ECONOMIC AND SOCIO-ECONOMIC EVALUATION OF BIOENERGY SCHEMES FUELED WITH ENERGY CROPS IN GREECE

Ms. Calliope Panoutsou

Doctor of Philosophy

ASTON UNIVERSITY

JULY 2002

ASTON UNIVERSITY

THESIS SUMMARY

ECONOMIC AND SOCIO-ECONOMIC EVALUATION OF BIOENERGY SCHEMES FUELED WITH ENERGY CROPS IN GREECE

Ms. Calliope Panoutsou

Doctor of Philosophy

2002

The main aim of this thesis is to evaluate the economic and socio-economic viability of energy crops as raw material for bioenergy schemes at the local level. The case examined is Greece, a southern Mediterranean country.

Based on the current state, on foreseen trends and on the information presented in the literature review (conducted at the beginning of the study), the main goal was defined as follows:

'To examine the evidence supporting a strong role for dedicated energy crops local bioenergy developments in Greece, a sector that is forecasted to be increasingly important in the short to medium term.'

Two perennial energy crops, cardoon (*Cynara cardunculus* L.) and giant reed (*Arundo donax* L.) were evaluated. The thesis analysed their possible introduction in the agricultural system of Rhodope, northern Greece, as alternative land use, through comparative financial appraisal with the main conventional crops.

Based on the output of this comparative analysis, the breakeven for the two selected energy crops was defined along with a sensitivity analysis for the risk of the potential implementation.

Following, the author performed an economic and socio-economic evaluation of *a district heating system fuelled with energy crops* in the selected region.

Finally, the author, acknowledging that bioenergy deployment should be studied in the context of innovations proceeded in examining the different perceptions of the key groups involved, farmers and potential end users.

Results indicated that biomass exploitation for energy purposes is more likely to be accepted when it is seen clearly as one strand in a national energy, environmental and agricultural policy which embraces several sources of renewable energy, and which also encourages energy efficiency and conservation.

Keywords: bioenergy, energy crops, district heating

TABLES	Pages

CHAPTER 1: INTRODUCTION

1.1 THE RESEARCH PROBLEM

Concerns about global climate change and air quality have increased interest in more environmentally friendly energy schemes, worldwide. Renewables (biomass, wind, solar, etc.) are nowadays the main resources promoted, through certain policy schemes and financial mechanisms, for decentralised, environmentally friendly power generation.

Among them biomass is considered an attractive option for energy production for a number of fundamental agricultural, industrial and rural development reasons (Maniatis, 1998). Firstly, it utilizes renewable resources as fuel, which could be sustainably developed in the future, the only physical constrain being the area of productive land available for cultivation of biomass species. Secondly, it has the attractive environmental property of recycling carbon by the photosynthesis process, thus leading to no net release of carbon dioxide and only limited sulphur emissions. Thirdly, it has a significant potential, at least in some regions of the European Union (EU) and, even more importantly, in most developing countries. In the latter, millions of people rely on biomass as an energy source. Worldwide (14% of the total energy needs are met by biomass (OECD, 2000). However, much of this use is in fairly simple, and often polluting, combustion systems that are not very energy efficient.

In the EU, use of available technology and biomass currently contributes around 3.7 % (European Commission, 2000b), some 45 million tonnes of oil equivalent (MTOE), of the respective energy needs. In the longer term, it is anticipated that biomass could contribute 20% of the current EU primary energy demand, with more than 20 million hectares used for energy crops cultivated in EU agricultural land. However, their introduction in bioenergy schemes under existing financial and legislative frameworks is still rather uncertain and in many cases uneconomic (European Commission, 2000a).

Among the most promising identified options so far are perennial crops. They are expected to greatly contribute to the targets of increased bioenergy development, by having low input requirements, over 10-15 years of productive life and high yielding potential (especially under south European climatic conditions) (Venendaal, 1997).

Bearing these in mind, the main hypothesis tested in this dissertation is:

"to examine the evidence, that suitably selected bioenergy crops are technically and economically feasible and socio-economically valuable in Greece, a south European country."

The hypothesis has technical, economic, socio-economic and policy aspects and therefore its investigation requires an interdisciplinary approach. Biomass is, as stated above, an attractive agro-based alternative source of energy which has rural development implications and involves on site energy production. Although biomass has been used extensively in the past, in simple stoves and low efficiency boilers, after the oil crisis in the 1970s much work has been done towards more efficient and environmentally friendly use of biomass for energy purposes. At the EU level, this work has been heavily supported by funding under the European Framework Programmes which involve many countries in joint efforts. Some funds are also provided by national programmes of the EU member states. Therefore, the author has relied heavily on the findings of EU funded projects in describing the current state of the art and recent progress in technical, environmental, social and economic aspects of biomass energy. Being professionally involved as a scientist in most of the EU funded projects allowed the author to make use of the research in writing the thesis and to compare the findings with those of other participating scientists.

The choice of the main hypothesis and the interdisciplinary approach were based on the premise that in order to reach conclusions that would be useful for strategic planning and future implementation, one needs to assess a number of aspects covering the whole dimension of bioenergy. More specifically, the testing of the overall hypothesis required the following investigations:

- Evaluation of energy crops suitable for the Greek climatic conditions and the local agricultural systems in technical (including field experiments) and monetary terms.

  The author was the scientist responsible for the experiments conducted in central Greece from 1994 to 1997 in the framework of the project AIR3 CT93 1089: Cynara cardunculus network. During this period, she worked in the field establishment, management of the crop and data recording. She was collecting data at monthly intervals from the plantations concerning:

  - Fresh biomass and dry matter yields per plant part (soil leaves, stem leaves, capitulas, stems and branches)
  - Height
  - Number of stems and branches
  - Number of capitulas

She was also co-author in all the technical project reports and in a scientific paper on the crop (Dalianis, 1996a, Panoutsou, 1997a).

The collected data were further used as inputs in the models for economic and the socio-economic analyses.

For giant reed, the author collaborated with the scientists involved in the experiments and reporting (Christou, 1998, Christou, 2000a, Christou, 2000b, Christou, 2000c, Dalianis, 1994a) and further elaborated their data in the models used in the respective thesis.

- Assessment of market distortions because of subsidies and tax regimes.

  The author collaborated with the external supervisor who was the scientist responsible for Beaver, an economic model developed by him and his team in the framework of the EU funded project: 'Models for the Economic Evaluation of selected biomass cultivation as an alternative land use in the EU (Beaver). 1994- 1996. During this collaboration the author with the assistance of the external supervisor, used the collected data from the two crops as inputs to further develop the model and to moderate it according to the requirements of the thesis. The author used the moderated model in the economic appraisal of the selected energy crops in comparison to conventional crops (wheat, barley and cotton).

  She performed detailed cost analyses for the conventional crops as well as for cardoon and giant reed, the selected energy crops. The output of these comparative analyses assisted in defining the breakeven for biomass crops along with a sensitivity analysis for the risk of their potential implementation. In addition, it contributed to the determination of an accepted selling price for the produced feedstock so as to be competitive with the other fuels used in the region for small/medium local communal heat production plants and in other regions for lignite power generation (heavy fuel oil, gasoline, lignite, natural gas, fire wood, straw).

- Identification of the most promising energy market where the introduction of biomass energy would be feasible.

  In order to define a market suitable for the energy crops' biomass the author conducted a detailed review on renewable energy sources and bioenergy in Greece in terms of resources and technologies, market opportunities, policies and support mechanisms. That review was done by the author and was based on a number of reports, legislative documents and personal communication with actors involved in this field.

- Economic and socio-economic evaluation of a crop-based bioenergy scheme in the selected region.

  Reaching the point of having identified promising crops for biomass, assessed their economic viability compared to conventional crops and defined a suitable market, the author realised that the next step for providing concise planning answers would be to evaluate the economic and socio-economic viability of a complete biomass to energy scheme for a suitable region. The BIOSEM methodology was used for this evaluation. The strengths and weaknesses of the methodology were also assessed.

  The author's ***original*** contribution in this evaluation was the case study for the selected region and the analyses for the biomass to energy scheme, which was also the national contribution in the respective EU project under the Fair Programme (1996a) (FAIR CT96 1389. 1996-1999: Socio-economic Multiplier Technique for Rural Diversification through Biomass Energy Deployment). The author was the scientist responsible for the Greek team in the project.

  Based on the BIOSEM methodology, the identification and description of the selected region was based on assessment of:

  agricultural activities
  energy consumption
  socio-economic profiles of the region

  All these parameters were examined along with data at both regional and national levels in the country in order to estimate the context in which the selected area operates. Combining the regional profile, financial information and the review on suitable markets for bioenergy in Greece, a local bioenergy scheme was selected and was further analysed in terms of economic and socio-economic viability.

- Evaluation of the potential adopters, taking into account the issues of adoption of innovation and the relevant context (networking formation and questionnaire surveys were used to conduct the assessment).

Introduction of bioenergy is an innovation involving farmers, energy producers, manufacturers of conversion equipment and consumers. Therefore the diffusion channels as well as the perceptions some of the main agents involved in the adoption of innovation were examined.

First, through a series of seven discussions, of the existing National Biomass Network team the author interviewed the key groups involved and monitored their perceptions. The national team was formed in the framework of the EU funded programme aiming to encourage dialogue between the industry, environmental organisations, the government, and the local community to create a consensus view on bioenergy schemes (Altener Programme, Bioguide, 1996).

The author was one of the actors in these networks and has been able to use the evidence on potential synergies and conflicts in the research.

Overall, the original contribution to knowledge of this investigation is:
" to identify the best options of introducing energy crop based schemes at the local level in Greece, in technical (agriculture and energy), monetary, social, and innovation diffusion terms".

This was achieved by capitalizing on active participation of the author in research and demonstration of energy crops in Greece as well as in methodologies assessing the economic and socio-economic viability of biomass energy schemes over nine years followed by the more specific investigations in completing this thesis. In summary, the components of the study were:

- For the technical aspects, work involved in collecting field data which were afterwards used as inputs to the models,
- For the financial and economic aspects, work involved collection of data from statistics and relevant surveys which were also used as inputs to the models and deriving and interpreting the results from the models (BIOSEM, Beaver), and
- For the socio-economic aspects, work involved networking formation and surveys with the key actors involved in a bioenergy scheme as well as using BIOSEM model in order to assess the socio-economic impacts.

The specific aims of the first chapter are to set the *scene* for bioenergy, in terms of terminology and deployment targets scheduled by certain policy measures and to outline the research phases of the thesis.

1.2 BIOENERGY: DEFINITION AND DEPLOYMENT TARGETS

Biomass includes material of biological origin. ***Bioenergy*** is the word used for energy associated with biomass, and ***biofuel*** is the bioenergy carrier, transporting solar energy stored as chemical energy (FAO, 2000). There are two forms of biomass:

- residues/wastes; and
- dedicated energy crops.

Residues/wastes are further distinguished in the following categories:

- Field crop residues that remain in the field after harvesting the main product. Such residues are cereal straw, cotton stalks, prunings, etc.
- Forest residues (loggings, early thinnings, etc.).
- Animal wastes.
- Agro-industrial wastes like olive kernels, cotton ginning residues, etc.
- The organic fraction of municipal wastes.

A number of policy measures have been implemented to enhance further bioenergy deployment. Two international measures of considerable significance are:

In the "***White Paper: Energy for the future: Renewable Sources of Energy***", (European Union, 1997), which is the most specific policy mechanism at EU level, bioenergy is described as one of the important constituents for achieving the target of 12% RES contribution in the European Total Primary Energy Supply (TPES). From the total projected increase of renewable energy sources to 108 MTOE between 1995 and 2010, bioenergy is expected to contribute 88 MTOE.

The ***Kyoto Protocol***, December 1997, signals political acceptance among the industrialised countries that carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions must be reduced. The signatories are committed to reducing their aggregate emissions of greenhouse gases to at least 5% below 1990 levels before 2012 (Kyoto Protocol, 1997).

