production is therefore relatively low. Due to climatic differences between Lowlands and Alps and between South and North agriculture is regionally specialised. In the Alps there is mostly animal production as well as forestry. Agriculture in the Alps is strongly dependent from subsidies. Subsidies are however linked to ecological requirements. Agriculture in the Lowlands is e.g. following the principles of integrated production as a consequence of the politic on subsidies. About 10% (102'000 ha in 2002 from the total of 1.07 Mio ha) is organic agriculture (http://www.biodiversitymonitoring.ch/pdfs/M5_Datensatz_V2.pdf, 3.5.05). Agriculture in Switzerland employs about 200'000 persons (http://www.bauernverband.ch/de/markt_preise_statistik/betrieb/se_2003_0112.pdf, figure for 2003, 3.5.05). Hersener and Meier (2003) assume that fallow land will grow to 6’000 ha in 2010. This increase takes place at the expense of meadows.

Austria

Agriculture in Austria employs about 575'000 persons (incl. forestry). Average farm has 34,9 ha. This figure increased between 1980 and 1999 from 24.8 ha to 34.9 ha. The 1999 census counts 217'500 agriculture and forestry farms. 80'200 farms (37%) are managed as a main job, 129'500 (59%) as a side job. Only 7'800 farms (4%) are owned by corporate bodies. About 85'400 (39%) are classified as mountain farms. The Austrian agriculture has still small structures. Two of three farmers operate less as 20 ha total surface, only 3% of the farms (7'200) have a surface of more than 100 ha. The tendency is however of higher farm units (source: http://www.statistik.at/fachbereich_landwirtschaft/txt2.shtml)

From approximately 100,000 hectares of set-aside land in Austria only 9.2-12.4% are utilised for non-food crops (www.ienica.net/reports/AUSTRIAupdate.pdf).

Set-aside of land as an element of stabilization of the market stays with the new legislation. The minimum size of the set-aside land is decreasing (http://www.agrarnet.at/article/archive/5069/). The plantation of energy crops are supported with an allowance of 45 € per ha. Pre-requisite is that the plants are used for the production of biofuels or for the production of energy from biomass. (http://www.agrarnet.at/article/archive/5069/).

6.3 Experiences with energy crops

6.3.1. Field trials

Comparison of different energy crops in field trials couldn't be found for Switzerland and Austria. Several energy crops are possible in Switzerland. However, the position paper of the Swiss Agency for Environment, Forests and Landscape (SAEFL) on the energetic use of energy crops shows that the intensive production is not favoured any more. Hersener and Meier 1999 also show that the highest potential of biomass in Switzerland is in wood and waste products. In the Alpine region mostly grass in meadows and wood is growing.

Hersener and Meier 1999 calculate with following yields for energy crops:

Rapeseed	3 t DS/ha
Miscanthus	18 t DS/ha
Hemp	12 t DS/ha
Kenaf	3 t DS/ha
Buffer area	3 t DS/ha

According to Handler et al. 2003 the problems of the plantation of miscanthus in Austria are mostly solved. However the harvesting as well as storage of great quantities must be optimized.

6.3.2. Energy crops development perspectives

Switzerland

The position paper of the Swiss Agency for Environment, Forests and Landscape (SAEFL) on the energetic use of energy crops shows that the intensive production is not favoured any more. The energetic use of energy crops from extensively farmed areas like meadows, ecological buffer area, set-aside land etc. is however welcomed (Binggeli and Guggisberg 2003)

BFE/EWG 2004 defines the potential of following crops as following:

a) Forest, woody crops, hedges

The forest has two kinds of potentials: an increase in the harvest use and an increase in the harvest itself. From the first one ($1.8*10^6$ m^3 harvested wood that stay in the forest actually) the potential is evaluated to be about $1.2*10^6$ m^3 (2/3 of this quantity), which corresponds to about 9 PJ/a. For the second one the authors calculate with the $4.2*10^6$ m^3 of forest increment that are at present not harvested. From these also 2/3 are evaluated to be possible to harvest, which represents 21.7 PJ/a.

For woody crops and hedges the potential is evaluated to be $0.35*10^6$ m^3, which corresponds to 2.8 PJ/a.

b) Energy crops

The share of energy crops is expected according to Hersener and Meier (2003) to increase to 5% of the open agricultural crop land, which corresponds to 20’000 ha until 2025, with a yield of about 10 t TS/ha. From 2025 to 2040 the authors evaluate the increase to be 10% of the open agricultural crop land, which corresponds to 45’000 ha. This increase occurs at the expense of intensive farmed crops like turnips, cereals, maize and intensive meadows.

c) Meadows

This category includes fallow land, extensive farmed meadows, permanent meadows (which have the biggest share of this category). Alpine meadows' potential is considered in the category "a) forest", as the increase in forest area occurs at the extent of alpine meadows. The yield of meadows for energy use is considered from the authors as 1% till 2025. Optimistic scenarios evaluate the potential to be 3%.

