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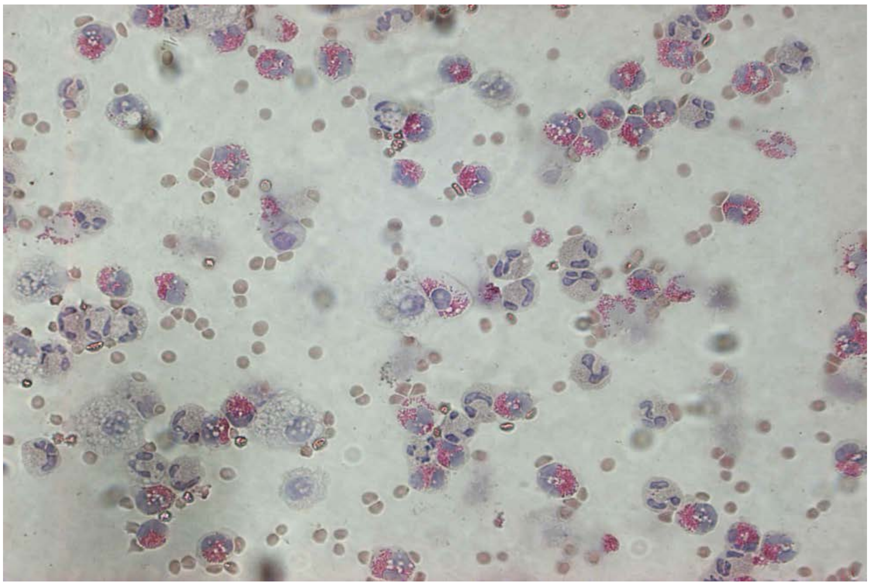

Produktionen av biomassa från kort omloppstid för energianvändning: Jämförelse mellan Sverige och Spanien

Production of biomass from short rotation coppice for energy use: Comparison between Sweden and Spain

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ABSTRACT

Wood energy is the main source of energy for more than two billion people. Over 14 percent of the world's total primary energy is supplied by biofuels, particularly fuelwood and charcoal according to FAO data.

Nowadays, ambitious targets for the use of renewable energy have been set in the European Union and particularly the interest for biomass energy sources has increased. Social and economic scenarios show a constant growth in the demand for woodfuels and it is expected to continue for some decades (Sixto, 2007).

To reach these goals, woody energy crops are necessary for assuring the sustainability of the rising biomass sector. In several countries, wood energy plantations are being considered to help in achieving greater energy independence. Wood energy crops are in the development stage in Spain, while in Sweden they already are operational.

The goal of this project is to make a comparative study between Sweden and Spain, explaining the current status of the production of biomass for energy use in each country. I will focus on production of biomass from short rotation coppice (SRC).

The purpose of this paper is to explain the differences in production of biomass for bioenergy purpose between both countries, analyzing how these have developed, the current situation and the possible future.

Keywords: *Biomass, bioenergy, short rotation forestry, short rotation coppice, renewable resources, Sweden, Spain.*

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Uppsala, May 2011

Cristina Arias Navarro

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ACRONYMS, ABBREVIATIONS AND UNITS

CAP Common Agricultural Policy

CHP Combined Heat and Power

EEA European Environmental Agency

EU European Union

EUR Euro (currency)

FAO Food and Agriculture Organization of the United Nations

IDAE Spanish Institute for Energy Diversification and Saving of Energy

PER Spanish Renewable Energy Plan

SEK Swedish Krona (currency)

SRC Short Rotation Coppice

SRF Short Rotation Forestry

toe ton of oil equivalent

Wh Watt hour

k =Kilo =10^{3}

M =Mega, Million =10^{6}

G =Giga =10^{9}

T =Tera =10^{12}

P =Peta =10^{15}

E =Ekta =10^{18}

Conversion coefficients

	toe	MWh	GJ
Toe	1	11,63	41,868
MWH	0,08598	1	3,6
GJ	0,02388	0,2778	1

1. INTRODUCTION

1.1 Biomass as an energy source in a European framework.

For millions of years biomass has been used for energy purposes and nowadays is the main energy source in developing countries used as firewood for cooking and heating.

The modern use of biomass is its conversion into high-quality energy carriers like biomass liquid fuels and electricity.

Examples of modern biomass use are: ethanol production in Brazil from sugarcane (Moreira & Goldemberg, 1999) combined heat and power (CHP) district heating programs in Austria and Scandinavian countries (Turkenburg, 2000) and the co-combustion of biomass in conventional coal based power plants in the Netherlands (AEA Technology, 2001).

Modern biomass energy would increase their contribution to the future energy market. This is accredited to the reduced cost of production and conversion of bioenergy, wider accessibility of the resources and the increased demand for CO_2 neutral fuels.

Biomass is a renewable source of primary energy, without CO2 emissions if managed sustainably, and contributes to achieving the targets of the Framework Convention on Climate Change (FCCC).

Currently, in the European Union, renewable sources of energy are unequally and insufficiently exploited. The contribution of these renewable sources to the internal energy consumption is less than 6%. The EU’s dependence on energy imports is already 50% and if no action is taken, is expected to rise over the coming years, reaching 70% by 2020 (White Paper for Community Strategy and Action Plan, 1997).