Recently (July 2001), governmental representatives for environment met in Bohn and decided to continue on the lines of the Kyoto Protocol until the year 2012. However, the USA accounts for almost a third of worldwide emissions withdrew from the Protocol.

1.3 RESEARCH STRATEGY AND THESIS OUTLINE

The thesis focuses on the technical, financial, economic and socio-economic evaluation of energy crops as raw material for bioenergy schemes at a local level in Greece, based on current bioenergy development trends and taking into account its peculiarities (combining agriculture with energy production, balancing economic benefits and costs against social, natural resource conservation and environmental considerations and examining the problems associated with the introduction of innovations in the rural economy).

Due to the multifaceted nature of the subject and in order to cover all the aspects involved, the research strategy comprises of technical, economic and socio-economic studies.

In the beginning a literature review was undertaken to point out the key features affecting bioenergy deployment and to avoid any duplication of the planned research work.

Furthermore, the study aims to be an objective analysis of the following set of questions:

(1)Do energy crops make financial and socio-economic sense? Which items determine the production costs of energy crops and what is the cost situation for some of the most promising options?

What is the opportunity cost of land devoted to the production of biomass? How can all relevant costs be compared to conventional cropping in a local agricultural system?

(2)What is the current policy for state support and justification for governments to promote biomass and especially energy crops for agriculture?

Is there a valid economic justification for promoting biomass crops for energy purposes?

(3)Which factors determine the future of energy from such crops?

Does technological development work in favour of energy crops?

(4) What are the problems of implementing an innovation such as cultivating crops for energy purposes?

Bioenergy and especially energy crops are an innovation that has to be carefully integrated in the agricultural communities, in the energy market and in the national policies.

The answers to the above mentioned set of questions were given through a detailed analysis of the country and the region selected in relation to technical, legislative and socio-economic aspects affecting bioenergy schemes. The sequence of topics as well as the methodologies and tools used to develop an integrated approach for the thesis are presented below.

1.3.1 Phases

The structure of the thesis was divided in eight phases. Their sequence is the same with the sequence of chapters in the thesis and is clearly outlined below:

- Literature review.
- Methodological Approach.
- Review of bioenergy and renewables in Greece.
- Energy crops in Greece. Selecting promising solutions.
- Site selection.
- Financial evaluation of energy crops compared to conventional ones, in the selected region.
- Economic and socio-economic evaluation of a crop-based bioenergy scheme in the selected region.
- Adoption of energy crops through networking in a national, regional and local context.

During the **first phase**, the author conducted a literature review concerning the specific features affecting bioenergy deployment.

During the **second phase**, the methodological approach was selected and the steps to be followed were analysed.

During the **third phase,** the author conducted a review survey on bioenergy and renewables in Greece, the country under study.

During the **fourth phase**, based on finished and ongoing research and development projects the author presented the situation for energy crops in Greece and selected two of the most promising options.

During the **fifth phase**, of the study, the author, following the analysis of bioenergy deployment in Greece, selected a suitable region to perform the research work on financial and socio-economic evaluation of energy crops.

During the **sixth phase**, the author conducted financial and economic analysis for the selected energy crops (comparing energy and conventional crops in terms of production factors - land, labour, energy, etc.- and current subsidisation policies).

During the **seventh phase** the author performed an economic and socio-economic evaluation of a district heating system fuelled with energy crops in the selected region. In this context the principles of the BIOSEM technique (FAIR Programme, 1997) were followed and the author adapted the methodology to the specific local conditions.

During the **eighth phase** the author, acknowledging that bioenergy deployment is an innovation involving a large number of people examined the diffusion channels as well as the different perceptions of actual and potential adopters.

In the following chapter, prior to selecting the methodological approach of the study, the author conducted a literature review concerning the specific features affecting bioenergy deployment.

Key considerations concerning: i) current policies, ii) environmental aspects, iii) economic viability of bioenergy and iv) social dimension of the implementation of bioenergy schemes, were the main points of the review.

CHAPTER 2. BIOENERGY: KEY CONSIDERATIONS

This chapter presents the literature review conducted by the author to define the specific features affecting bioenergy deployment. Key considerations concerning: i) policies, ii) environmental aspects, iii) economic viability of bioenergy and iv) social dimension of bioenergy schemes, are addressed.

2.1. BIOENERGY AND ITS POTENTIAL BENEFITS FOR EU

By its nature, biomass has a strong influence on the economy of the EU countries not only in the pulp and paper, but also in the forest and general wood industries as well as agricultural products. Therefore, amongst the renewables, this sector can play an important role to counter the slowdown in economic activity, not only at union level, but also at national and local level.

European companies that specialize in energy generation from biomass and wastes are world leaders, with strong exports and the industrial competitiveness of this sector is very significant (Millich, 1997).

The industries concerned are not confined to the biomass conversion system (such as a boiler), but also steam and gas turbines, environmental protection systems (such as ceramic filters and scrubbers), tree harvesters, chippers transport systems, special materials and alloys, automated control systems and so on. Thus the competitiveness of the sector in general has a widespread effect in numerous sectors of the Union's industry.

Furthermore, agriculture and forestry (the "raw material" sectors) are job intensive industries, and energy crops have the added advantage that they can be grown on set-aside and marginal lands, thus assisting job creation in these industries.

Concerning bioenergy scale and market potential, SMEs play an important role in the biomass and waste sector due to the fact that they are a factor for innovation, performance and flexibility and, for this reason, are a major contributor to job creation. From the last paragraph above, it is obvious that strong performance by the industry will have a significant effect on job creation in numerous sectors of the Union's industry.

Biomass and waste are also interrelated with environmental protection. Biomass is the only energy source, which can recycle carbon dioxide, while waste must be controlled in order to protect the environment. Co-utilisation of biomass and waste with fossil fuels has an important positive influence on emissions.

Finally, energy generation from biomass and waste is mostly applicable at the local level (as well as the production of the production of biomass and waste), and thus the social and economic cohesion is significantly improved. Furthermore, adjustment to industrial change and changes to energy generation systems such as those achieved by the sector, are essential for increasing competitiveness and therefore it is an important element for social cohesion.

2.2 POLICIES

The oil marketing policies of the Organisation of Petroleum Exporting Countries initiated the so-called first oil shock in 1973-74 and changed, probably forever, the international oil markets and the energy policies of most industrialised nations. In 1973, Middle East light crude oil spot market prices rose to about US$13/bbl from a low of about US$2/bbl (Klass, 1995).

Many policy changes and legislative actions were undertaken in several industrialised countries to counteract these conditions. Programmes were initiated to develop and utilise modern biomass energy technologies and other renewable energy resources to displace oil.

National energy policies began to include\budgets to develop biomass as an indigenous energy resource. As late as the mid-1800s, biomass supplied the vast majority of the world's energy and fuel needs and only started to be phased out as the fossil fuel era began, slowly at first, and then on a grand scale. However, with the first oil shock, biomass was again realised by many governments and policy makers to be a viable, domestic, energy resource that had the potential to reduce oil consumption and imports and improve the balance of payments, and deficit problems caused by oil imports.

Three general types of incentives exist in order to support further development of biomass, and other renewables, development:

Financial incentives

In many countries, including Greece, the government programmes provide subsidies directly to end users to encourage conversion of industrial and residential energy systems to biomass as well as the construction of new biomass installations.

Taxation

Tax incentives are provided in several countries (EU member states, USA, Canada, etc.) with the following form:

tax credits for commercialised biomass energy systems

- tax incentives to ethanol-gasoline and biodiesel-diesel blenders
- heavier taxation on fossil fuel plants as CO_2 polluting ones

Research and development Programmes

Research efforts are enhanced towards raw material availability and advanced conversion technologies. In detail, work includes:

dedicated feedstock (energy crops) development,

- improved biomass handling and feeding systems,

- better methods of extruding and densifying biomass,
- district heating with wood chips,
- improved emission controls for municipal incinerators and landfill gas collection systems,
- advanced gasification and Pyrolysis,
- extractive fermentation processes for conversion of biomass to liquid fuels.

2.2.1 European Union policies

Due to the role of energy in almost all walks of life, EU policies in this area have to be considered within a wider context extending to climate change, waste disposal, agriculture (the Common Agricultural Policy, including aspects of support for non- food crops and set aside land) air and water policy, the single market and the place of the EU in world trade. With this background, the Commission has developed an analysis covering competitiveness, environmental protection, security of supply, external energy relation and the promotion of energy efficiency and Renewables.

In particular support of Renewables is based on the realisation that the use of fossil fuels is damaging the environment and that support in this sector can aid industrial development, provide jobs, avoid fuel imports, improve regional development and result in export of technology to countries outside the EU. As indicated above, the strategy has been reviewed in the White Paper: Energy for the future: Renewable Sources of Energy.

In detail, concerning bioenergy the projected additional contribution in 2010 is set up to 90 MTOE, deriving from:

Biogas exploitation	15 MTOE
Agro-forestrial residues	30 MTOE

Energy crops 45 MTOE

The EU has also initiated a Campaign for Take-Off as a means of setting targets and promoting RE through partnerships, conferences, awards and public relation activities. These activities will help the Community reach its goals in reducing atmospheric carbon dioxide levels, as set out in the White Paper: Energy for the Future: Renewable Sources of Energy (COM 97- 599). The Commission has targeted priorities for future calls for RTD projects in this area and recognises the need for greater cohesion between efforts made by Member States, and has also identified the need for further investigation of socio-economic and environmental impacts of biomass energy.

Presently, biomass in Western Europe accounts for 5.8 % of primary energy. A number of developed countries also use biomass quite substantially, e.g. Finland derives 18% of its total energy from biomass, Sweden 16% and Austria 13 % (Hall et al., 1993; Chartier et al., 1995). However, due to the size and the complexity of markets and interests within the EU, there are variations in the extent to which existing and proposed Regulations and Directives interact to stimulate the use of biomass and wastes in different markets. Obviously, the latter will be affected by legislation aimed at reducing waste and defining methods of disposal. Suggestions concerning tax concessions of benefit to liquid transport fuel are a continuing matter of debate, as are those covering imposition of taxes on fossil fuels that can give Renewables a competitive edge, while continuing changes in agricultural policies affect support measures for farmers wishing to grow energy crops.

On balance the concepts and the extent of funding for development of renewable energy should help the EU reach the targets set for biomass. However, the rate of progress will also be influenced by decisions made in other areas of policy.

2.2.2 National policies

Most Member States of the EU now have renewable energy related policies (European Commission, 2000), but there are variations in use, legislation, incentives and markets supported (AFB network, 2000).

Sweden produces around 25% of energy from renewables, with wood and wastes contributing to district heating, and has an energy policy that includes an extensive national RTD programme focused on biofuel fired CHP and new processes for ethanol production.

Denmark has a detailed plan that aims to reduce carbon dioxide emissions by 20% by year 2005 linked to an increased contribution of renewable energy from 8% to 14%, with an emphasis on use of biomass and green electricity.

Germany has made climate protection a key area and looks to double the present 2% contribution of Renewables. The Eco- tax Reform introduced in 1999 was followed by the Renewable Energy Law in 2000, guaranteeing green electricity prices.

The Netherlands has a plan for a five- fold increase from current contribution of renewables of 1%, and is funding an extensive RTD programme.

Portugal already has a high use of wood for energy, and policies supporting Renewables.

Ireland has privatised its energy sector and expects Renewables to provide more than 500 MWe by 2005.

Greece has introduced similar measures that have led to more than 100 requests for permits for renewable power generation over the last few years, while 6% of energy comes from wood used in the domestic sector.

The UK has adopted a new strategy including obligation for all licensed electricity suppliers to supply a proportion of electricity from renewables, or pay a buy-out price, with a supporting programme of RTD to provide the technology push and help overcome both technical and non- technical barriers.