In the context of a common project of the Swiss Agency for Energy with the Swiss Agency for Environment, Forests and Landscape, the most important process chains of the production of energy out of biomass are been studied and compared. The experiences with pilot and demonstration plants show that the general framework is of great importance for the development of the energy use of biomass. Following points are being discussed to promote and increase the use of biomass for energy production:

- Electricity redelivery, tax on CO_2, promoting programs
- Exemption of tax for biofuels
- General promoting of biofuels and their sources

Austria

The biomass association of Austria (http://www.biomasseverband.at/default.htm, downloaded on the 23.05.05) analyses as follows the biomass potential in Austria:

The government has following goals: Toronto goal (reduction of CO_2 emissions of 25%), the Kyoto goal (reduction of CO_2 emissions of 15%) and the national environment plan (trial of a realisation strategy on scientific basis). Until now the government realised a small increase of the tax on fossil fuels, a tax on electricity and a small investment program for energy from biomass.

The biomass association proposes to increase the share of bioenergy from a total of 138.2 PJ (of a total 862 PJ consumption) to 200.3 PJ. This increase to 200 PJ represents a realistic goal for the next 5-10 years. The increase for the fuels would be from 0.3 PJ to 3.9 PJ. The following table shows the share of the biomass products:

Biomass	Total energy
Wood and wood side products	45 PJ
Straw	2 PJ
Biofuels (Rapeseed)	3,5 PJ
Biogas, sewage gas	3,6 PJ
Energy plantation, 20 ha per commune	8 PJ
Total	62,1 PJ

6.3.3. **Economical feasibility**

Switzerland

BFE/EWG 2004 studied the costs of the production of bioethanol on the basis of ligno-cellulose biomass in Switzerland. Borregard Schweiz AG is the biggest producer of ethanol in Switzerland with a yearly production of 11 million litres ethanol. It plans a new plant which will produce bioethanol out of ligno-cellulose by 2010. The costs of the production of bioethanol is divided in feedstock transport costs (14%), feedstock non-transport costs (30%), investment costs (43%), fixed operating costs (9%), variable operating costs (4%). The total price in 2010 is estimated to be 1.46 CHF/l (comparison: conventional gasoline would be 1.37 CHF/l), in 2025 1.15 CHF/l (conventional gasoline 1.87 CHF/l). The results depend of course on assumptions on the development of the price of conventional gasoline.

BFE/EWG 2004 also studies the costs of production of bio-diesel from Fischer-Tropsch process. The costs (assuming that bio-diesel is exempted from taxes) are 0.15 CHF/kWh in 2010 (conventional diesel: 0.14 CHF/kWh), in 2025 also 0.15 CHF/kWh, conventional diesel however more expensive (about 0.20 CHF/kWh). The authors also calculate the costs in CHF/km for a VW Golf Trendline in 2010 (about 0.54 CHF/km).

The authors of BFE/EWG 2004 conclude that at present ethanol is far from being competitive with gasoline. The tax on alcohol would need to be reduced compared to gasoline so as to allow bioethanol to be competitive on the vehicle fuel market. Calculations also don't take into account the positive effects of bioethanol on the environment and in the social dimension. They also conclude that Fischer-Tropsch technology using biomass as a feedstock may become a competitive option. It is however depending on the condition that the costs of biomass should be decreasing below its actual projection (4 cts/kWh). A major constraint for the implementation of biomass-based FT process in industrial scale would be the competition for biomass resource with other biomass energy technologies which may turn out to be less capital intensive and offer lower production costs in short to medium term. The detailed assessment of future availability and cost of biomass is necessary for an economic assessment of the FT-biofuels technology.

Austria

According to Handler et al. 2003 the problems of the plantation of miscanthus in Austria are mostly solved. However the harvesting as well as storage of great quantities must be optimized. Therefore the economic efficiency cannot be assessed seriously.

The attainable straw price in the future is determining for the agriculture and therefore determining how the culture of straw will develop (Handler et al. 2003).

6.4 Energy crops market development

Switzerland

BFE/EWG 2004 sees the most relevant developments in the biomass use for energy goals in the production of heat from wood furnaces and of electricity from biomass in wood gasification and biogas plants. The development of the production of biofuels has in the contrary more restraints: the technology is not yet mature and the potential of biomass production in Switzerland for this application has not been studied yet. As the agriculture area isn't sufficient for the food production for the whole population and as food imports are already necessary, it cannot be expected that big areas in Switzerland can be used for energy crops like miscanthus. Forest area is however increasing, mostly in the Alpine regions.

The Swiss agricultural policy defines the goals of agriculture in Switzerland, which are to maintain a multifunctional agriculture with food production. The authors of BFE/EWG 2004 assume therefore that grassland will be used mostly for animal production also in the future and that the energy production with biomass will stay marginal.

Austria

The Austrian Energy Agency (http://www.eva.ac.at/projekte/res_overview.htm) sees great potential for biodiesel, which depends mostly on following factors: development of raw oil prices, marketing in market niches and EU-eastern expansion. Biodiesel could be get in the future concurrence for the available areas from the production of biogas from energy crops: biogas can reach a three times higher energy yield per ha as biodiesel.

The Austrian Energy Agency also quotes the organisation ARGE Biogas. According to this organization, biogas could become the most important renewable energy in Austria with the increased use of energy crops in big community facilities (Gemeinschaftsanlagen).