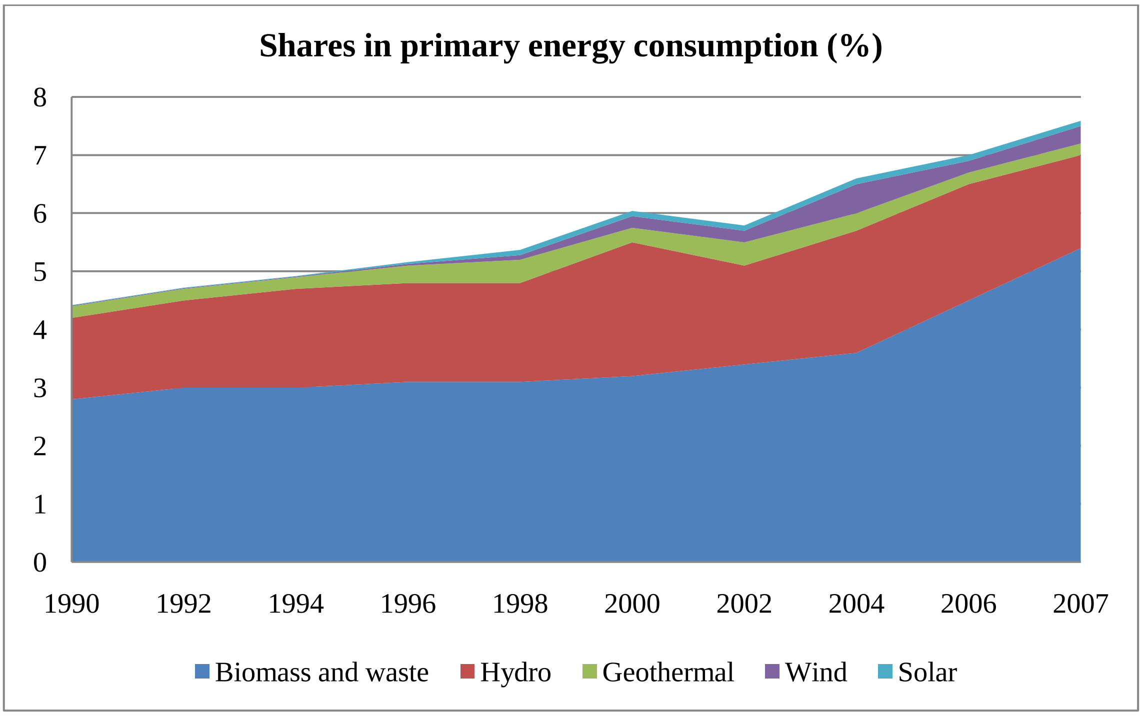

Figure 1. Contribution of renewable energy sources to primary energy consumption in the EU-27. (Eurostat. Energy statistics, 2007)

Figure 1 shows that the share of renewable energy sources in gross inland energy consumption (GEIC) has increased in the EU-27 from 4.4% in 1990 to 7.8% in 2007. The strongest increase came from wind (more than one hundred thirty-fold) and solar energy. In absolute terms, biomass accounted for 79.2 % of the increase and wind for 13.1 % (Eurostat, 2007).

Based on the potential of bioenergy in many European countries, biomass has become a key factor in energy, environmental and agricultural policies because it may make a foremost contribution to the security of supplies. Ambitious goals have been established, with emerging plans for the construction of biomass power plants.

The interest in forest residues and energy crops for the production of bioenergy has grown exponentially. It is promoted as an environmentally sound source of energy (principally for heat and power generation) that would be an alternative for fossil fuels and has the capacity to help to decrease greenhouse gas emissions. Renewable energy in the form of biomass offers an answer to global commitments of decreasing carbon dioxide emissions.

The new community challenges for 2020 are very ambitious regarding renewable energy use and require an increasing use of biomass to produce heat, electricity and biofuels. A high development of the biomass sector based on energy crops is expected in the next years (Sixto et al, 2007).

In Europe, 54% of primary energy from renewable sources comes from biomass, however, it only accounts for 4% of the total energy .It is not enough due to the potential of biomass and the available technologies (IDAE, 2007).

France leads the production, followed by the Scandinavian countries, which are considered as the true leaders, for example, Finland covers 50% of its heating needs and 20% of primary energy consumption with biomass (EurObserv’ER, 2010).

Although the availability of biomass is abundant in Europe supply has not yet been organized in many cases, being necessary to promote a European market for biomass. Increases in use of bioenergy from forests or agricultural land are not restricted by technology. This can be addressed by a combination of targets and incentives.

Among the different types of biomass possible, woody energy crops allow planning resources, not as residual biomass production, which is disconnected from energy production targets. At the same time, they provide alternatives to abandonment of traditional crops in rural areas and, as substitutes for fossil fuels, have the potential to decrease the carbon dioxide emissions that contribute to climate change because energy crops recycle atmospheric CO_2.

The interest in energy crops such as specialized forms of production of raw materials for energy production has been increasing over the past twenty years and currently, energy crops are considered as necessary for the development of energy production from renewable sources in the short and medium term policies of many countries.

1.2 The role of energy crops in ensuring bioenergy sector.

In a world where the productive agricultural land is becoming ever more of a scarce resource the choice of raw material for fuel production is becoming crucial.

The Second Assessment Report of the Intergovernmental Panel on Climatic Change (IPCC) gives the maximum liability to the biomass for the future development of renewable energies. According with this paper the contribution of biomass at the end of the century could reach a quarter of global energy production. Biomass from short rotation plantations has an important role for the new renewable energy's requirements.

The use of biomass for energy purposes has environmental benefits since reduced CO_2 emissions. The energy use of this renewable source implies to involve the combustion, but the amount of this greenhouse gas that it causes can be considered to be the same amount that was captured by plants during their growth. That is, not an increase of this gas into the atmosphere.

Although the availability of biomass is abundant in Europe, the supply is not yet organized in many cases, being necessary to promote a European market for biomass.
SRF has become important, as a suitable way of providing raw materials in relatively short time. In the last decades the interest in the use of woody energy plantations for bioenergy has grown exponentially (Dopazo et al, 2010).

Because of this creation of a carbon sink (a component which solar and wind energy do not have), bioenergy from closed loop energy crops represents an effective choice in alternative energy options.