Finland already produces more than 20% of its energy from forest industry by- products.

Austria's energy supply includes more than 10% derived from biomass (largely wood for space heating) as a result of subsidy and research policies.

Italy has a National Energy Plan that includes laws favouring electricity from Renewables (with more than 3,700 MWe in place).

Wood also contributes significantly to domestic energy supply in ***Spain*** and ***France*** where the governments have set targets for use of specific Renewables including biomass.

2.3 ENVIRONMENTAL CONSIDERATIONS

In general, the renewable forms of energy are considered "green" as they cause little depletion of the Earth's resources, and because wind, solar and wave energy cause zero air emissions during power generation.

Biomass energy is renewable, but shares many characteristics with fossil fuels. Biofuels can be transported and stored, and enable base load generation, complementing other renewable energy sources which are wind and solar in an energy mix with a high dependence on intermittent sources such as wind. These similarities account for the major role biomass is expected to play in future energy scenarios. Also in common with fossil fuels, the environmental impacts, including air emissions, are significant at the conversion stage.

The threat of significant climate change has added urgency to the need for commitments to non-fossil and low-carbon approaches to meeting our energy needs. Fossil energy is often rejected on environmental grounds, and therefore it is essential that we assess the environmental profile of the technologies, which we propose should displace it.

Various methodologies have emerged which can be used to assess the relative environmental merits of energy options, such as life-cycle analysis (LCA) and the estimation of external costs. In any case, whichever method one decides to use, three major points must be borne in mind when attempting to assess the environmental profile of biomass energy.

- Biomass energy is diverse and its impacts are site (and management) specific. The raw materials can be purpose- grown residues, woody or herbaceous. They can be treated to produce solid, liquid or gaseous fuels. These in turn can be used in various ways for heat and power or transport. Different approaches will be appropriate for different localities. Given this diversity no single, composite figure or indicator can express the environmental impacts of biomass energy in general.

- The development of modern biomass energy systems is at relatively early stage. Much of the R&D in the biomass energy field focuses on the development of fuel supply and conversion routes, which minimise environmental impacts, such as low input/ high yield energy crops technology, and efficient power generation using gasification. Where a technology is some way off maturity it can be misleading to predict its environmental profile.
- Any attempt to arrive at a composite indicator of environmental performance, even for the purpose of ranking different options, involves subjective and speculative considerations regarding environmental impacts. The relative weight given to acidification, global warming or soil erosion will depend largely on an analyst's education, locality and preferences, and may change over time. When discussing environmental impacts in other countries one should hesitate to put priority on issues held to be important from one point of view, when other issues in another country may eclipse them.

Recently, with the realisation that biomass energy could become part of the modern energy economy on a large scale there have been increasing concerns as to the short and long-term environmental effects of such a strategy. Fortunately, a number of environmental and biomass energy groups acknowledged some time ago that if biomass was to play an important role in future energy policy then its production, conversion and use must be environmentally acceptable. These latter two factors are likely to be the most crucial constraints on future biomass developments and must be addressed in some detail in order for scenario builders to appreciate the opportunities and problems associated with biomass energy production and use. These environmental aspects also have the highest priority in recommended strategies for future research and development policy, as ensuring environmental sustainability will be a fundamental factor in future biomass for energy development.

More specifically, concerning energy crops production and land availability issues about possible conflicts between food and fuel production are now less of a problem due to the acknowledged surplus agricultural capacity in Europe (and North America) which has been highlighted by the problem of overproduction in the EU (Hall and de Groot, 1988; Netherlands Scientific Council for Government Policy, 1992). The integration of energy crops in agricultural land should be done with respect to the requirements for food at national and exporting level. However, it is worthwhile to mention that food production should also be properly integrated so that all countries can have a respective proportion of their needs. It is not sustainable to produce food in one place only and then export it to huge distances. This has also serious environmental implications with respect to increased transportation.

Therefore, the most sensible way at planning level is to integrate food and fuel production according to the regional needs, the land types available, the soil- climatic conditions, etc.

The following should be consulted for a more comprehensive coverage of environmental factors: Pasztor and Kristoferson (1990), Beyea et al. (1991), Cook et al. (1991), Ranney (1992,1994), Ledin and Alriksson (1992), Office of Technology Assessment (1993), Shell/WWF (1993) and Gustaffson (1994).

There is a complementary report by Jordan (1993) on the scientific basis for codes of good agricultural practice in Europe.

2.4 ECONOMIC VIABILITY

The economic viability of bioenergy schemes relies on a number of issues dealing first with the availability and the opportunity cost of the raw material compared to the conventional fuels and secondly on the conversion technology and its efficiency.

Coal is traded internationally for approximately $1.8/ GJ. Some wood residues, and energy crops in southern EU regions can be produced at this level, but currently wood fuel typically costs 2 or 3 times as much as coal in Europe or the USA (Hall, 1998). In Sweden the price of wood fuel fell by 50% in real terms between 1984 and 1994, to $4 GJ, despite a rapid increase in demand (Hillring, 1997). At this price wood fuel is competitive with fossil fuels in Sweden because of the tax regime favours renewable energy, largely through carbon dioxide tax on fossil fuels.

The cost problem for biomass is also compounded by low conversion efficiencies, which relate to the small scale of most biomass energy facilities.

Both problems are being tackled progressively with the development of dedicated biomass feedstocks (energy crops) and forest fuel industries, and the development of more efficient power stations based on gasification and combined heat and power generation (Hall, 1996).

However, when examining the comparability of biomass fuels with fossil ones, it is worthwhile to mention that the international price of fossil fuels is in many cases kept artificially low by government subsidies aimed at protecting domestic fuel security and/or regional employment.

The Kyoto Protocol calls for abolishing the fossil fuel subsidies in the signatory nations [Article 2.1 (a) (v)], 'Progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse gas emitting sectors that run counter to the objectives of the Convention and apply market instruments'.

In OECD countries annual price support to food producers are of similar magnitude, which thus raises the market value of land and thus increases the cost of competing land uses such as energy crops.

A hidden subsidy is additionally made to the fossil fuel sector in the form of costs borne by third parties in terms of health, environmental damage and global warming.

Under current market structures modern biomass energy is comparatively expensive, but this is by no means the natural outcome of the operation of a free market.

These real (and perceived) problems will continue to limit the market penetration of modern bioenergy.

Energy market liberalisation may promote small-scale power generation (Patterson, 1996) including biomass. However, in the USA the real prices of coal, oil and gas have fallen by 45%, 70% and 44% respectively between 1980 and 1994 (Parfomak, 1997). It appears that if biomass is to become a major fuel of the future then cost reductions must be a priority, but concerns for the environment in the context of growing world population and energy demand will also be driving forces.

An approach which has not yet received the co-ordinated attention that it deserves but which may well be able to help gear up biomass deployment rates significantly is the more obvious linkage of residues exploitation to mainstream (dedicated crops) biomass developments. This approach uses the driver of immediate need to cope with a problem (residues disposal mostly) and scales up appropriately to draw in a dedicated biomass resource. The result would be significantly larger projects or hybrid ones, which at one and the same time deliver more RES whilst also taking developers, financiers (key stakeholders) forward into more mainstream biomass ventures able to deliver greater and earlier replication (Richards, 2001).

The attractiveness of growing energy crops depends in large part on what net profit is possible, in comparison with the next-best crop alternative. What would be needed for an energy crop, such as switchgrass, to allow farmers to breakeven with other commonly grown crops such as corn? (Paine, 1996). The net return for growing corn in Wisconsin varies from over \$300/ha or \$100/acre to close to zero on poor land (Gumz, 1994)). Switchgrass can produce between 4 and 14.3 t/ha dry matter. Production cost estimates range from \$380/ha to over \$600/ha (Brower, 1993, Turhollow, 1994). On prime land, a farmer would need to gross a minimum of \$680/ha (&380 production costs, plus \$300 in return) to make as much profit as he/ she would by growing corn. Assuming a high yield of 14.3 t/ha on prime land, the required selling price of the switchgrass would have to be at least \$48/t. To simply recoup production costs a yield of 8t/ha would be required.

In another study conducted in the framework of EU funded AIR programme (AIR3-94-2455), results from energy crops' economic assessment indicate that (Hanegraaf, 1998):

- For electricity, conversion routes using poplar and willow are in general the cheapest. Prices are from 0.04 to 0.08 EURO per kWh_e using fallow grass as reference, and are comparable with the expected market price of electricity (0.05 EURO per kWh_e). This means that with an area payment of 500 EURO these crops could be economically feasible without CO_2 levy or premium for CO_2 reduction. The use of hemp, silage maize and miscanthus is slightly more expensive, with electricity prices of 0.05-0.09 EURO per kWh_e for hemp and 0.06 to 0.13 Euro per kWh_e for silage maize and miscanthus.
- With respect to the costs of CO_2 reduction, conversion routes producing electricity using poplar and willow are generally the cheapest, with cost prices from below zero

to a maximum of 35 Euro/t of CO_2 avoided. The cost price of CO_2 reduction with hemp is slightly higher: 2-41 Euro/t, depending on the conversion route.

Mitchell *et al.* (1999) conducted a financial assessment for short rotation forestry compared to conventional crops in the UK. The main results are presented in the table below.

Below are some examples of the gross margins which are expected from some conventional agricultural crops and which can be compared to the equivalent annual value from a short-rotation coppice plantation.

Table 2.3.1. Financial comparison of SRC with conventional agricultural crops

Crop	Productivity (t/ha)	Gross Margin Without subsidy (euros)	Gross Margin With subsidy (euros)
Spring barley	4	422	807
Winter wheat	6	680	1,065
Winter oil seed rape	2.7	272	759
Short-rotation coppice	8	11	296

Source: Chadwick (1996)

The first commercial bioenergy scheme fuelled with energy crops in Europe is the ARBRE project in Yorkshire, UK. It will produce enough electricity for the domestic electricity consumption of 33,500 people from clean and sustainable wood fuel sources (ARBRE, 2001). The ARBRE plant will generate 10 MW of electricity, of which 8 MW will be exported to the local grid. The power will be generated from wood chips provided from forest and short-rotation coppice sources, namely:

• Short-Rotation Coppice - Short rotation coppice consists primarily of densely planted willow shrubs harvested on a three-year cycle. The rootstock is left in the ground and after each harvest new shoots emerge, as in a traditional coppice.

• Forestry Sources - materials derived from forest and woodland management.

Energy crops offer an exciting new commercial opportunity for farmers and growers. Short rotation coppice production allows diversification of land usage and offers substantial environmental benefits compared to intensive arable farming. These include reduced use of agrochemicals and greater ecological and landscape diversity.

In a conventional coal fired power plant the coal is burned to produce heat to raise steam. The steam drives a turbine to generate electricity - a simple steam cycle. ARBRE has adopted a new and more advanced technology for converting its wood fuel, one that offers higher efficiency. The wood will first be converted to a gas, known as syngas, which has a calorific value of around 5.4 MJ per cubic metre. The syngas will be combusted in a combined cycle plant that contains a gas turbine and a steam turbine to maximise efficiency. This system is termed Biomass Integrated Gasification Combined Cycle (BIG-CC).

The plant is currently at the commissioning stage and little is published for the economics or performance.

Economics of energy crops' production were also presented in the EU financed project: European Energy crops' overview (FAIR Programme, 1997) and are summarised in an overview paper by Venendaal *et al.* (1997). The main findings are listed below per participating EU country and energy crop.