According to Tretter 2005 (in http://www.eva.ac.at/(publ)/publ/pdf/en4-04.pdf) the Austrian government intends to increase the share of biofuels from 2.5 % of the total energy content from Otto and diesel fuels to 5.75% in 2008. Driving force of this development is the European directive on biofuels of 8th of May 2003.

6.5 Regional recommendations for energy crops

Switzerland

The most important biomass for energy use in Switzerland is wood and organic waste. The authors of BFE/EWG 2004 assume therefore that grassland will be used mostly for animal production also in the future and that the energy production with biomass will stay marginal.

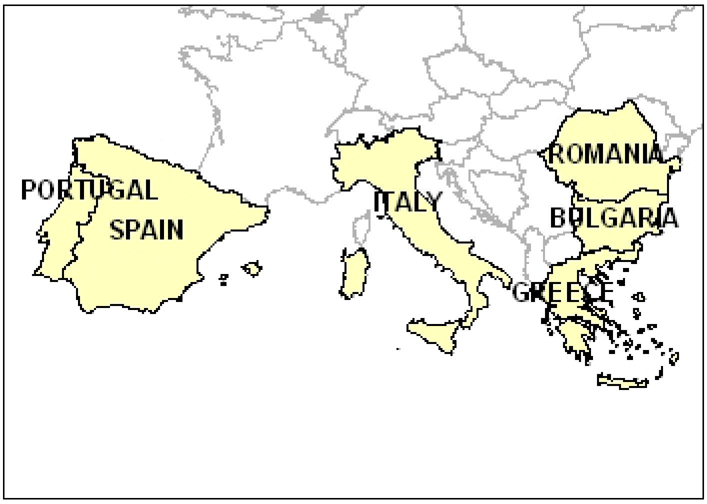
Austria

The most promising crops for Austria are rapeseed, followed by sunflowers and soy bean (Handler et al. 2003). Surface to be used are the set-aside areas. On these surfaces rapeseed is the most important crop actually cultivated. Miscanthus has also good potential in Austria; however there are still problems by the harvesting technique and the storage of great quantities which should be solved.

7. SOUTH (GREECE)

The Southern region consist of following countries:

Greece Spain Portugal Italy Romania Bulgaria



7.1 Natural conditions

The climate of the south is characterized by mild rainy winters and warm to hot dry summers, with high solar radiation and high rates of evaporation (Boydak and Dogru, 1997). The climate may be broadly defined as Mediterranean and one in which winter rainfall is more than three times summer rainfall (Aschmann, 1973 and Wigley, 1992). This seasonal contrast is most pronounced in the south and east of the region, where most of the annual rain may fall in a few days of torrential downpours. In the south, the influence of the sea makes coastal areas cooler and rainier. Mountains, such those in former Yugoslavia, Bulgaria and western Greece, receive more rain. This complex pattern of spatial and seasonal variability is exacerbated by the unpredictability of rainfall from year-to-year (Hulme, 1994).

The soils throughout the Mediterranean region have some common features. Red and reddish-brown soils of heavy texture have been developed over limestone, the Chromic Cambisols and the Chromic Luvisols. Despite their high clay content, these soils are well drained because of their texture and the presence of permeable subsoil. They are associated in level areas and in depressions with heavy dark clay soils, the vertisols, which, although fertile, present management problems because of unfavorable physical properties and shrink/swell characteristics. The luvisols are sensitive to erosion and they are used for vineyards, olive and citrus cultivation (EEA, 1995).

Shallow and stony soils (lithosols, cambisols, and rendzinas) are also present in the Mediterranean region. Although these soils are unsuitable for intensive arable farming and use of heavy machinery, they are commonly used for such agricultural practices in the plains.

In contrast with the soils of northern Europe, Mediterranean soils are not so vulnerable to acidification due to their calcareous parent material. However, the procedure of neutralizing the acidity (caused from extensive use of fertilizers) by $CaCO_3$ could lead to the loss of CO_2 to the atmosphere. Mediterranean sandy soils have humus-poor topsoil with limited capacity for absorption of pesticides and heavy metals. These contaminants are, therefore, available for uptake by soil fauna and flora and for leaching from the topsoil (EEA, 1995).

7.2 Agricultural characteristic

Agriculture in south European Mediterranean countries is characterized by farm holdings of small sizes. There are a large number of holdings of less than 10 ha, which are less efficient in terms of economic costs than larger farms. Although the farms are of a small size, the traditional methods of farming have changed over the last decades. Today, the duration of rotations has been minimized to 2 or 3 years and farming has been focused on more commercially productive crops (Papadopoulos and Salapas, 1978).
In addition, agriculture has become more intensive with extensive use of heavy machinery, fertilizers, agrochemicals, and large irrigation schemes. As a result of the small farm size it is rather difficult to apply a management plan on a watershed scale in order to sustain the agricultural production and minimize the environmental risks (EEA, 1995).

Employment

The more labour-intensive Mediterranean-type production which predominates in Italy, Spain, Greece and Portugal results to a higher percentage of agricultural employment which accounts for 9% of jobs on average, with Greece and Portugal rising to over 10%.