Short rotation woody crops are a potential primary biomass resource and its development has been encouraged in countries as Sweden, where SRC willow plantations are viewed as reliable sources of high quality biomass. Energy crops are expected to play an important role in guaranteeing the sustainability of the rising bioenergy sector, not only providing a high quality feedstock that minimizes transportation costs, and improving the logistics but also increasing the security of biomass supply.

Despite the fact that Short rotation coppice has the chance to become a key source of renewable energy because of its high biomass yields, good combustion quality, environmental advantages and relatively low biomass production costs, the current production areas in Europe are quite a bite small (Kauter et al, 2001).

Given the long experience and numerous studies in Swedish plantations, one can say that the main ecological and environmental factors for Short Rotation Forestry for energy are:

-There is no net contribution of CO_2 to the atmosphere.

-Compared with fossil fuels the amounts of sulphur pollutions are insignificant.

- SRF provides better chances for reduction of nutrient leakage and pesticide use.

-There is a continuous improvement of the resistances to fungi, insects and frosts due to genetic research.

- Efficient use of nutrients owing to a well-established root system and a long annual growing cycle with no periods of bare soil.

- Improvements in soil properties as humus content and soil structure.

-Willow is suitable as a vegetation filter for treatment of wastewaters and sludges.

- Compared with conventional agricultural crops SRF involves a higher biodiversity.

The main hindrance for a more widespread use of biomass from SRC as a renewable energy source is the economic background. Biomass from SRC has to compete with fossil fuels, forestry and agriculture residues and with other renewable energy sources. In most cases it is in a disadvantage under the economic and political frame conditions (Kauter et al, 2001).

The energy crops can make an effective addition to conventional agriculture because they contribute to diversify the productivities and markets promoting development and energetic activities. Consequently, with the purpose of promote the use of biomass from SRC as an energy source, production and use costs have to be decreased. This can be achieved by increasing productivity and optimising fuel quality.
The main barriers for large plantations schemes are socio-political (Weih, 2004). The future of energy plantations depend on subsides for set-aside land and taxed on fossil fuels. Decisions on agricultural and energy policies taken by the European Union countries will be those that will make possible the development of these crops for the production of biomass for energy purposes (Larsson, 1998).

The Swedish development during the last years provides an immense experience to make this expansion a reality.

1.3 Short Rotation Coppice method. Characteristics of the species used.

During the last decades, Short Rotation Forestry, (SRF) has become relevant, as an appropriate way of providing raw materials in relatively short time. This mode of cultivation is considered among the most promising in their ability to provide biomass for energy. (Ledin & Willebrand, 1995).

Short rotation forestry is a silvicultural practice in where fast-growing tree species are grown under intensive management (Hansen, 1991) and it can produce large amounts of biomass.

Short rotation coppice (SRC) is a woody, perennial crop, in which the rootstock or stools remain in the ground after harvest and new shoots emerge the following spring. A plantation could be viable for up to 30 years before re-planting becomes necessary, although this depends on the efficiency of the stools (Ceulemans & Deraedt , 1998).

Silvicultural treatments used in the large-scale production of biomass do not differ greatly from the agricultural ones. These are site preparation by ploughing, discing, harrowing, followed by planting of cuttings or rootstocks. To ensure sufficient nutrients levels and weed control fertilizers and herbicides are often applied. To stimulate sprouting, stems can be cut back after the first growing season. Harvesting typically occurs in the winter using purpose-built harvesting equipment. After harvesting the stumps are left to coppice and a new crop is grown (Hall & Richardson, 2001).

Woody energy crops are generally established at higher densities than conventional forestry plantations and can be managed in short rotation coppice systems with rotations of, generally, 2-5 years.

Several clones for production have been identified and crops have been improved by selecting for fast growth and tolerance to pests, then matching them to the best soil and site conditions. In the northern hemisphere, operational yields move towards 10-15 tons ha^{-1} $year^{-1}$, larger yields are possible where biological limitations are less.

A 20 MW steam cycle power station using energy crops would require a land area in the order of 8,000 ha to supply energy sustainably in rotation (Coombs, 2002).

Potential species to be considered for production biomass by SRC should have a number of important characteristics such as high energy content and fuel quality, ensure high yields, have fast juvenile growth, show good ability of sprouting, present great adaptability to different sites and resistance to biotic and abiotic stress, etc (Ceulemans, 1996).

Over the last decades, short rotation techniques have been developed for growing poplar (*Populus*), willow (*Salix*), eucalyptus, *(Eucalyptus)*, or perennial grasses (*Miscanthus*) (Hall, 2002).

The genera *Salix*, *Populus* and *Eucalyptus* are considered the greatest potential in the field of the European Union (Armstrong, 1999). These species have very rapid growth, a broad genetic base, easily to resproute after cutting, etc. All these features make these species suitable for productive purposes.

1.4 Biomass resources and technologies in Sweden and Spain.

The countries considered, Spain and Sweden constitute two case studies with significant differences such as history, economic, social and technical aspects which have had an influence on the development of renewable energy and particularly in the production of biomass from short rotation coppice.

According to FAO, Spain is the fourth country in Europe in terms of forest resources with 14.4 million hectares of forest cover, following Sweden, Finland and France (but excluding the Russian Federation).Sweden's forest land covers 28.4 million hectares.

In terms of land, Sweden has more forest than most other countries, 58 percent compared with the global average of 30 percent. About 90 percent of bioenergy in Sweden today comes from the forestry sector. Most of bioenergy in Sweden is used in industrial processes and district heating (EurObserv'ER 2010).

In Europe, France is the greatest amount of biomass for bioenergy consumed (more than 9 million tons of oil equivalent) followed by Sweden. Spain ranks fourth in the list with 3.6 million toe (Eurostat, 2007).