- In Sweden, the basic production costs of willow are reported to be 3.64 Euro/GJ (excluding grants), while the market price of similar biomass delivered to district heating plants is 2.0- 4.0 Euro/GJ, with an average of 3.7 Euro/GJ. The market price of coal to the industry and non-industrial users is respectively, 4.3 and 7.5 Euro/GJ, while for light oil market prices are 6.1 Euro/GJ (industry) and 9.8 Euro/GJ (others). For non-industrial users, the general energy and environmental taxes are 5.82 Euro/GJ for coal and 5.56 Euro/GJ for gas oil. ***Thus the raised tax level for fossil fuels makes biomass feasible. In addition, grants are available for willow plantations.***

- In France, calculated production costs for miscanthus and winter rye are 4 Euro/GJ and for willow 4.8 Euro/GJ, while the market price for coal amounts to 3 Euro/GJ for the industry and 6.5 Euro/GJ for private households. Solid fuel energy crops are at an early development stage in France, but considering these price levels, the gap between energy crops and fossil fuels is not as big as in many other countries. However, ***according to French ADEME (Hevin, , 1996), the latter is of less importance for France; to make energy crops feasible the investment costs for biomass fuelled boilers should be reduced by 50%.*** Liquid biofuels are much more favoured in France since esters and ethanol have high tax exemptions, of, respectively, 9 and 13 Euro/GJ. Currently, the sugarbeet sector is more efficient in the production of bioethanol than the wheat sector in France.
- In Austria, the gross margin of most energy crops is negative when grants are not included. Higher yields with lower costs should improve this situation. Without compensation measures, the gross margin for biodiesel production amounts to 115-144 Euro/GJ negative and for sunflower 180- 210 Euro/GJ negative. The gross margin for energy grain is 123 Euro/GJ negative and for poplar is 1750 Euro/GJ negative. ***To make biodiesel production economic in Austria, the government established a tax exemption for 100% biodiesel of 0.28 Euro/l or about 7 Euro/l (Luger, 1996).***
- In the UK, total costs per ha per year (excluding grants) are 1064 Euro for willow and 1467 Euro for miscanthus. Expressed in Euro/GJ, the costs are 5 Euro/GJ for willow and 4 Euro/GJ for miscanthus. The market price for coal in the UK is1.25 Euro/GJ, while oil costs 2.4 Euro/GJ (Roberts, 1996). ***Thus financial incentives are needed to make energy crops feasible in the UK.***

- In Germany, some preliminary calculations on miscanthus show that production costs inclusive of farmer profit are in the range of 4- 11 Euro/GJ, depending on the yield level. Reported annual costs of poplar production are 640 Euro/ha or 4 Euro/GJ (at 10 odt/ha and 16 GJ/odt) (Kaltschmitt, 1996). ***Neither solid energy crops nor biofuels are competitive with fossil fuels without incentives in Germany.***
- In the Netherlands, basic production costs of 5 Euro/GJ were reported for willow (inclusive land rental) and hemp, while for miscanthus 3 Euro/GJ was mentioned. In more recent calculations, in which land rental and sufficient income for the farmer are incorporated, minimum costs of 7 Euro/GJ for miscanthus have been calculated. These costs must be compared with the cost of coal, which is at the level of 2 Euro/GJ at the gate of big power plants in the Netherlands. ***With the recently introduced tax in the Netherlands, willow might just about break even, while the production of miscanthus with the inclusion of land rental and farmers income is unfeasible without grants or other incentives (Brown, 1996).***
- ***In Denmark, legislative and tax regulations have made energy use of existing biomass resources such as straw and wood chips feasible.*** Current mean market prices are 4.7 Euro/GJ for wood chips and 4.0 Euro/GJ for straw at the energy plant gate. The price of coal for power production is about 1.1 Euro/GJ, while it is about 7 Euro/GJ for heating purposes. The price of fuel oil is about 12.5 Euro/GJ for heating. Basic production costs for willow are calculated at 4.4 Euro/GJ for direct delivery of wet wood chips during winter and at 4.7 Euro/GJ for the storage and delivery of drier whole stems. Similar costs for miscanthus are estimated (3.8 v for the storage and delivery of dry big bales) while the cost of wet chips delivered directly from the field

to plant during the winter is estimated to be 2.9 v. Cost of production, storage and delivery of winter rye is calculated at 4.1 Euro/GJ (Jorgensen, 1996).

From the abovementioned costs and prices in several EU Member States, it is clear that biomass either in the form of residues or energy crops is feasible ***if and only*** incentives or tax exemptions are applicable. Under the current agricultural policy, where most of the crops are subsidised, biomass and especially energy crops should receive at least a similar amount of incentives in order to provide a net farm income equal or higher to that of the conventional crops.

Otherwise, farmers will not face the risk of this new venture especially when their family income relies on agriculture and they have to be very careful on their choices.

2.5 SOCIAL IMPLICATIONS

There is a social dimension of bioenergy choice and implementation. This form of energy production and use involves a large group of people and affects the social development of the farming and the local community in terms of income and jobs maintenance and/or creation.

Several reactions might arise from the planning stages of a bioenergy scheme. Social structures, such as status, norms, solidarity and conflicts can influence the development of a bioenergy market.

The perception of district heating projects in Austria was different from village to village (Rakos, 1995). In some cases, the whole village enthusiastically supported projects and almost everybody decided to connect to the grid. In other villages the project was received more sceptically or it even led to serious local conflicts. Significant local resistance in some locations could confront even an environmentally sound, comfortable, highly subsidized technology with a positive image in the general public. The local opposition was explained by distrust towards bioenergy in the agricultural population, political and personal conflicts and conflicts between old villagers and new settlers. These conflicts not only threatened the realization of a district heating plant, they also seriously affected the economics of a project. Investment costs of projects that experienced resistance were on average 30% higher than projects that experienced little or no resistance. This depended on mitigation measures required in conflictive licensing procedures, the necessity to build the plants at sites outside of the village (high additional costs for piping). Local conflicts also affected the readiness of customers to connect to the district-heating grid. Sometimes half of the village did not connect to the grid for political reasons.

Biomass projects can be controversial in similar ways. It is therefore essential to carefully examine the diffusion channels in the local community so that any potential risks can be foreseen and handled properly during the planning phase.

2.6 CONCLUSIONS

The main aspects affecting bioenergy deployment are political, environmental, economic and social.

From the literature review presented in this chapter, it is evident that significant biomass resources are already available in the form of residues and wastes and good potential exists for energy crops. However, although the environmental benefits of biomass are well known, in the current economic environment, it is difficult for bioenergy to compete with other energy sources. Biomass fired plants are typically smaller than coal ones, thermal efficiencies are low, and delivered fuel prices are sometimes driven up by competition from other plants. Together with the relatively low price of other fossil fuels and natural gas, these factors create a competitive disadvantage for biomass energy.

Further increase in bioenergy deployment, to reach the specific targets set in official policy documents, as the White Paper for Energy, would require more efficient schemes both in terms of raw material (dedicated energy feedstocks) and higher efficiency and reliability conversion technologies.

The current state of policies in certain EU Member States gives a shift to bioenergy compared to other countries where no favourable support mechanisms are applied. In order to make biomass competitive government energy, environmental and agricultural policies should be aligned to break down the regulatory barriers to developing and implementing the technology.

Concerning the social dimension of biomass, community partnerships involving all stakeholders in a project would reduce barriers and enhance the chances for success of a biomass power scheme.

In the following chapter, the methodological approach and the steps taken for this study are analysed.

CHAPTER 3: METHODOLOGICAL APPROACH

This research comprises a five-year study on the financial and socio-economic evaluation of energy crop-based schemes at the local level in Greece.

Due to the multi-faceted nature of the study the research strategy was designed so as to allow the evaluation of selected energy crops in technical, economic and social integration terms in a local bioenergy scheme (Figure 3.1).

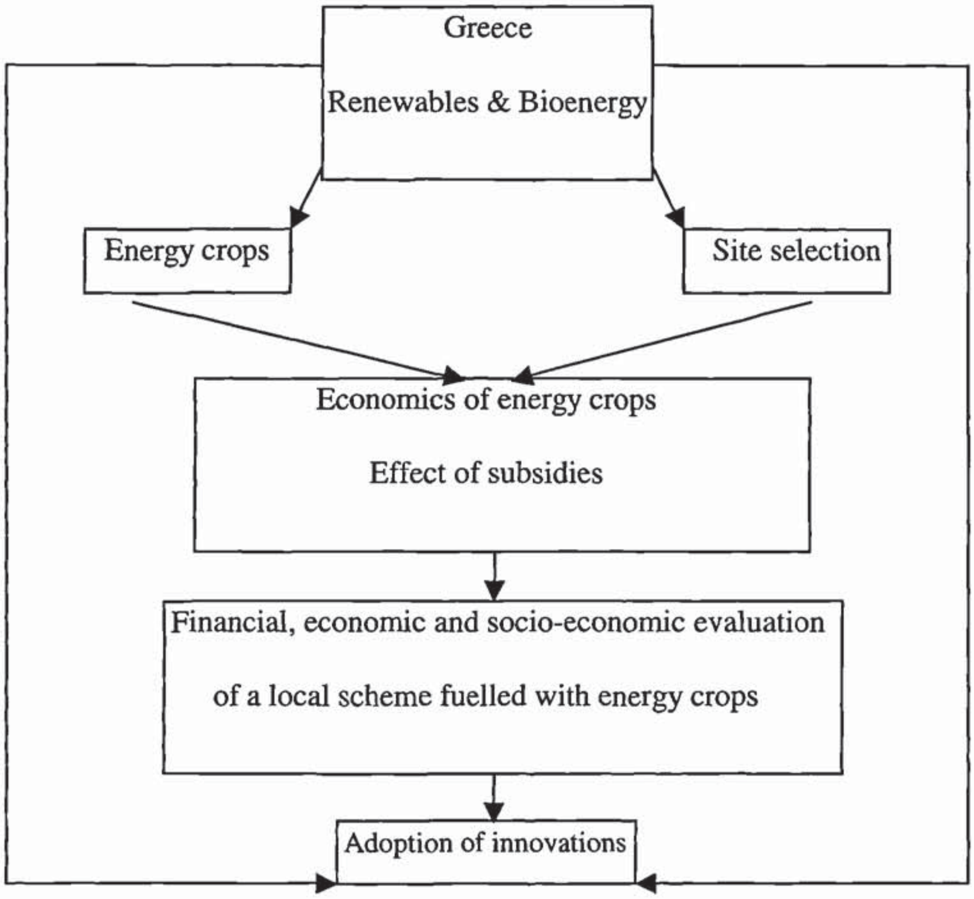

Figure 3.1. Schematic view of the research phases of the thesis

The selection of energy crops as the biomass resource was based on the results of numerous – ongoing and completed- research and development projects, in which the author has participated during the last nine years as research assistant and/or scientific project manager. The methodologies used in these projects were experimental and tested the adaptability, growth and biomass productivity of different energy crop species under Greek soil- climatic conditions throughout the country (Mardikis, 2000). The main research topics as well as conclusions and results for each crop are presented in Chapter Five where the selection of promising energy crops is presented.

In the framework of the thesis, the choice of energy crops as the biomass raw material provided important features for such a study along with important technological factors for bioenergy development, namely:

- Security of long-term feedstock supply in the bioenergy scheme under study.
- Alternative land use options for existing agricultural systems- increased productivity per land unit with low input production systems.
- Environmental benefits arising from the exploitation of low fertility, degraded and/or erosion vulnerable fields as well as from the use of sewage sludge effluents for irrigation.
- Raw material with uniform, optimised characteristics that permits the use of "modern, higher efficiency" conversion-to-energy technologies.
- Locally produced biomass, establishing network links within the community and maintaining rural employment both in the agricultural and the energy sectors.

Focused on the objective analysis of the questions set in Chapter One, on the literature review presented in the previous chapter as well as on the multifaceted nature of the subject, the methodological approach was divided in the following phases, which are thoroughly analysed with the same sequence, in the next chapters.

Renewables and bioenergy in Greece

During this phase, the author conducted a review of renewables and bioenergy in Greece, the country under study, in terms of present policies for renewables and the electricity market. The review on bioenergy includes presentation of biomass resources, currently examined conversion technologies as well as potential bioenergy markets.