There are also differences between northern and southern Europe in terms of the age distribution of heads of holdings. The proportion of elderly farmers is generally higher in the Mediterranean countries, with nearly one in two farmers over 55 years of age as opposed to only 1% in Germany. Just 4% of Portuguese farmers and 6% of Italian farmers are under 35 (the Community average is 10% under 35).

Another important element is part-time employment in agriculture which is much more widespread in the countries of southern than northern Europe. In Greece, Portugal, Italy and Spain, nearly half of all farmers (compared to less than 30 % in the other eleven Member States) and more than half of all agricultural labourers work part-time. In Italy and Greece, more than one in three farmers spend less than half of their working time on the farm. The large number of seasonal activities in southern Europe is one explanation for this high level of part-time work. Part-time work may mean that full-time work is impossible or that the farmer is involved in other non-agricultural gainful activity.

7.3 Experiences with energy crops

7.3.1. Field trials

During the last decade years, several energy crops have been tested in the south European countries, namely Italy, Spain, Greece and Portugal.

Table 9. Energy crops

Annual	Perennial energy crops
Sweet fiber sorghum (Sorghum bicolor L. Moench)	Giant reed (Arundo donax)
Abessinian mustard (Brassica carinata)	Cardoon (Cynara cardunculus)
Rapeseed (Brassica napus)	Eucalypts (Eucalyptus globulus, Eucalyptus camaldulensis)
Kenaf (Hibiscus cannabinus)	Miscanthus (Miscanthus sinensis x giganteus)
	Black locust (Robinia pseudoacacia)
	Switchgrass (Panicum virgatum)

The main topics on which the R&D activities have focused on, are the following:

Agronomic aspects:

The main aim of this field is to obtain optimum performance by matching topography, soils, climate and location for a variety of species, varieties, hybrids, genotypes and cultivars. Three major categories are distinguished depending on the measured characteristics of each crop:

- Adaptability under different pedoclimatic conditions and cultural practices such as plant density, nitrogen fertilization applications, irrigation management, etc.
- Growth characteristics such as LAI, height, number of tillers per plant, etc. As a result, data sets for plant growth modeling are recorded.
- Biomass production as well as biofuel production per plant and per plant part.
- Biomass full chains including logistics.

Fuel characterization

The main aim of this research aspect is to categorize the energy crops according to the calorific value, fuel origin and properties (e.g. ash characteristics). Chemical analyses of various fuels include fuel proximate and ultimate analyses, ash stoichiometric analyses and characteristic ash-fusibility temperatures.

The expected deliverables of the above research tasks are recommendations on the biomass type and ratio in the fuel blend.

Environmental aspects of biomass production

Environmental impacts of crop production and energy generation are the main targets of the conducted research on this subject. Particularly, water and nitrogen balance, nitrate leaching, soil erosion and agrochemical inputs are currently being examined in cropping systems including some of the aforementioned crops. Furthermore, emissions and air quality are carefully monitored.

Conversion to energy technologies

Biomass types have also been categorized according to the suitable applied conversion technology. Namely, the systems of Pulverised Fuel Combustion (PFC), Fluidized Bed Combustion (FBC) and Pre-treatment Techniques (Gasification, Pyrolysis, and Leaching) are being used. Additionally, the preparation requirements like milling, particle size and water content, as well as specific operational problems and restrictions set by the combustion system are recorded.

Economic and social dimensions

The feasibility of energy crops to replace conventional ones is analyzed along with their exploitation for energy purposes. The cost is analyzed per production factor such as land use, farm size, agricultural income, conventional crops, energy market, etc.

Results

High biomass yields up to 30 t/ha/year dry matter have been observed in experimental trials. The examined crops can be divided to annual and perennial. The main types are presented in the Table 10 & 11 above. So far, research for energy crops aimed mainly to maximise their yielding potential per unit land, to optimise key quality characteristics as well as to develop techniques for their optimum handling processes (harvesting, baling, storing and transporting). The following tables (2, 3, 4) present data from 12 years field experimentation in Greece.

Table 10. Annual energy crops

	Sweet sorghum	Fiber sorghum	Kenaf	Rapeseed
Sowing date	May T>15°C	May T>15°C	April July	Sep.-Dec (early) Mar.- Apr (late)
Weed control	Pre-planting Post planting	Pre-planting Post planting	Pre-planting Post planting	Pre-planting Post planting
Density (plants/ha)	70,000-200,000	70,000-200,000	17,000 -32,000	130,000
Irrigation (mm)	300-700	300-700	300-700	0-500
Fertilisation (kg/ha)	N: 50-100	N: 30-50	N: 60-120	N: 30-100
Flowering	September	September	July (early maturity) September (late maturity)	March - April
Harvesting	September - October	September	November - January	June- October
Dry biomass (odt/ha)	20-40	27	8-24	3-8