The factors influencing the consumption of biomass in Europe are:

- Availability of resources: this is the factor to be studied first to determine access and of the resource.
- Geographical factors: due to weather conditions in the region, which indicate the heat needs required for each area, which may be filled with biomass.
- Energy factors: the profitability of biomass as an energy resource. This will depend on market prices and energy at each moment.

Spain has great potential for development of energy crops. There are an estimated 2.5 million hectares of agricultural land which could increase its value through crops for energy use. These crops would cover about 16 percent the current primary energy demand in the country by 2030 (IDAE, 2007).

2. OBJECTIVES

The aim of this paper is to make a comparative study between Sweden and Spain, explaining the current status of each in relation to the production of biomass for energy use. Among the different types of biomass possible, I will focus on production of biomass from short rotation coppice (SRC).

The main objectives of this study were:

- Identification of the economic, social and technical aspects which have influenced the development of this type of energy production.
- Analysis of the current situation of production of biomass from SRC
- Review the role of woody crops in ensuring the sustainability of the bioenergy sector. Limitations and possibilities in both case studies.
- Explanation of the possible differences between both countries based on the comparison of results.
- Proposal of some improvement alternatives for better development of SRC system.
- Future trend of energy woody crops.

3. MATERIALS AND METHODS

The FAO database concerning forest products, woodfuel, etc. (FAOSTAT), Bioplat, Sveo and Eurostat statistics and several publications are used for gathering the data.
The purpose of this paper is to explain the differences between both countries, analyzing how these have developed on the matter, the current situation and the possible future. The limitations of each case study are identified and improvement or alternatives are proposed. This study comprised the most important tree species used in SRC method in both countries: *Populus* in the Spanish case study and *Salix* in the Swedish one.

4. RESULTS & DISCUSSION

4.1 Economic, social and technical aspects.

To understand the present situation of each country it is necessary to make a brief review of history focusing on the economic, social and technical aspects which have influenced the development of this type of energy production.

According to the WWF European Policy Programme, Sweden has a long history of using biomass, both for heat and power. In 2009, biomass energy overtook oil and has become the largest contributor to Sweden's energy mix.

In the late 1960s, due to a predicted shortage of raw material for the pulp and paper industry, Sweden started research on short rotation willow coppice. During the oil crisis in the 1970s, Swedish society decided to make significant investments in research on alternative energy sources. SRF was considered the most reasonable and long-lived. When the need for non-fossil fuels began to become more important in the 1980s, willow growing for energy started to be commercialized in Sweden (Mirck et al, 2005).

However in Spain, the interest in this possibility began in the late 1970s (San Miguel & Montoya, 1985) starting the first trials with poplar, species of great tradition in many areas of the country. In the last decades there has been risen new interest for biomass production with short rotations, from 1 to 5 years. Currently, researches are ongoing and a demonstration program at the national level is started (Project On-cultivos). Sweden has in the four last decades carried out research on short rotation willow coppice (SRWC), leading to a large base of theoretical knowledge and variety of practical applications of willow growing -systems not only for energy purposes but also for environmental applications (Mirck et al, 2005).

4.2 Energy trends.

It is convenient to analyze the energetic trends of the two countries to understand why energy crops have been developed positively in Sweden while Spain is still in research and development phases.

Today, 46.3 percent of Sweden's energy supply (electricity, district heating and fuel) comes from renewable energy, which is more than in most EU countries. The reason for this is the large share of hydropower and biofuels in the energy system. (The Swedish Institute, 2011).

As we can see in the figure 2, the energy use in Sweden is characterized by:

•Reasonably high energy consumption, due to cold climate and heavy industries. According to the Swedish energy agency the energy consumption is estimated to 16000 kWh $person^{-1}$ $year^{-1}$.

•Hydro and nuclear lead electricity production. Almost no CO2-emissions in electricity production.

•High use of bioenergy in heating.

•Only OECD country with less than 50% from fossil fuels (37.1%)

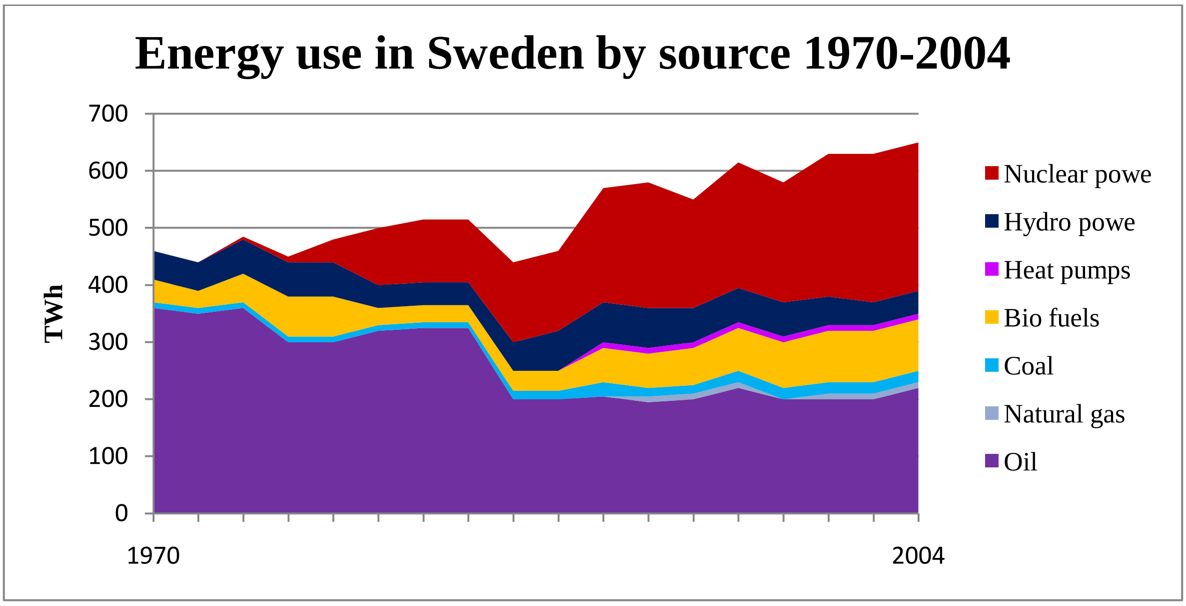

Figure 2. Energy use in Sweden by source 1970-2004. (Swedish Energy Agency).