Energy crops. Selecting promising options

Based on finished and ongoing research and development projects, the current state for energy crops in Greece is presented. In the end, two of the most promising options were selected cardoon (*Cynara cardunculus* L.) and giant reed (*Arundo donax* L.).

Site selection

Following the analysis of bioenergy deployment in Greece, the author selected a suitable region to perform the research work based on a thorough analysis of the main sectors involved in bioenergy deployment namely economy, agriculture and energy sector at national, regional and local level.

The selected region is Rhodope, northern Greece. This region presents certain characteristics (Liapis, 1993, Panoutsou, 1998b, Panoutsou, 1998e, Kypriotis, 2000, Panoutsou, 2000a), which favour the potential development of energy crop bioenergy schemes:

- agriculture is intense both in terms of land use and on active population,

- the agricultural sector is one of the most important economic activities of the region and the sector is facing economic difficulties,
- the unemployment rate is higher than the national average, especially among young people and
- the climatic conditions favour the use of heat produced in a bioenergy scheme.

Economic evaluation of energy crops compared to conventional ones, in the selected region.

Following, detailed cost analyses were performed for the conventional crops, wheat, barley and cotton, as well as for cardoon and giant reed. The output of these comparative analyses assisted in defining the breakeven for biomass crops along with a sensitivity analysis for the risk of their potential implementation. In addition, it contributed to the determination of an accepted selling price for the produced feedstock so as to be competitive with the other fuels used in the region for small/medium local communal heat production plants and in other regions for lignite power generation (heavy fuel oil, gasoline, lignite, natural gas, fire wood, straw). During the economic appraisal the following set of questions was analysed:

<u>What is the cost and profit situation of conventional crops in the region?</u>

Our basis for comparison was conventional crops traditionally cultivated in the selected region, such as durum and soft wheat, barley and cotton.

In this way, realistic scenarios could be presented both for alternative land use in the region and for the economic feasibility of the potential introduction of energy crops in the regional agricultural systems. In order to allow comparison between conventional crops and the selected energy crops, the cost analyses estimated production costs and profit before subsidies.

Table 3.1. Income analysis for conventional crops

	Conventional crop
Cultivated Area (ha)	
Yields (t/ha)	
Selling price (Euro/ton)	
Gross income (GI)	
- Variable expenses[1]	
- Labour[2]	
- Other expenses[3]	
- Land rent[4]	
- Equipment rent[5]	
- Depreciation of irrigation equipment[6]	
Total production costs (TPC)	
= Profit before subsidies (GI- TPC)	
+ Subsidy	
= Profit after subsidy	
Farm income 1 (own labour, equipment, land)	
Farm income 2 (hired equipment)	
Farm income 3 (rented land, hire equipment)	

Since the terms for grants are neither uniform nor stable for crop types, conventional and energy, their production costs and farmers' income was estimated net of subsidies.

The following table outlines the parameters taken into account for the cost analysis of the conventional crops.

Detailed estimations were provided for the income generated by durum wheat, soft wheat, barley and cotton in both irrigated and non-irrigated land.

[1] Variable expenses consist of the following:

		Coonventional crop		
		annual q'ty/ha	cost/ unit	cost/ha
1	Seeds			
2	Fertilisers			
3	Pesticides/Herbicides			
4	Irrigation water			

[2] Cereals cultivation is mechanised to a great extent. Labour is only needed in relatively small quantities during harvesting. The cost of unskilled man-hour is equal to 3 EUR.

[3] Includes financial and other expenses

[4] Land rent reflects current market prices for irrigated and non- irrigated land in the area. The same is true for the cost analysis of energy crops (below).

[5] It is assumed that most of the necessary equipment is hired. This is common practice in the area because farm sizes are too small to justify ownership of expensive equipment. In the case of irrigated wheat it is assumed that the farm owns the irrigation equipment.

Do energy crops make financial sense? Which factors determine the cost of crops for energy production and what is the cost situation for the most promising options?

Cost analyses of the selected energy crops were based on the BEAVER model on which the necessary adaptations were made.

For the estimation of the production cost, a number of agricultural activities were taken into considerations, which were further categorised as establishment and annual ones (table 3.2).

Several cost estimations were run, by adapting the Beaver model to the requirements of this study. Available data from the statistical services Greece as well as other sources like EUROSTAT, FAO, etc. were used to perform the analyses.

Apart from the previous type of cost analysis, a different cost layout was examined for the selected energy crops, by breaking down total cost by production factor:

- *Labour*, categorised as skilled and unskilled, depending on the skills used in each cropping technique.
- *Land*. Land rent is estimated as the opportunity cost of land based on its previous use (fallow land, cereal cultivation).
- *Machinery* such as tractor, harvester, travelling gun has been added in the cost analysis, assuming that all is hired.
- *Variable inputs* include seed/ stem cuttings for crop establishment, fertiliser and pesticides for increased production, irrigation water, etc.
- *Energy* used to perform the cultivation- mainly diesel fuel for the machinery operation- is also taken into account.

Cost of working capital and overheads were added to the agricultural costs.

Table 3.2. Establishment and recurring costs for energy crops (Euro/ha/year)

	Energy crop	
Establishment costs	**Euro/ha**	**%**
Ploughing		
Harrowing		
Herbiciding		
Initial fertilising		
Sowing/ Planting		
Initial irrigation		
Exit costs (Grubbing up)		
(a) Total Establishment costs		
(b) Annual equivalent of establishment costs[6]		
Recurring costs (in all years ex. Harvesting)		
Land rent		
Irrigation		
Fertilisation		
Harvesting		
Cost of working capital		
Other costs (incl.depreciation of trav. Gun)		
c) Total recurring costs		
Total annual equivalent cost (b+c)		

Given the economic cost, what determines the competitiveness of energy from biomass crops?

Following the economic appraisal, barriers affecting the competitiveness of energy crops were determined, the most important being:

- Legislative
- Agricultural
- Economical
- Non- technical ones

The barriers were analysed and possible scenarios to overcome them were presented.

What sort of price can the energy crops get in the local heat market?

In order to define competitive selling prices for the energy crops in the local heat market, a comparative analysis was presented.

Based on that, a range of energy crop prices was set, similar to the range of the other fuels, and the farmers' income was estimated for the 'new' crops.

[6] In cost analysis the establishment costs are annualised and the annual equivalent [$e= ci/ 1- (1+ i)^{-n}$, **where c= purchase cost, i= discount rate and n= item lifespan**] is added to the recurring costs in order to estimate the total annual equivalent cost.

Finally, taking into account all prices and income situation the best-case scenario for the raw material in the local bioenergy scheme was chosen.

Economic and socio-economic evaluation of a crop-based bioenergy scheme in the selected region

Based on the BIOSEM methodological approach, the following were achieved:

- Identification and description of the selected region in terms of:

  agricultural activities

  energy consumption

  socio-economic profiles of the region

All these parameters were examined along with data from both regional and national level in the country in order to estimate the context in which the selected area operates.

Combining the regional profile and financial information from the previous phase, a local bioenergy scheme was selected and was further analysed in terms of economic and socio-economic viability.

Adoption of energy crops through networking in a national, regional and local context.

During the fifth phase, the author acknowledging that bioenergy deployment is an innovation involving a large number of people proceeded in examining the diffusion channels as well as the different perceptions. More specifically, she undertook the steps described below.

First, through a series of seven discussions, of the existing National Biomass Network team she interviewed the key groups involved and monitored their perceptions. The national team was formed in the framework of the EU funded programme aiming to encourage dialogue between the industry, environmental organisations, the government and the local community and to create a consensus view on bioenergy schemes (Altener Programme, Bioguide, 1996). The network provided a unique forum for discussion and met regularly to consider both the environmental and the socio-economic aspects of developing biomass energy. Most specifically the main objectives of the formation of the national team were:

- To provide a forum for discussion on the environmental issues surrounding the production and use of biomass between interested government departments and environmental organisations.
- To develop a consensus view on the environmental status of individual biomass resources and their potential contribution to environmental objectives in global, national and local terms.
- To advise on the extent to which the results of existing R&D address the specific environmental and socio-economic concerns.
- To make recommendations on the need for further research to address particular environmental and socio-economic concerns.

The groups involved in the network consisted of scientists, local planners, environmental groups, farmer co-operatives and government representatives. During the meetings, the main aims were:

1. To explore perceptions and attitudes of those who might be most affected by energy crops developments.
2. To assess how the views of the selected key groups are affected by personal circumstances and expectations about the local agriculture.

3. To identify what sorts of information each group needs to help it understand and accept the need for extending the use of energy crops for fuels.

Secondly the author designed detailed questionnaires for farmers and end users in the region and through surveying she analysed the features of the two main groups involved. Conclusions about the features favouring or hindering adoption of energy crops and bioenergy derived from surveying fifty farmers and fifteen end users in the region.

Due to the multifaceted nature of the research work, several of the abovementioned topics were based in elements of the following EU funded R&D projects, in which the author has been involved as a research assistant and/ or scientific project manager contributing in their development/operation as well as the Greek data and results (except for the last one):

1. JOUB-0036. Sweet sorghum productivity network (JOULE Programme, 1992)
2. STRIDE HELLAS 289. 1992-1994. An integrated and innovative R&D approach exploring the potential of biofuel production in Greece from renewable biomass resources. (STRIDE HELASS, 1992).
3. AIR-CT92-0041. 1993-1995. 'Sweet sorghum': A sustainable crop for energy production in Europe: Agriculture, industrial improvement, optimization and implementation. (AIR Programme 1992a)
4. AIR-CT92-0294. 1992-1995. Miscanthus productivity network. (AIR Programme 1992b)
5. AIR-CT93-1089. 1993-1997. Cynara cardunculus network. (AIR Programme 1993a)
6. AIR-CT-942455. 1995-1997. Environmental aspects of biomass production and routes for European Energy Supply. (AIR Programme 1994a)
7. AIR-CT-931671. 1994-1996. Development of a standard methodology for integrating non-food production in rural areas with niche energy markets. (AIR Programme 1993ba)

8. RENA-CT94-0053. 1995-1996. Eurec agency study on Biomass.

9. AL/4.1030/94-05. BIOGUIDE. 1996-1998. Best Practice Guidelines for the development of an economically and environmentally sustainable industry. (Altener Programme, 1996).

10. FAIR CT96 1389. 1996- 1999. Socio-economic Multiplier Technique for Rural Diversification Through Biomass Energy Deployment. (FAIR Programme. 1996a.)

11. Models for the Economic Evaluation of selected biomass cultivation as an alternative land use in the EU (Beaver). 1994- 1996. The specific model was adapted and used for the purposes of this study.

3.1 DATA COLLECTION

The survey on labour, expenditures and revenues, material flows along with the public perception of bio-energy schemes was conducted by base line questionnaires in the selected region (Rhodope, N. Greece).

The field research was undertaken from November 1997 to April 1998 and was realised in order to i) understand the main features of local agriculture and its environment, ii) test data reliability, iii) contact local organisations, iv) select survey farmers and end users. In addition to the field research and micro-level data analysis, the regional development trends of the prefecture (East Macedonia and Thrace) as well as the social, natural, institutional and economic environment have been described and analysed in some depth based on an extensive literature review as background and complement to the microeconomic approach. This enables better understanding of farmers decision- making, their reaction towards energy crops and the role such crops can play.

Data concerning the national and regional agriculture were incorporated from National Agricultural Statistics, FAO and EUROSTAT.

3.2 NATIONAL AGRICULTURAL STATISTICS IN GREECE

Since 1961, the National Statistical Service of Greece has been carrying out, through the special Statistical Service by the Ministry of Agriculture, an annual survey on agriculture, livestock and forestry and since 1975 on inner waters and inshore fishing by low powered fishing vessels, the results of which are published in separate issues.