Table 11. Perennial grasses

	Cardoon	Giant reed	Miscanthus	Switchgrass
Propagation	Seed	Rhizomes Cuttings	Rhizomes Cuttings Seeds	Seeds Rhizomes
Establishment	September	March	March- April	March
Weed control	Pre-planting	Pre-planting	Pre-planting For first 2 years	Pre-planting
Density (plants/ha)	10,000 -50,000	12,500-25,000	400.000	400.000
Irrigation (mm)	-	0-700	600	400
Fertilisation (kg/ha)	N: 0-100	N: 40-100	N:50	N:50
Flowering	March- April	September - October	September - October	August- September
Harvesting	July - August	February	November	February
Dry biomass (odt/ha)	17-32	20-35	26-32	26

Table 12. Short rotation forestry (SRF)

	Eucalypts	Robinia
Propagation	Seedlings Cuttings	Seedlings Cuttings
Weed control	Post planting in the establishment years	Post planting in the establishment years
Density (plants/ha)	10.000-40.000	10.000-20.000
Rotation (years)	2-3	2-3
Dry biomass (odt/ha)	18 - 24	14

7.3.2. Energy crops development perspectives

So far crops dedicated for energy purposes present a promising solution for the future providing high yields per land unit. However, there are still key factors for which further effort is required so that the continuity of supply and the quality of the produced materials are secured. The most important are listed below:

- Economic viability of these crops compared to the conventional ones.
- Pilot actions should be undertaken to evaluate full chains of energy cropping for energy and industry.
- Combination of the energy markets with the already existing alternative markets for the residues (animal feeding, pulp and paper, etc.).

7.3.3. Economical feasibility

In table 13, detailed cost estimation is provided for a number of traditional and energy crops in northern Greece. The analysis was conducted for a national project and is representative for this region. Cultivation techniques are similar for most crops with slight differences in fertilising, soil preparation and irrigation requirements.

The following highlight some of the particularities from an economic point of view.

Yields: depend mainly on irrigation. It is evident that both cardoon and miscanthus have substantially higher yields than traditional crops.

Land rent: The amount of required irrigation affects the choice of land and its opportunity cost or rent, which in the specific cases is more than double (285 euro/ha for all irrigated crops) the non-irrigated land cost (120 euro/ha).

Data for this estimation were based on national statistics (National Statistical Service of Greece, 2000), on raw data provided by the General Directorate for Agriculture in northern Greece and by local farmers interviews.

The model used to estimate farm income is based on the following equation:

$$P_{bs} = GI - TPC$$

Profit before subsidies (P_{bs}) is estimated by excluding production costs from the gross income. In detail:

Gross income (GI): is estimated as the revenue resulting from multiplying the produced quantity with the current market price.

Total production costs (TPC) are estimated by adding the various expenses (land rent, labour and equipment rent) as well as depreciation of equipment. All the costs used are market prices without subsidies and taxes involved.

Table 13. Cost analysis of traditional and energy crops in northern Greece

		Rapeseed (non-ir)	Sunflower (non-ir)	D. Wheat (ir)	Sweet sorghum	Corn	Cardoon	Miscanthus
	Yields (t/ha)	1,8	1,75	5,5	70	12	15	15
	Selling price (€/t)	400	250	130	20	132	50	50
	Gross Income (GI)	720	437,5	715	1400	1544,4	750	750
	Land Rent	120	120	285	285	285	120	285
	Ploughing	90	90	90	90	112	50	50
	Soil preparation	100	50		100	75		
	Fertilising	192	40	144	107	250	131	131
	Sowing / planting	132	84	117	92	206	40	85
	Fertilizing	101				102		
	Weed control	92	46	100	81	128	60	98
	Howing	62	62	62		201		
	Irrigation			100	300	311		161
	Harvesting	90	90	90	174	174	120	120
Euro/ha	Total production costs (TPC)	979	582	988	1229	1844	521	930

	Profit before subsidies (GI-TPC)	-259	-144,5	-273	171	-299,6	229	-180
	+ Subsidies	294	294	510	260	563	45	45
	subsidy	35	149,5	237	431	263,4	274	-135

7.4 Energy crops market development

At the moment no market for energy crops is clearly established.

8. SUMMARY

Natural conditions

There are significant variations in agro-climatic conditions among European regions. Thus spatial suitability for relevant crops is a strong limitation. The region with temperate climate (western and central part of Europe) is generally more flexible for different energy crops, while northern and southern countries have stronger agro-climate limitations.

In the southern region of Europe there are high solar radiation and high rates of evaporation, which necessitates irrigation of crop. Irrigation substantially adds to the production cost. The most favourable cultivation areas are in the coastal areas of the southern part, which are colder. In the northern countries crop cultivation is mainly located in the south parts, where the climate is temperate with vegetation period of more than 180 days, but with canary reed grass and plant breeding, cultivation further north is possible. In the region of western and central Europe only restrictions for cultivation areas due to natural conditions are limited to mountains.

Soil may cause some limitations to crop cultivation. Shallow or stony soils make intensive field operation impossible. Sandy soils are very sensitive to droughts, as they do not have good abilities for water storage. Clay soils can be regarded as most suitable for crops.