Svebio analysis show that the use of renewable energy in Sweden is very high compared with the targets set by the EU. Today, 46.3% of the energy consumed in the country comes from renewable sources. The Swedish government is very near to its target to achieve 50% renewable by 2020.

On the other hand, as figure 3 shows, the Spanish energy consumption is based on:

-Steady growth of energy consumption has increased by over 50% in less than two decades.

-The energy consumed in Spain is predominantly based on the use of three types of fossil fuels. Petrol remains the most important energy source followed by Natural Gas that has had a strong growth and Coal (50%, 20% and 10% of energy consumption respectively).

-Nuclear energy covers only 10%. The expansion of this energy stopped in the late 80's with the nuclear moratorium.

-Low incidence of the renewable energy consumption (9%), despite having been incorporated into the mandatory regulatory framework to cover part of the energy needs with these energies. The presence of renewable energy is growing at a slow rate.

-Hydro energy in relative decline (1%)

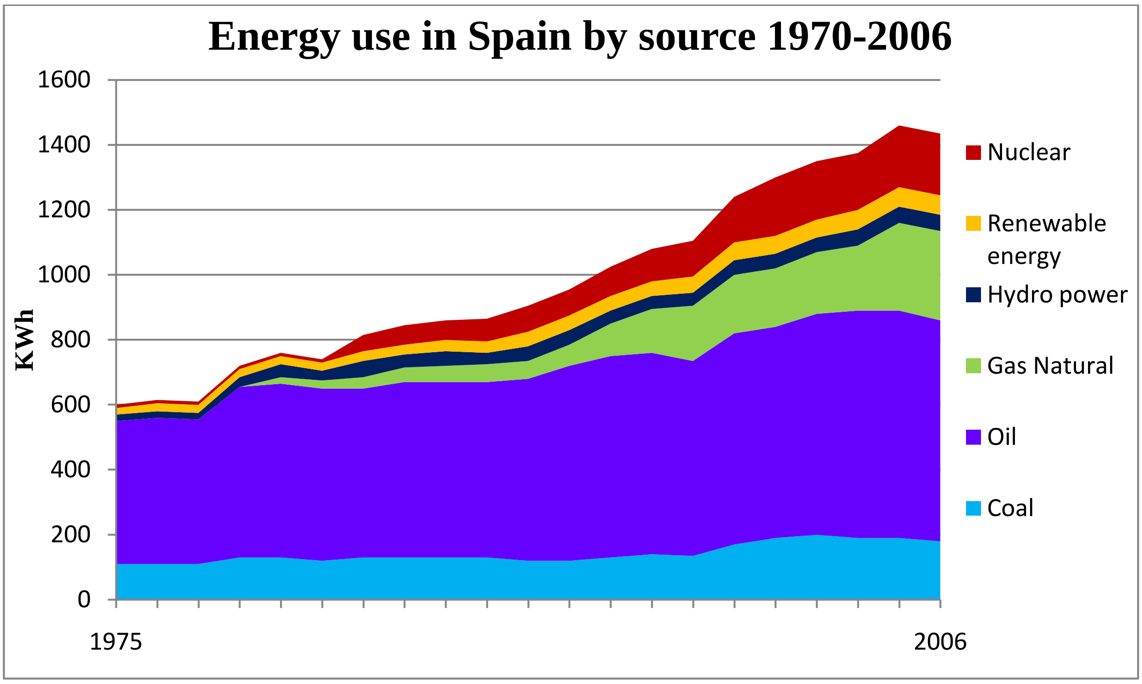

Figure 3: Energy use in Spain by source 1975-2006. (Observatory of Sustainability in Spain).

Spain is poor in energy resources, with the exception of coal. Rapid industrial growth has intensified the problems caused by insufficient oil reserves, dwindling supplies of easily accessible high-quality coal, and inadequate water for power generation.

Currently, Spain is a country heavily dependent on energy imports. In fact, now imports about 80% of energy consumed. Furthermore, its economy, against the tendency of the EU, has a production base with high and rising energy intensity. Both factors add special value to the energy produced from renewable energy sources, autochthonous, and independent.

Oil provides nearly half of total energy consumption in Spain, making it the eighth European Union country more dependent on black gold. That percentage amounts to nearly 12 points the European average, which stood at 36.6%, according to the European statistical office (Eurostat, 2007).

Sweden adopted a vision that in 2050 the country will have no net emissions of greenhouse gases in the atmosphere. This is possible due to the vast resources of forests and biomass. As has been said before, Sweden has a long history of using biomass. It is commonly used for combined heat and power production and as heat source in industry. Incentives for transport and standards in buildings are as well relatively high. However, the concentration on biomass has turned the focal point away from developing electricity end-use-efficiency, restructuring industry and investing in infrastructure.

The Spanish Renewable Energy Plan (PER 2005-2010) hoped to achieve a biomass consumption of 9,207,300 toe by 2010.

The 40% of the objectives set for biomass in the Renewable Energy Plan was for energy crops. (At this time the new plan is being revised and the data from 2010 are not available yet).

For this energy source, the factors most likely to affect the time to complete the goals set in Spain, are technology and investment efforts (Regio, 2006), given that for the collection, preparation, blending, processing and transportation of biomass the present available technology is not adequate for obtaining profitability.

However, the European Union will promote the adaptation of technology developed in countries of Northern Europe as Sweden in countries like Spain, which will allow an improvement in yields and profitability of projects which will attract investment.