The area included within the administrative boundaries of each Commune (or Municipality) has constituted the survey unit. The survey has covered, on a census basis, all the administrative subdivisions of the Country.

For the data collection, local agents are employed, namely the Secretaries of the Communes (or Municipalities) or their representatives, assigned as Statistical Correspondents. Very often, the latter are assisted by the rural guards, or by experienced and eminent farmers recruited for this purpose.

The survey has been taken, since 1968, in two phases as follows:

a) During the period of June to December, the above Statistical Correspondent, assisted by other local agents, completes, for each Commune (or Municipality), a uniform questionnaire referring to the areas under the several crops, the irrigated areas, the number of fruit trees, agricultural production, livestock production, forestry production, the number agricultural machinery operation and the inner waters and inshore fishing by professional vessels of 19 HP or less.

b) During August and December, the above Statistical Correspondents, complete, on the basis of the data inserted in the uniform questionnaire, extracts A and B which refer to the areas and production of principal agricultural and livestock products respectively.

The collected data, except for those on oil production, are based on subjective estimates of the above local agents. Data on oil production are collected by the Statistical Correspondents directly from the owners of olive presses.

3.3 AGRICULTURAL EXPERIMENTS

In order to define promising solutions for energy crops in Greece, a number of experiments have been conducted in a representative region in central Greece. The research methodology will be presented for the two crops selected in this thesis. Additionally, it should be mentioned that most of the experiments have been conducted in Kopaida, central Greece. The results obtained, so far are considered applicable to Rhodope, the area under study.

The author was the scientist responsible and the project manager for the experiments on cardoon (Cynara cardunculus, L.) while data for the experiments on giant reed (Arundo donax L.) have been taken from work conducted by other scientists.

3.4 DATA ANALYSIS

The methodological approaches concerning economic appraisal of energy crops as well as economic and socio-economic evaluation of the selected bioenergy scheme are thoroughly described below.

3.4.1. Economic appraisal of energy crops. Application of the Beaver model

The economic appraisal of the selected energy crops was conducted using the main principles of the BEAVER model doing additional modifications for the needs of the study.

BEAVER is an investment appraisal and cost analysis model for the economic evaluation of biomass cultivation. Its knowledge and databases currently hold detailed information about three biomass crops, namely sweet sorghum, poplar and willow. The system is mainly addressed to the agricultural consultant and the planner, but it will be useful to a large number of others, including farmers, economists, researchers, businessmen, administrators and politicians.

BEAVER contains a Financial Appraisal economic module based on discounted cash- flows and estimating standard investment appraisal indices. It also contains an Income and Cost analysis facility, which pays more attention to the business aspects of biomass cultivation and calculates values of Gross Sales, Farm Income, Net Profits, Total Production Cost, etc.

All data and calculations assume no inflation throughout the appraisal period.

Beaver also includes a biomass biological growth model for sweet sorghum, calibrated for various European soil climatic conditions. This growth model estimates biomass yields according to a number of cultivation parameters such as the irrigation depth, the amount of seeds and irrigation water, the dates of emergence and harvesting, etc.

Beaver utilises a genetic algorithm for the optimisation of a relatively large number of decision variables such as labour requirements, hired cultivation area, depth and frequency of irrigation, dates of emergence and first irrigation, and selection of most appropriate machinery equipment in order to maximise Net Present Value or Profits or minimise Total Cost. All of the parameters involved can be constrained in various ways. Additional constraints can be set to Total Quantity Produced and Total Cost of Production.

The system has been designed as a typical MS-Windows application for the convenience of the user and is programmed using Delphi, and C++ programming languages. An on line context sensitive help system and a number of worked examples are available. Knowledge base assistance and guidance have been added, as the system could be used not only by experts but also by much less experienced users.

Moreover, Beaver incorporates a diagnostic expert system module. This expert system serves two purposes, user input validation and model results interpretation. It helps the user work with the Beaver model and prevents input of erroneous or contradictory data.

3.4.2. Economic and socio-economic evaluation of the selected bioenergy scheme. Application of the Biosem model

The economic and socio-economic evaluation of the selected bioenergy scheme was conducted using the principles of the BIOSEM model, which is described below.

BIOSEM (Biomass Socio-Economic Multiplier) was developed in the framework of FAIR EU Programme "FAIR CT 96- 1389: Socio-economic Multiplier Technique for Rural Diversification Through Biomass Energy Deployment. 1996-1999".

The Author was the scientific project manager and contributed to the adaptation of the model for Greek conditions as well as the respective case study.

BIOSEM is a quantitative model designed to capture the socio- economic effects of local bioenergy production. It can trace both the extent and distribution of income and employment gains, and can assess the merits of differing (energy and agricultural) policy packages, such as grants and subsidies on bioenergy production.

A range of biomass fuels and conversion processes can be modelled (e.g., from residues to dedicated energy crops), as can the recipient markets for heat and electricity. Modelling takes place in two phases: firstly, to identify the financial feasibility of the plant, and then, secondly, to determine the employment and income benefits from the complete bioenergy chain. It evaluates both the backward linkages (i.e., the impact of increased demand in the supply chain) and the forward linkages (i.e., the re-spending of additional regional income) before combining these figures to provide a complete analysis of the impact of bioenergy production on a local economy.

Phase 1 of the model, the financial assessment, is based on a cash- flow analysis of the plant over a twenty- year period. During this time, investment and profit margins can be traced to determine key financial indices for both feedstock production (gross margin) and for the conversion plant (such as the net present value, the internal rate of return and the payback period). These can be used to assess the actual commercial feasibility of the plant. This is an important element because, unless the plant is commercially viable, the developer will not undertake the investment. Consequently, all employment and income forecasts would be meaningless.

Phase 2, the socio-economic analysis, is based upon the Keynesian income multiplier technique. By this means, the model captures the following impacts:

- Direct and indirect employment and income impacts for both agricultural and bioenergy plant activities;
- Direct displacement impacts for any displaced agricultural activities;

- Induced impacts caused by the spending of additional wages and profits for both agricultural and bioenergy plant activities.

3.5 CONCLUSIONS

The evaluation of a bioenergy scheme fuelled with energy crops requires a multi-faceted research methodology in order to identify properly all the aspects involved and define the main parameters of such an implementation.

The research in this thesis was planned so as to allow the overall evaluation of the selected bioenergy scheme under technical, economic and socio-economic terms. This involved a number of methodologies, namely:

- Experimental work with energy crops at several sites to test their adaptability and biomass productivity and identify the best solutions under economic terms.
- Economic appraisal of biomass crops and conventional ones in order to identify farm incomes as well as the 'distortion' effects of subsidies on them.
- Economic and socio-economic evaluation of bioenergy schemes at local level to estimate their economic viability as well as the possible effects on employment.

Prior to selecting the energy crops and the site it was considered appropriate to analyse firstly the current state of renewables and biomass and secondly, the situation for energy crops in the country, thus defining some promising solutions. In this way, the context under which the potential bioenergy scheme will be developed is defined.

In the next chapter, the current state for renewables and biomass is presented along with potential markets for bioenergy in Greece

CHAPTER 4. RENEWABLE ENERGY SOURCES (RES) AND BIOENERGY IN GREECE

Renewable Energy Sources contributed a total of 1,356 ktoe to the Greek Energy system in 1998. This corresponds to 5.04% of the Greek Total Primary Energy Supply (TPES), which was 26,900 ktoe. Biomass and hydro electricity provided most of the energy produced; biomass (mostly wood used directly in the domestic sector) accounted for 66.9 % of the total energy produced from RES, and hydro for 23.7 %. Wind, solar heat and geothermal heat constitute the remaining 9.4 %. Electricity generation from renewables was 3,806 GWh in 1998 with a total installed capacity of 3,057 MW. The major contribution to the electricity generation was from hydroelectric plants (3,731 GWh) the majority of which belong to the Public Power Corporation. Wind energy contributed a total of 73.1 GWh of electricity, while photovoltaic contributed only a small amount, mainly in installations that are not grid connected. Solar energy applications are almost exclusively used for water heating. Greece is the European Union's leader in surface installed for solar thermal applications, with about 30% of the total installed surface in the 15 EU member states. The forecast for primary energy demand (Gross Inland Consumption) based on the Conventional Wisdom scenario of DG XVII is 25 Mtoe in year 2000 and 32 Mtoe in year 2020 ("European Energy to 2020"). The corresponding forecast for the contribution of renewable energy sources to the GIC is 1.62 and 3.36 Mtoe respectively. An estimation performed by Centre for Renewable Energy Sources (CRES, 2000), using the latest data about the progress of the projects funded by the Operational Programme for Energy and the Public Power Corporation's (PPC) development plan, concluded that in early 2000 the contribution of RES would be about 1.5Mtoe, corresponding to 6% of the TPES of Greece.

4.1 PRESENT POLICIES

The main policies that affect the penetration of R.E.S. in the Greek energy system are:

- The new law 2773/99 regarding the liberalisation of the electricity market in Greece. The main points are:
  - Priority is given by the system Operator to the electricity produced from RES to cover the demand of electricity.

- A ten year contract will be given to the producers of electricity from RES by the System Operator at a price which will be 90% of the existing medium voltage tariff, at maximum, for the energy produced.

- Law 2244/94, regarding revisions on the electricity production code from RES, and the implementing Ministerial Decision 8295/95, which broke new ground for the promotion of RES in Greece. This was the necessary regulation tool for the production of electricity by independent producers, making a distinction between independent producers, selling the total of production to PPC, and auto-producers, covering primarily their own energy needs and selling surplus energy to the Public Power Corporation (PPC). This law will remain in force only until the end of 2000, and will then be replaced by law 2773/99, which is described above.
- The Renewable Energies Sub-programme of the Operational Programme for Energy (1994-1999), which is the main funding mechanism for RES installations. The programme has a total budget of 340 MEuro (139.6MEuro being public funding and 200.4MEuro private funding), and supports mainly RES investments, but also broad "infrastructure" work, such as the development of the National Certification System, the assessment of the technically exploitable RES potential or the determination of the optimum administrative and legislative framework for RES.
- The development law 1892/90 together with its amendment 2234/94, which is a general "development law" that provides subsidies (40-60%) for investments by the private sector, including renewables.
- The new development law 2601/98, replacing 1892/90, which is expected to be the main funding tool of RES applications in the future. The law foresees a combination of subsidy options that is either a) capital investment subsidies up to 40%, interest subsidy up to 40% and subsidy for leasing up to 40% or b) tax deduction up to 100% and interest subsidy up to 40% for investments in RES.
- A new law is also under consideration, considering low enthalpy geothermal applications, which will probably simplify even further the procedure required for such installations.

The main financial instrument to support RES, is the Operational Programme for Energy, as was already mentioned.

Through the two calls for proposals, there were 82 Projects approved for funding corresponding to 241 MWe and 79 MWth with a total budget of 340 MEURO.
It must be noticed that most of these projects are now in the phase of construction or commissioning, while there is a small number of projects pending or canceled.
In addition to the above, Law 2364/95, foresees tax exemptions for the purchase and installation of renewable systems and natural gas systems (about 75% of the total investment for individuals and enterprises).
Finally the new development law, which is expected to be the main funding tool in the future and foresees: a) capital investment subsidies up to 40%, interest subsidy up to 40% and subsidy for leasing up to 40% or b) tax deduction up to 100% and interest subsidy up to 40% for investments in RES.