Agriculture characteristics

Intensive agricultural production system in Europe can be divided into two main categories, intensive and semi-intensive or extensive system. The differences result in yields levels, mainly due to different rates of fertilizers and active substances usage in the crop cultivation, and machinery application.

The most substantial difference in agricultural production is between Western and Eastern Europe and West-northern and Southern Europe. In Western Europe very high yields are achieved. Agricultural production is organized in large and highly specialized farms. The subsidies from Common Agricultural Policy have been having a great influence on the Western European agriculture making the choice of crop production strongly dependent on dedicated financial support. On the contrary, in Central and Eastern Europe agricultural production is organized in small fragmented farms, e.g. average farm area in Poland is 8.4 ha. Economic transformation of 1990s has resulted in dramatic fall in agricultural production profitability. Yields achieved are at the 50% of potential water limited yields (Rabbinge, van Diepen, 2000).). Similar to the CEE countries, the Southern European agriculture production is rather extensive with relatively low yields. Crops' yields are strongly limited due to low water availability in hot climate. In northern countries crop production is relatively intensive, however yields are limited due to cold climate. In the Alpine region large share of farms are farms located in mountainous areas. Agricultural production can be classified as semi-intensive with farms regionally specialised. Milk and beef production is very common in the Alps.

In countries of EU-15 a set-aside obligation was introduced in the CAP reform in 1992. Introduction of 10 % of the set-aside resulted in decline in the cereal production area. Widespread adoption of voluntary set-aside is common especially in southern Europe. Also in the central and eastern Europe most countries have large areas of set-aside and fallow land available, especially in Poland.

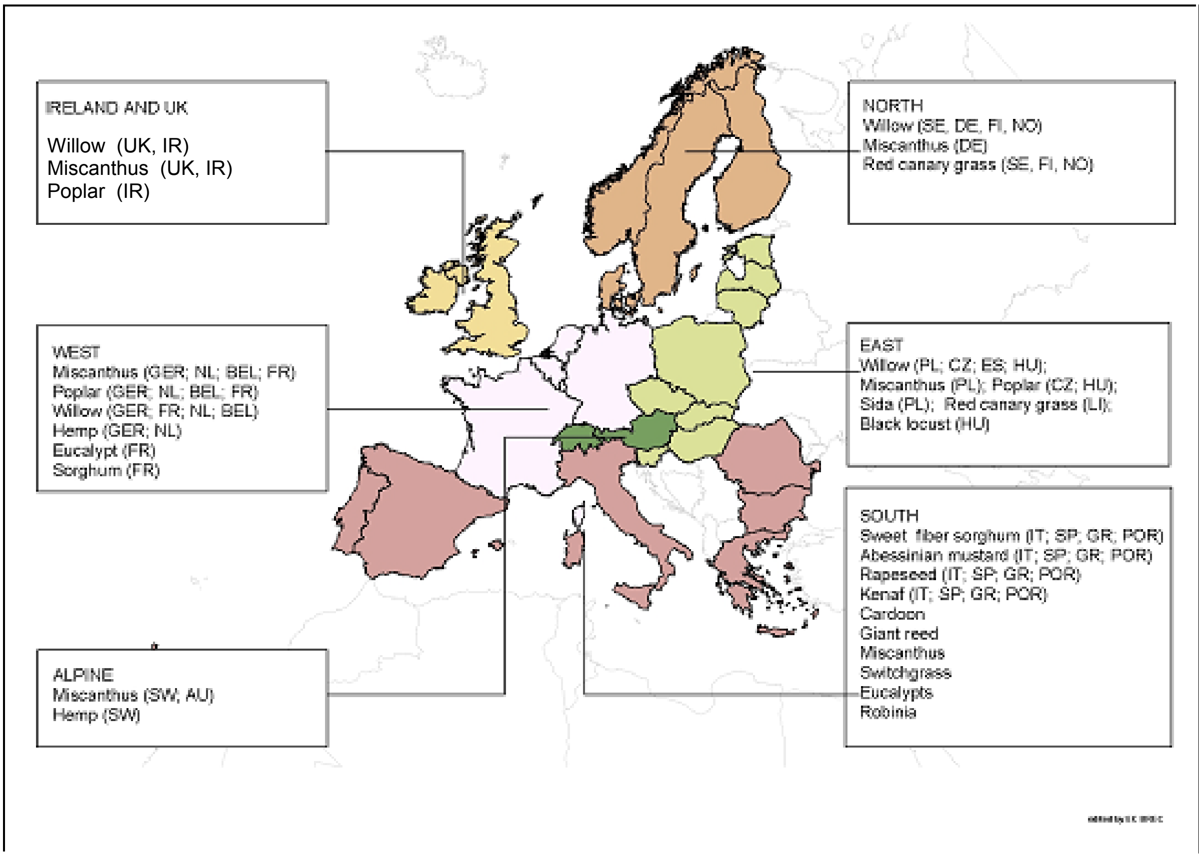
Energy crops

Energy crops production has been regarded as an interesting issue in most European countries. Research and field trials with different species of energy crops have been performed to estimate yields, growth rate, survival rate, harvesting technology, *etc.* Most promising crops for certain agro-climatic conditions have been selected in some countries.