4.3 Current situation of biomass production from SRC in Sweden & Spain.

4.3.1 Sweden

The Swedish energy forestry approach is a typically SRF one. In late 1980s the first commercial plantations were established.

In the first half of the 1990s, a wave of *Salix* (willow) planting rolled over Sweden, powered by subsidies and positive market prospect. The idea was to grow *Salix* for energy use. Nearly 1200 Swedish farmers established willow plantations, covering some 15 000 hectares. Planting cost per hectare decreased rapidly because besides others subside, a specific set-aside hectare subsidy was introduced for Salix planting in 1991 when the income from cereals was low.At the same time, the infrastructure was developed. Research grants supported breeding of Salix as an energy crop and this began to yield practical results in terms of increased productivity for farmers. Also new or improved machinery for planting and harvesting became accessible (Helby et al, 2006).

In 1996, as a result of the inclusion of Sweden in the EU, farmers were deterred from further large scale plantings because the Common Agricultural Policy (CAP) program reduced the compulsory “set aside” area. The planting subsidy was reduced to a third of its previous amount. It signalled a turning point in the development of willow. The number of new plantations dropped significantly (Helby et al, 2006).
The annual planting rate dropped from 2,000 hectares to 200 hectares in only one year. Many farmers and small contractors lost interest in willow crops and between 10-15 farmers withdrew their service (Larsson & Lindegaard, 2003).

After that year, the subsidy for the establishment of willow plantations was raised again and in 2001 energy taxes were reduced (Johansson, 2002). The total area planted in Sweden was more or less constant because several plantations that were poorly established in the 1990s were removed at the same rate that new plantations were established (Nordh, 2005).

The increasing demand for wood fuel has improved the economics of growing willow considerably. The price for willow wood chips in Sweden has increased (Swedish Energy Agency) but some farmers keep their negative view of willow. They may take time to recover their reliance.

About 16.000 hectares of SRC willow are being cultivated in Sweden and they are managed for the production of chips consumed in biomass power plants and around 500 hectares are added every year in the form of new plantations (Swedish Board of Agriculture’s statistics, 2009).

The crop is commercially grown, for the most part on agricultural land, and the biomass created is used in district heating plants for combined heat and power production. Every winter SRC willow is harvested from approx. 2,500 hectares for delivery to around 25 heating / power plants in central and southern Sweden (Swedish Board of Agriculture’s statistics, 2009). Willow material used earlier in coppice plantations for bioenergy consists of clones propagated from wild or naturalized stands of the species *Salix* (Larsson, 1998). The main species consist of different willows, grey alder and poplars, of which the willow species *Salix viminalis* dominates (90–95%) (Perttu 1998).

According to the Manual for SRC Willow Growers Produced by Lantmännen Agroenergi, planting takes place in the spring and early summer (March-June), using one-year old shoots (Nordh 2005). In the winter (November-April), when growth has finished and the leaves have fallen harvesting is carried out at intervals of 3-4 years. In order to grow well the SRC willow plantation must also be fertilized once the SRC willow plantation is established.The recommended amounts of fertiliser are around 70 kg N ha^{-1} yr^{-1}, during the first cutting cycle, applied principally during the third and fourth year (Ledin *et al*. 1994, Ledin & Willebrand, 1996). There is no need for re-planting because new shoots grow from the coppiced stools after harvesting. During the successive cutting cycles the amount of N varies between 60 to 80 kg N ha^{-1} yr^{-1} (Ledin *et al*. 1994, Ledin & Willebrand 1996).

The most common design in Sweden is the double-row system. The distance between rows is 0.75 m and 1.5 m, and spacing between cuttings, within the rows, is 0.6m. The densities have been reduced over time and the most recently plantations have 12 000 cuttings per hectare (Nordh 2005).

The life period of a well-managed SRC plantation is estimated to be more than 25 years, which means that an SRC plantation can be harvested at least 5-6 times during its life.

The stools can be broken up and mulched and the land can be returned to arable cropping regimes using conventional agricultural equipment when a SRC willow plantation is to be removed.

As other agricultural crops, SRC willow requires good management.

The main component of achieving a high yield in the long term is a successful establishment. The weeds must consequently be controlled efficiently. Apart from planting and harvesting, the most part of the management actions can be performed using normal agricultural equipment.

Today the majority of willow plantations in Sweden are established on private farms, but administrated by the Federation of the Swedish Farmers Coops, and managed by Lantmännen Agroenergi AB (formerly known as Agrobränsle AB) who is located in central Sweden. Lantmännen Agroenergi has contracts with 1,250 willow growers, and liaises with processors and utilities to guarantee a proper handling of the crop. The organization takes care of the harvest and delivery of wood chips to nearby district heating plants.

In the breeding programme at Lantmännen Agroenergi the emphasis is on increasing yield, resistance to pests and diseases and tolerance to frost i.e. make willow more competitive as an energy source.

Of the total nation's arable land in Sweden, willow plantations cover about 0.5 %. (Larsson & Lindegaard, 2003), Today, biomass production of willow grown commercially in Sweden is about 6 to 12 tonnes per hectare per year, depending strongly on site conditions(Larsson & Lindegaard, 2003),

Nowadays, the new willow plantations involve recently bred varieties. A part of being more productive, they are also more resistant against pests and diseases. These factors will bring about more constant yield levels. Until recent times there has not been frost tolerant material for some areas in Sweden. The variety Gudrun can be used in areas with an elevated risk of frost. (Larsson & Lindegaard, 2003).