4.2 ELECTRICITY MARKET

The PPC's programme for the development of renewable energy sources forms part of the electricity utility's 10-year Development Plan, for the period 1994 - 2003. The program for RES covers wind energy, PV, geothermal energy and power from small hydro systems. According to this plan, a total of 306MW installed capacity of large hydro, 17MW small hydro and 37MW of wind parks will be in operation, by the year 2003. These installations are expected to add about 85ktoe to the amount of energy produced by RES in Greece.
The implementation of law 2244/94 has led to a significant increase in the number of applications for investments in the area of energy production from RES since 1995. This is the main regulation tool for the production of electricity by independent producers.
According to this law, for independent producers and for installations of 50 MW or less, restrictions for electricity generation from RES are removed and regulations are liberated. Auto-producers may counterbalance 80% of the electrical energy produced using RES (90% for local authorities, government organisations and farm co-operatives) with their electricity consumption from the PPC network. Other provisions of the law include removal of restrictions for the exploitation of small water falls, the simplification of bureaucracy involved in the permitting of RES installations (two licenses instead of three are now required for the installation and operation of RES plants) and the setting up of a new improved pricing system. The implementing ministerial decision includes provisions regarding permitting, i.e.,

defines procedures and documentation required for the issuing of installation and operation permits for power plants, and general technical and economic terms of the Purchase Agreements between electricity producers and the PPC.

By December 1999 a total of 105 permits have been issued for the installation of Renewable energy sources applications, corresponding to a total installed capacity of 378 MW (54 wind energy projects 304 MW, 45 small hydro projects 53MW, 5 biogas projects 21MW and one PV project of 0.08 MWp). The possible projects for realisation, (according to the issued licenses for installation) apart from those included in the OPE or PPC's plan (already mentioned) amount to 61 with a capacity of 200 MW.

In addition to the above, legislation in order to comply with the EU Electricity Directive, has been issued in December 1999. According to the EU directive, 26% of the electricity market in Greece will be liberalised during the first stage, starting in February 2001. According to Law 2773/99, the Public Power Corporation (PPC) will own and develop all transmission and distribution facilities, and will remain under the control of the state. An independent system operator will be formed, who will ensure that the electricity demand is met by the supply by the PPC and all the independent producers. Finally the Energy Regulator will provide permits to the producers of electricity. During the initial period of liberalisation, only the large consumers (over 100GWh annual consumption) will have the possibility to choose their electricity supplier. The smaller consumers as well as all the islands that are not connected to the mainland grid, will be supplied by the PPC. The law states that the System Operator should give priority to electricity produced by RES and co-generation over the other technologies, in order to meet the electricity demand.

4.3 BIOENERGY IN GREECE

In 1998, biomass deriving mainly from wood fuel accounted for 67% of the total energy produced from RES (1.358 ktoe), amounting to 907 ktoe. Domestic use of wood (702 ktoe) accounted for about 77 % of the estimated energy produced from biomass in 1998, while biomass used in the industrial sector (mainly wood residues, cotton ginning residues, rice husks and straw) accounted for 205 ktoe. Additionally, biogas-to-electricity (a 240 kWe plant in a municipal solid waste landfill/Thessalonica and a 180 kWe plant in a municipal wastewater treatment plant/Heraklion) as well as numerous biogas-to-heat applications (with a total heat production of 29 TJ) have been installed and others being finalised. In total, approximately, 60 plants operating on biomass resources have been recorded until 1999 in Greece (Panoutsou 1998d, Panoutsou, 2000b).

Technological developments

A large number of programs have been conducted in Greece during the last decade aiming at increasing the development and deployment of biomass energy resources and technologies. These programs have made many significant contributions in the development and demonstration of technologies that can convert biomass materials (e.g. wood wastes, agricultural residues and dedicated crops) to fuels and feedstocks for heat and electric power, industrial products and transportation.

In particular, research and technological developments on bioenergy are mainly based on the exploitation of agricultural (field and processing ones) and forestry residues with the development of high efficiency advanced conversion technologies. Much emphasis is also placed on research towards the introduction of new non-food crops dedicated for energy purposes. In detail, research for biomass can be analysed as follows:

4.3.1 Resources

The diverse topography of Greece combined with favourable climatic conditions favour the wide variability in agricultural activities and the consequent production of residual biomass forms. Additionally, a large number of energy crops, tested so far in different soil climatic conditions present good adaptability and high biomass yields with relatively low inputs (water, fertiliser, etc.).

The main biomass resources in Greece, towards which research and development activities take place, are (Dalianis, 1996b):

- *Residual biomass types* such as field agricultural residues, agro-industrial residues and by-products, animal wastes and forestry residues, and
- *Energy crops* such as giant reed, cardoon, miscanthus, sorghum, switchgrass, kenaf, rapeseed, etc.

Residual biomass types

1. Agricultural residues

Under the term field agricultural residues, we define two categories: *crop residues* and *arboricultural residues* (Panoutsou, 1998a).

Crop residues are those that remain in the field after the crops are harvested. Depending on the crop, the harvesting method and other parameters, crop residues may include various plant parts such as stems, branches, leaves, chaff, pits, etc. varying in composition, moisture content and energy potential. The main crops producing considerable quantities of crop residues in Greece are winter cereals, rice, corn, cotton and tobacco.

Arboricultural residues are those that remain in the field after farming activities performed during the cultivation of perennial crops (prunings of grapes and trees) as well as from the final disposal of old trees or from the removal of whole grape or tree plantations. The main arboricultural residue resources are: *grapevines, peach, almond, orange* and *olive prunings*.

2. Agro-industrial residues and by-products

The main types of agro-industries in Greece are: flour industries, rice industries, cotton-ginning factories, fruit industries, wine factories, seed oil industries, olive oil and olive kernel factories.

Most agro-industrial residues are used for animal food production. However, certain types of agro-industrial residues (cotton ginning, olive husk, sawdust, fruit kernels, etc.) are used for energy production (mostly heat generation).

3. Animal wastes

Steep topography existing throughout Greece along with low rainfall and sparse pasture do not favour intensive animal raising and therefore animal manure density is relatively low compared with other livestock EU countries.

The estimated amount of animal manure produced is 38,000 ton/day, theoretical potential of 1.4 million cubic meters of methane if anaerobically digested, an energy equivalent of 1.2 MTOE.

Taking into account that the largest portion of Greek livestock farming is extensive, the available biogas potential normally does not include sheep, goat and lamb breeding. These are usually shepherded and the produced manure is spread all over the grazing land (Panoutsou, 1999).

However, sufficient manure quantities remain unexploited, mainly from cattle, pigs and chicken, and could, hence, be utilised for energy production although it is not considered for the moment as a way to dispose animal wastes.

4. Forestry residues

Under the term forestry residues, we define the following categories:

- early thinning material
- logging residues
- material occurring from removal of understorey vegetation for protection against forest fires
- wood processing wastes

Research for residual types of biomass focuses on: a) development of methodologies for the assessment of the technical and economic availability taking into account the current "opportunity costs", b) development of methodologies to assess the environmental aspects of exploiting and using residues for energy purposes and c) fuel analyses.

a) Technical and economic availability: The total quantities of agricultural residues are estimated using data such as the quantities of the main product produced per year for each crop, the cultivated land areas and coefficients that indicate the ratio of residues/main product or residues/hectare. The coefficients used to estimate the quantities and the energy potential of agricultural field residues derived from measurements, estimations and references.

The estimation of the quantities of agricultural residues available for energy production is also based on the degree of availability, which is different for each crop, varies from year to year and depends on several factors such as:

✓ the harvesting method

✓ the moisture content

✓ the demand of agricultural residues for non-energy purposes (cereal straw, for example, is used for animal feeding, animal bedding, as substrate for other cultivations, etc.).

Although there are sufficient quantities of residues in the country, certain parameters should be taken into account before making a strategy for their energy exploitation.

- Small farming size (increases harvesting and transportation costs).
- Environmental risks caused by the removal of field residues (erosion in sloping and low-fertility areas, etc.).
- Opportunity cost of the residue (e.g. cereal straw has already a market price as it is sold for animal feeding purposes).
- Lack of commercial harvesting machinery for certain residue types (e.g. cotton residues).

The methodologies concerning the assessment of agro-industrial by-products and wastes are based on the types of agro-industries as well as on their annual capacity for the main products and by-products.

Surveys on animal wastes are also made in order to identify possibilities for biogas installations in Greece.

b) *Environmental aspects:* The environmental aspects of biomass production and conversion routes are examined through the development of decision base models, which also use data from life cycle assessment methodologies.

The methodological approach considers the following impact categories: a) energy resources, b) mineral resources, c) ground water, and d) land resources.

c) Fuel characterisation: The main aim of this research aspect is to categorise the residual types according to the fuel origin and properties (e.g. ash characteristics). Chemical analyses of various fuels include calorific value determination, fuel proximate and ultimate analyses, ash elemental analyses and characteristic ash-fusibility temperatures. The expected deliverables are tables with fuel and ash characteristics, which help the fuel assessment properties.

In addition to the previous results, technical classifications of the residual biofuels are also conducted. Biomass types are categorised according to the suitable applied conversion technology. Namely, the systems of Pulverised Fuel Combustion (PFC), Fluidised Bed Combustion (FBC) and Pre-treatment Techniques (Gasification, Pyrolysis, and Leaching) are 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.

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

5. Energy crops

During the last decade years, several energy crops have been tested under Greek climatic conditions. High biomass yields up to 30 odt/ha/year have been observed in experimental trials. The examined crops can be divided to annual and perennial.

Research aims for energy crops include to maximise yield per unit land, to optimise key quality characteristics as well as to develop techniques for optimum handling (harvesting, baling, storing and transporting).

Additionally, methodologies assessing the economic viability of these crops are used along with other techniques to examine possible socio-economic effects of integration into Greek farming systems (Panoutsou, 1999).

Table 4.3.1 Energy crops tested in Greece

Annual	*Perennial*
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*)

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 research 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 energy cropping.
- Combination of the energy markets with the already existing alternative markets for the residues (animal feed, pulp and paper, etc.).
- Clear legislative framework for energy crops. A combination of agricultural and energy policy would provide support to their development.

4.3.2 Conversion to Energy Technologies

Technologies for the conversion of biomass to energy include pyrolysis, gasification and combustion. A series of research, development and demonstration projects, have been undertaken within years in Greece.

1. Pyrolysis

Different feedstocks have been tested (woody biomass, i.e. mixed hardwood and softwood, and agricultural residues i.e. wheat straw). During the performance of the pyrolysis experiments, the following aspects are being investigated:

- Development of feedstock logistics for Bio-Crude Oil (BCO) production via fast pyrolysis.
- Evaluation of the scale-up potential of biomass fast pyrolysis.
- Combustion of the produced bio-oil in a modified Stirling engine for combined heat and power production.
- Techno-economic evaluation of the technology, including Life Cycle Assessment (LCA).
- Market studies for the penetration of both biomass fast pyrolysis technology and end-use applications.
- Development of a combined sequence for thermal hydrogenation and fluid catalytic cracking, for the production of transportation liquid fuels from biomass flash pyrolysis liquids
- Development of selective catalytic systems for the production of methyl aryl ethers to be used as gasoline octane improvers, via catalytic methylation of the phenolic compounds from biomass flash pyrolysis liquids and their chemical characterisation
- Evaluation of commercial catalysts for biomass flash pyrolysis for the production of improved liquid turbine fuels

2. Gasification

Technical aspects under study in Greece include:

- Investigation of various potential energy crop fuels concerning their handling and characteristic performance in FB gasification.
- Study of the selection of energy crops fuels in combination with cheap bulk bed-materials in view of their interactions in the fluidized bed reflecting partial sintering, agglomeration and de-fluidization.
- Experimental testing (bench-scale) of combinations of fuel and bed material mixtures in association with revealing gasification regimes, i.e., temperature, pressure and feed rates that may be more adequate for energy crops.

- Stipulation of operational conditions, i.e., temperature, pressure and feed rates that will avoid or minimise de-fluidization through the selection of optimum combinations of energy crop fuels and bed materials.
- Assembling of a manual for optimal commercial utilisation of energy crops as gasifier fuel for heat and power generation.