Based on the review of the R&D results it was derived that the **suitability of energy crops species** in European regions is influenced much by the agro-meteorological conditions (soils, vegetation period length, temperature, rainfall balances). Herbaceous crops seems to be more suitable for southern EU (e.g. *Miscanthus, Sorghum, Cynara, etc.*), whereas woody SRF (Salix and Poplar) can be cultivated with better results in colder climate northern Europe. In central part of Europe both herbaceous and woody crops reached good results in R&D trials. In the South irrigation is important for providing good survival rate and yields of energy crops.

In most countries in Europe **experiences with ligno-cellulose energy crops** are limited to field trials. In some countries energy crops are cultivated on demonstration fields, e.g. Greece (*Sorghum, Eucalyptus*), Germany (*Miscanthus*), Finland (*Reed Canary Grass*), etc. Commercial cultivation of ligno-cellulose energy crops has developed only in Sweden so far, where commercial willow plantations cover 15.000 ha. Such development was driven by the implementation of comprehensive support system in the early 1990s. It must be stressed that energy crops production in commercial plantations cannot give the yields level typical for experimental fields trials, which was proved in many cases.

Figure 3. The most promising energy crops in Europe – regional recommendations.



Energy crops production will have to **compete for land areas** with other crops. In countries where large areas of fallow and set-aside lands are available high production potential for energy crops is expected. The primary aim of agricultural production is food supply, which is highly related to population. Agricultural land resources per capita are very different in Europe. The Baltic States (Estonia, Latvia, Lithuania), Ireland, Greece and Spain have the largest agricultural land resources per capita (0.8-1.2 ha/cap). On the opposite there are Belgium, Netherlands, Germany, Switzerland and Italy (0.1-0.3 ha/cap). This will influence the availability of total land area available for energy crops.

The conditions of **existing farming systems** are especially important for the **implementation of large-scale energy crops production**. These are such agricultural characteristics as structure of production system, labour resources, infrastructure, farmers' acceptance, decision patterns, *etc.* Agricultural production in Europe is based mainly on annual arable crops, typically cereals. Especially in Western Europe for many years the crops production have been influenced by the CAP very much, which offered high subsidies for most crops cultivated for food or feed. Shift to energy crops and especially woody crops may be regarded by many farmers as too innovative as they are very stacked to traditional food crops supported from CAP. Countries with great traditions with animal stock farming such as Ireland or Switzerland may also have less attention to alternative agriculture production, such as energy crops. In Central and Eastern Europe large areas of agriculture land have been withdrawn from production and there is growing interest in alternative cultivation, especially energy crops. However, the existing farming system based on annual crops is not relevant for woody energy crops, such as SRF. Thus, in the early stage of implementation of energy crops it would be rational to develop large-scale production of perennial crops with annual harvesting cycle, e.g. Miscanthus. This will give the opportunity to make use of the available traditional agricultural machinery.

The **farmers' decision on energy crops** production will be based on the **profitability** from different agricultural productions. Economic parameters (profitability, energy crop economic competitiveness with traditional crops, subsidies) very strongly influence the energy crop plantations development. So far only several countries in Europe, e.g. Sweden, UK, Denmark, the Czech Republic, introduced dedicated support for energy crops cultivation (subsidies for establishment of the cultivation, energy taxes influencing competitiveness of fuels from SRF with fossil fuels, R&D programs and farmers education). Common Agricultural Policy have introduced in 2003 special annual premium of 45 EURO/ha for energy crops cultivated on land, which is not included in the obligatory set-aside land. In CEE countries, which jointed EU in 2004, no support for energy crops is available from CAP. Energy crops may be supported only from national budget, which is the case of Poland, but only since 2005.

Lingo-cellulose energy crops cultivation in Europe is currently mainly for the purposes of **heat and electricity production**. The directive on 'green' electricity promotion is a driving force for the usage biomass from energy crops for electricity generation, e.g. Poland. As far as transportation sector is concerned in many countries oilseed production is supported for biodiesel production.