The expansion of willow can be promoted by the establishment of long-term contracts between district-heating companies and farmers (Helby *et al*. 2004). It can contribute to the decrease of the risks taken by the farmer. This has been followed in Enköping, in central Sweden. The model is based on agreements between the main actors involved in the biomass supply and demand (Börjesson & Berndes, 2006). The agreements include the obligation of the CHP plant to buy the harvested willow at the current market price, and the farmer has to sell their willow chips to the plant. Furthermore, the CHP is encouraged to recycle the wood ash back to the plantation.

Enköping is one example of large-scale phytoremediation systems in Sweden.

The nitrogen-rich wastewater from dewatering of sludge, which formerly was treated in the wastewater plant, is distributed to a willow plantation (75 ha) during the growing season. The water is pumped into lined storage ponds during the winter and used for irrigating short-rotation willow coppice during the summer.

The municipality covered all costs for the storing ponds, pumps, automatic filters, and irrigation pipes .The farmer/landowner planted the willows and is responsible for maintenance of the irrigation pipes.

The produced biomass is used in the local district heating plant. It contributes to the local supply of heat and electricity. The ash from the boiler is recycled back to the willow plantation. As a result, the treatment system is an admirable example of how treatment and recycling of society's waste products can be combined with production of biofuels

Figure 4. Willow phytoremediation system at Enköping, central Sweden (P. Aronsson)

4.3.2 Spain

Due to technical difficulties that prevent the profitability, energy crops in Spain have been grown scarcely despite the great potential (Regio, 2006). In the middle

1980's a program of research began on the cultivation of poplar in short rotation for energy. The objectives were to determine the production, planting density, rotation age, establishment and cultivation techniques, appropriate treatments, selection of clones, and to know the balance of energy, nutrients, internal dynamics (competition, mortality), and its potential profitability. These investigations have obtained very promising results (Ciria, 2009).

Studies with poplar biomass carried out up to now refer to short rotation (4-5 years) poplar plantations for energetic use. (San Miguel & Montoya, 1984; Ciria, 1990).

The main characteristics for growing energy crops are reduced rotation age and high density plantations. Poplar has some peculiarities that make it suitable for use in these conditions as an energy crop, which coincide largely with those proposed by the International Poplar Commission of FAO (1982), on the ideal type of material capable of being used intended use. Poplar has fast juvenile growth, consistently high shoot production, immunity or large resistance to foliar diseases, good healing of cuts annual operating, small deterioration of the stump, reaction to improved conditions growth, low level of pest insect attacks, aptitude to grow in dense plantings, capacity utilization throughout the growing season, copious foliage and elevated energy content.

The identification of varieties which are more suitable for the conditions of woody energy crop management is basic for ensuring the success of forest energy crop plantations.

Several recent significant studies in woody energy crop plantation management and breeding studies are reviewed for offering some perception of current achievements and challenges of the future in the development of poplar energy crops as commercial sustainable biomass source of energy. One example of these is a research of the feasibility of two year rotation plantation of poplar trees for energy in Salamanca (Spain) (García Robredo et al 2002) that shows that poplar crops for biomass production can be a substitute to conventional 12-year rotation plantations from a technical point of view. Productivity is high and the necessary technology is available but under the Spanish subsidies and circumstances, for the same species, poplar plantations for industrial uses are more profitable than for energy use. Consequently for private investors energy crops use are not attractive.

The existing reticence to open the forest sector to energy market makes difficult that the existing forest plantations (mostly eucalyptus) can be valued as biomass for bioenergy.(Spanish technology platform of biomass, BIOPLAT).

One factor to consider in the development of energy crops is the consideration which makes of them The Common Agricultural Policy (CAP). One of the proposals already agreed on is the elimination of aid for energy crops. The entry into competition with other markets as well as the disappearance of the CAP subsidies has created uncertainty and has slowed the development of energy crops in Spain.

At this time in Spain is conducting the project “On-cultivos” supported by the Ministry of Education and Science. It is a singular and strategic project for the development, demonstration and evaluation of the viability of energy production in Spain from biomass energy crops.

The main objective of this project is to promote energy production on a commercial scale from energy crops, to enable the sustainable implementation and the diffusion of the possibilities of the resource and viable alternatives for penetration of the energy market.

Applications set out in the project relate to: production of heat for heating, power generation, production of biofuels and gasification. Within this project the economic profitability also is evaluated, including environmental and energy costs of the production process.

The estimated area for the demonstration of the crop is about 10,000 ha and the Autonomous Communities involved are spread over the North (Navarre, Aragon, Catalonia, Castilla y León), Center (Castilla la Mancha, Madrid) and the South and East (Andalusia, Extremadura).

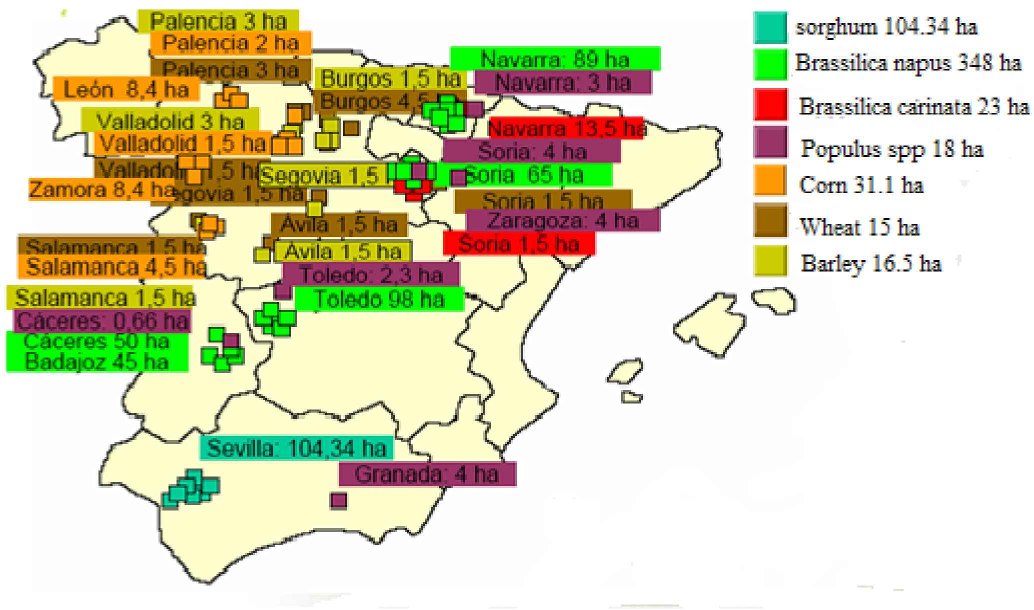

Figure 5. Demonstration areas of crops 2006. (Ciemat.web: www.oncultivos.es)

As the figure shows, tests with poplars are currently conducting in several Spanish provinces. On the other hand, in León is being built a biomass gasification to evaluate the behaviour of the matter obtained from these energy crops. The idea is to bring this possibility to the producers of the area. When technicians will have the first economic profitability data, the transfer will be made to farmers and small entities holders of communal land (MICINN, 2011).

The development of energy crops in Spain might involve:

-To replace surplus crops in the food market. That may offer a new opportunity for the agricultural sector.

-May cause economic growth in rural areas.

-Reduces external dependence fuel supply.

The investigation must focus on the following points:

-Increasing the energy efficiency of this resource.
-To minimize negative environmental effects.

-To amplify the market competitiveness of products.

-In enabling new applications of interest such as biofuels.

In connection to the crop, the main challenges to reach for generate scientific and technical knowledge needed to achieve sustainable production, could be translated into:

-The need for clonal selection specified for the purpose of production, paying attention to the interaction genotype / environment and considering issues not directly linked to production, such as the efficient use of resources(mainly water) the response to pests and diseases, the architecture of the clone, etc.

-Optimize production depending on the design of the crop, considering densities and rotation age, which also will be linked to the logistics of collection.

- The energy characterization will give a measure of the adequacy of the biomass produced for their possible uses.

- The proper development of the resource goes for attending one of the major current weaknesses. This is the need for high mechanization of the production system and the development of appropriate logistics.

- Finally it is need to know the life cycle of the crop in such a way that makes possible a realistic view of economic and energy balance based on criteria of sustainability.

Although the production of biomass from short rotation poplar for energy purposes is feasible in the short term, investment in research will optimize productions and streamline costs

Further development is necessary to achieve a large scale introduction of energy crops on a commercial market. The financial viability might be improved by stimulating progress of the bioenergy sector through biomass programs and investment incentives of the government.

4.4 Differences between both countries

As a result of the 1973 oil crisis, triggered by the Arab-Israeli war arises a dramatic escalation of oil prices. This event translates into the need for global energy planning by the uncertainty of energy self-sufficiency, to minimize future risks. This is in fact the starting point of the differences between the both countries.

On the one hand, Sweden adopted a policy based on making significant investments in research on alternative energy sources and considered that SRF was the most reasonable and long-lived. On the other hand, in Spain, the fundamental objective was to reduce the oil in the national balance energy, promoting domestic coal, hydroelectricity and thermonuclear power.

The initial Spanish energy plans, and its subsequent revisions, focused exclusively on energy consumption of fuels fossils, with a growing share of nuclear energy.
After the nuclear moratorium in the middle 1980s, renewable energies began to develop in Spain (Azcárate & Mingorance, 1996).

Sweden is a true leader in the production of bioenergy from SRC. This is caused by the policy of subsidies and incentives, higher taxes on fossil fuels, and a biofuel market based on forest fuels. (Rosenqvist et al 2000)**.** This has made achievable the development of these energy crops. There is a planting willow subsidy of 5,000 SEK per hectare (exchange rates, approximately 10 SEK=1.1 EUR) (Larsson & Lindegaard, 2003).

Swedish environmental policy has evolved over the years in response to changing environmental problems as well as changing priorities. The nature conservation, environmental protection and energy efficiency are usually priority in policy and have largely been welcomed by the public.
Sweden outlined its current energy policy in 1997. Government wanted to encourage efficient and sustainable use of energy and efficient energy supply that facilitate the transition to an ecologically sustainable society (Swedish energy agency, 2010).
Currently, few countries have higher power consumption and however, Swedish carbon emissions are low compared with other countries as Spain.

32% of all energy in Sweden comes from bioenergy (Swedish energy agency, 2010). Biomass power plants have become the third supplier of electricity in Sweden after the hydroelectric and nuclear. Some projections predict an area over 200 000 ha of SRC willow plantations in Sweden in the near decades (Larsson & Lindegaard, 2003), although observing the recent trends there can be serious doubts about the practical accomplishment of these estimates (Helby et al 2004).

Spain meanwhile, according to the provisional report published by Red Eléctrica Española (REE, 2010), has taken a step as an international electricity producer, of mainly wind, hydro and solar power, making cover 35% of electricity demand, 6 points higher than the previous year and not far from the target 40% of electricity by 2020. Due to the energy policies of Spain, production of biomass for bioenergy (and consequently, energy crops) has not developed as well. The solar and wind power are the energies that receive more subsidies in absolute terms. They take almost two thirds of the total.

5. CONCLUSIONS

Due to years of experience and the extension of the area planted, Sweden is the only country in Europe that has sufficient knowledge concerning the introduction of a new energy crop at a commercial level. If the ambitious targets set by the energy policies of the EU are to be accomplished, there is an urgent need to develop tools and methods to study the development of the bioenergy Swedish sector and the application of this experience to other areas of the EU.

For a development of short rotation energy crops in Spain it will be first necessary to analyze the role of the policy incentives applied in Sweden and the different actors involved in the development of the sector. Reliable yield projections based on this commercial experience must be provided to put into practice regional energy and policy plans.

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