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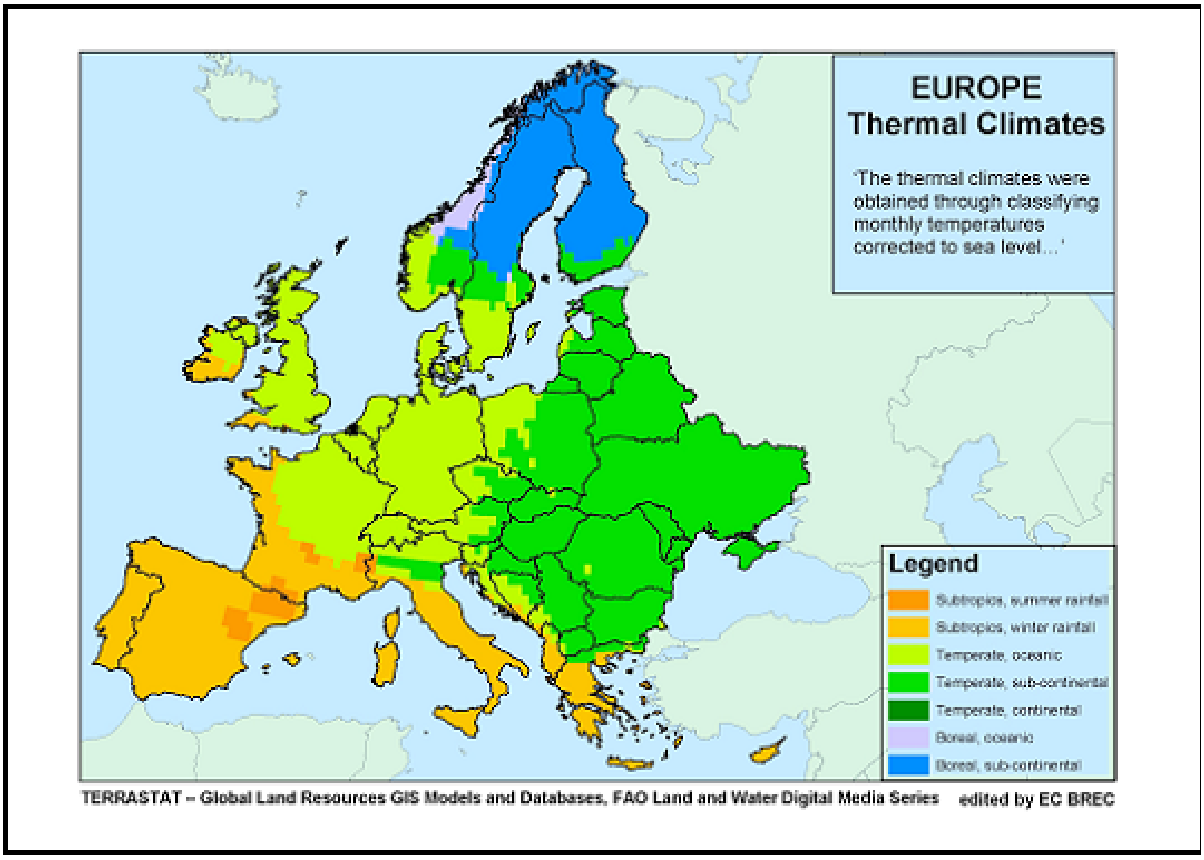
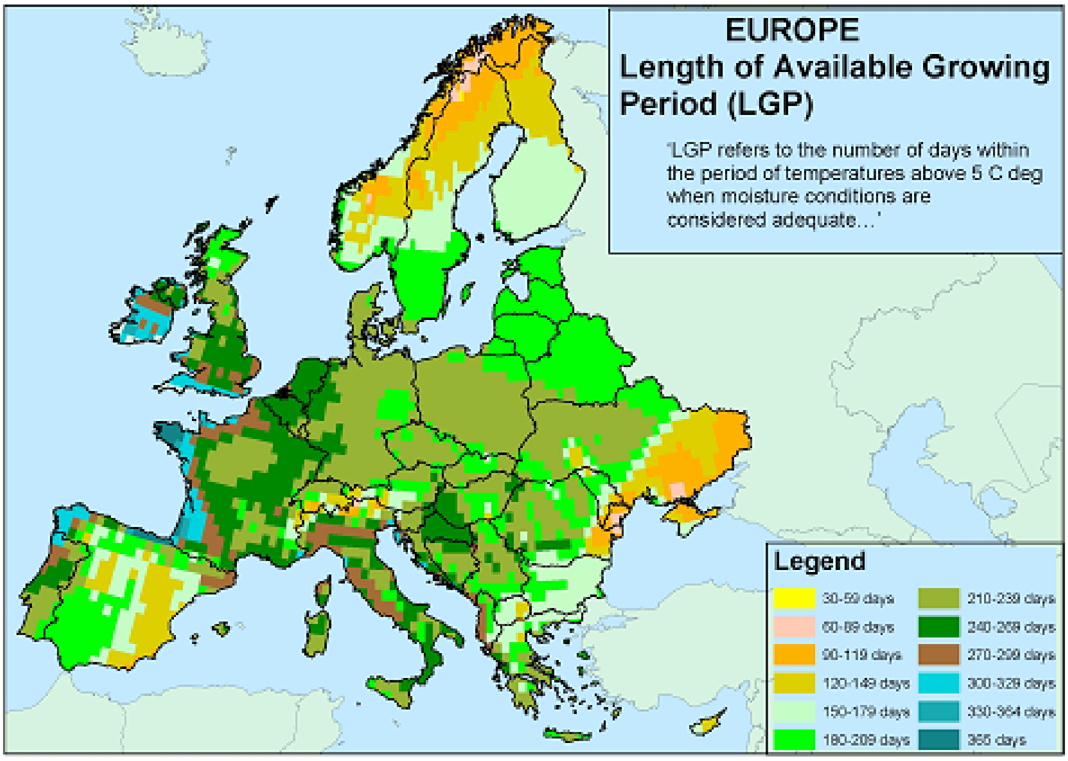
APPENDIX 1. AGRO-CLIMATE CONDITIONS

Thermal Climates



Length of Available Growing Period (LGP)



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Dominant Soils