3. Combustion

The Greek Centre for Solid Fuels Technology and Application (CSFTA) in co-operation with the Laboratory of Steam Boilers and Thermal Plants (NTUA), the Laboratory of Environmental Fuels and Hydrocarbons (CPERI) and a wood processing company have participated in an EC project aiming to demonstrate on industrial scale low emission co-combustion of different waste wood species and lignite derived products thus contributing to the thermal recycling of significant waste quantities.

4.4 POTENTIAL END USES FOR BIOMASS IN GREECE

Bioenergy schemes can be based on a wide range of feedstocks and use many different conversion technologies to produce solid, liquid and gaseous fuels. These fuels can then be used to provide heat and electricity or to power vehicles. They may also be used in burners, boilers, generators, internal combustion engines, turbines or fuel cells. It is also possible to upgrade biomass to obtain fuels that are identical to, or have properties close to, those of fossil fuels (European Commission, 2000a).

At present combustion of biomass and waste is most common, at varying levels of efficiency, to provide space heating, for industrial process heat and/or to generate electricity. It should also be emphasized that most of the facilities producing heat in the EU to date (5 to 65 MW thermal) or power (1 to 35 MW electric) use some type of residue, (European Commission, 2000a) rather than an energy crop. The fuel is often of mixed origin and is sometimes combined directly or indirectly with fossil fuel. Typical plants have been designed to use straw or woodchips alone, or may take a specific form of industrial by-product, such as sawdust or chicken litter.

The use of biomass for energy reflects a combination of national policies and related legislation and fuel costs, as well as opportunities for the use of heat, that in turn reflect the location of the plant (urban or rural) and the local climate.

Until today in Greece, several activities for the promotion of Renewable Energy Sources (RES), the protection of the environment, the industrial development, etc., are being currently realised, and it is within this framework that proposals for biomass-to-energy projects have been submitted and are being implemented.

From the current bioenergy schemes it is evident that the most viable options are heat generation from residues in agro- industries, sewage treatment plants and landfill gas exploitation (OPE, 1997, Panoutsou 1998d, Panoutsou, 1999). This is clearly shown from the ongoing bioenergy projects in the country (CRES, 2000b) as well as from the applications for subsidy to the Operational Programme for Energy (OPE, 1997).

CHP production and electricity generation from biomass are still at the very beginning with only two plants being finalised under the Operational Programme for Energy (OPE, 1997)

Table 4.4.1 Biomass CHP plants in Greece in 2000

Plant type	Number of plants	Electricity Output (MWe)	Heat Output (MWth)
Municipal CHP plants	2	13.19	13.23
Municipal DH plants	2	0	21.4
Industrial CHP plants	2	7.9	10.1
Industrial steam boilers	61	0	224.5
Total	**67**	**21.09**	**269.23**

Source: CRES, 2000.

Based on current bioenergy schemes in the country (CRES, 2000b), on foreseen trends and on the information presented above for EU we can clearly outline the fields where bioenergy penetration would be feasible in the Greek energy market for the near future (five to ten years) (Panoutsou, 2000c).

Small to medium scale heat generation for the industrial and domestic sectors.

- Medium scale CHP for industries, which can exploit the excess heat (processing needs/heat requirements) or are located close to other industries willing to buy the produced heat.
- District heating in remote agricultural communities.

Of course such estimates would only be realistic if they are integrated approaches combining environmental and social aspects of rural development with the economics of a new investment.

Although these trends have been identified a long time ago and much effort continues to be expended from experts within the country and from all over Europe, bioenergy deployment rates still remain stubbornly low in the country, around 3% of the Greek total primary energy supply (CRES, 2000c). This is the case for the last ten years. Such a position raises severe doubts as to whether the favourable conditions in terms of biomass resources and the market potential would lead to increased bioenergy deployment in the near future.

4.5 CONCLUSIONS

Bioenergy in Greece presents good theoretical potential but low level of increase in the total primary energy supply during the last decade. The main applications at the moment are heat generation in agro-industries and two biogas CHP plants.

An approach which has not yet received the co-ordinated attention that it deserves but which may well be able to help gear up biomass deployment rates significantly is the more obvious linkage of residues exploitation to mainstream (dedicated crops) biomass developments. This approach uses the driver of immediate need to cope with a problem (residues disposal mostly) and scales up appropriately to draw in a dedicated biomass resource. The result would be significantly larger projects or hybrid ones, which at one and the same time deliver more RES whilst also taking developers, financiers (key stakeholders) forward into more mainstream biomass ventures able to deliver greater and earlier replication (Richards, 2001).

> *Bearing these in mind, the main hypothesis tested in this thesis is the evidence supporting a strong role for dedicated energy crops local bioenergy developments in Greece, a sector that is forecasted to be increasingly important in the short to medium term.*

In the next chapter, the current state of energy crops in Greece is presented so that some promising ones can be selected for further evaluation under economic terms.

CHAPTER 5. ENERGY CROPS IN GREECE. SELECTING PROMISING OPTIONS

In order to secure the successful implementation of a bioenergy scheme, continuity in supply of raw material is considered the key factor. This is well achieved with the development of a dedicated feedstock supply system, namely a crop or a combination of crops that can be successfully produced in an economical and environmentally sustainable way in the quantities required to support energy production.

Biomass crops could become important feedstocks for power, liquid fuel and chemical production (Graham, 1999). With targeted research programs that boost yields and develop appropriate power and chemical conversion technologies, biomass from crops might compete with fossil fuels in a broad range of uses.

This chapter summarises the achievements on energy crops research and development activities in Greece. The author conducted this review in collaboration with the other scientists (Mardikis, 2000) of the Biomass Department of the Centre for Renewable Energy Sources (CRES). The review was based on the evaluation of scientific results presented in a selected number of technical project reports for energy crops as well as scientific papers available. In addition, personal communication with the researchers who participated in the respective experiments (the author being one of them) was used in the final stage of the review to verify the results presented.

This review can be used as state-of the art overview for planners and policy makers who need complete information on energy crops in the country. In the framework of this thesis the review was used to select promising options for bioenergy schemes fuelled with energy crops. Concluding, the research methodologies and the achieved results for the selected crops, cardoon and giant reed are presented.

Summarised information on all the crops is included in Appendix I.

5.1 ENERGY CROPS IN GREECE

R&D efforts for energy crops in Greece started in the late 80's and focused on important technological barriers affecting the successful implementation. Research programmes are being conducted on: i) agronomic aspects, ii) fuel characteristics, iii) environmental aspects of biomass production, iv) conversion to energy and v) economic and social dimensions of energy crops in Greece. In detail, the following are studied:

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 soil- climatic conditions and cultural practices such as plant density, nitrogen fertilization applications, irrigation management, etc.
- Growth characteristics such as Leaf Area Index (LAI), height, number of tillers per plant, etc. As a result, data sets for plant growth modelling are recorded.
- Biomass production as well as biofuel production per plant and per plant part.

During the last decade more than sixty (60) experiments have been conducted throughout Greece in order to evaluate the biomass yielding potential of several energy crops. So far, the following annual and perennial crops have been thoroughly studied:

I. Annual crops:

1. *Sorghum bicolor* L. (sorghum)
2. *Brassica carinata* L. Braun (ethiopean mustard)
3. *Brassica napus* L. (rapeseed)
4. *Hibiscus cannabinus* L. (kenaf)

II. Perennial crops:

1. *Cynara cardunculus* (cardoon)
2. *Arundo donax* L. (giant reed)
3. *Miscanthus x giganteus* (elephant grass)
4. *Panicum virgatum* L. (switchgrass)
5. *Eucalyptus globulus* Labill. (eucalyptus)

6. *Eucalyptus camaldulensis* Dehnh. (eucalyptus)
7. *Robinia pseudoacacia* (black locust)

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 elemental 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.

Conversion to energy technologies

Biomass types are also 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 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. Table 5.1.1 summarizes the factors taken into consideration for each type of energy crop.

Table 5.1.1: R&D topics studied on several energy crops during the last decade in Greece.

Energy crop	1	2	3	4	5	6
Sorghum	30	√	√	√	√	√
Kenaf	3	√				
Rapeseeds	5	√				
Cardoon	3	√	√			√
Giant reed	7	√	√	√		√
Elephant grass	5	√	√	√	√	
Switchgrass	2	√				
Eucalyptus	3	√	√			
Black locust	1	√				

1 number of experiments, 2 agronomic aspects, 3 fuel characterization, 4 environmental aspects, 5 conversion to energy technologies, 6 economic and social dimensions

Environmental aspects of biomass production

Environmental aspects 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 monitored.

Economic and social dimensions

The feasibility of energy crops to replace or fit in with conventional ones is analysed along with their exploitation for energy purposes. Costs are analysed per production factor such as land use, farm size, agricultural income, conventional crops, energy market, etc. and potential farm incomes and selling prices are estimated.

Main results per examined crop

In general, most of the studied crops performed high yielding potential under Greek climatic conditions. However, differences have been observed so far depending on the crop species, the climate and the cultural practices. A summary presentation of results of the tested energy crops separated in annual, perennial herbaceous and woody energy crops is presented in tables II, III and IV, respectively. In particular, the recorded results for each energy crop are presented below:

Sweet sorghum

Fresh biomass yields ranged from 45 to 141t/ha while dry matter yields ranged from 13 to 45t/ha, depending on site, variety and the cultural techniques. The bioethanol potential under

Greek conditions in well watered and fertile fields was estimated at 6,750 l/ha. Water use efficiency (WUE) for sweet sorghum has been estimated at 181 to 206 kg water per kg dry matter while aerial radiation use efficiency (RUE) at 3.5 gr dry matter per MJ intercepted.

Fibre sorghum

Experimental data obtained so far from central Greece indicate that fibre sorghum exhibits high biomass yields, similar to that of sweet sorghum. Fresh biomass and dry matter yields recorded in autumn, reached up to 90 and 27t/ha, respectively.

Kenaf

All varieties tested performed good adaptability and high yields. It should be mentioned that the late-matured varieties were more productive than the early ones. Varieties and maturity types presented fresh biomass ranged from 33.8 to 88.6t/ha and dry matter from 7.6 to 23.9t/ha. Seed production was always feasible for the early varieties while the late ones were occasionally able to produce seed, depending on the climatic conditions during autumn.

Rapeseed and ethiopean mustard

Experimental data indicate that dry matter yields ranged from 3 to 8t/ha and seed yields could reach up to 1.4t/ha, depending on the variety and the site.

Cardoon

The final plant height reached up to 2.6m, while dry biomass yields, depending on plantation density, ranged from 17 to 30t/ha. Calorific values for the various plant components ranged from 14.6 to 21.6MJ/kg d.m. Respective values for the energy potential ranged from 6.9 to 12.9toe/ha/year.

Giant reed

Dry matter yields reached up to 30t/ha from unimproved wild populations and conventional cultural methods. Calorific value of 17.1 MJ/kg was determined and based on this value an energy potential up to 12.9toe/ha/year, was estimated.

Miscanthus

The average height of the plantation reached up to 3m, while dry biomass yields ranged from 11 to 34t/ha and the estimated energy potential was 13.8toe/ha/year. The mean calorific value and ash content of stems were 4,360kcal/kg d.m. and 2% d.m., respectively, while leaves seem to be a rather inferior fuel due to the higher ash content (8% d.m.) and the lower calorific value (4,056 kcal/kg d.m.). The RUE obtained was 4.03 gr dry matter per MJ intercepted.

Switchgrass

Experimental data for switchgrass refer to 2-years results due to the corresponded programme has recently started, dry matter yields was satisfied ranged from 14-25t/ha depending on variety and cultural practice.

Eucalyptus

Depending on soil fertility and cultural practices, dry matter yields up to 35t/ha/year were obtained. The mean gross calorific values ranged from 16 to 19 MJ/kg d.m. depending on the plant part (leaves, stems) and the respective energy potential was up to 15toe/ha/year.

Black locust

Dry biomass yields ranged from 5.6 to 17.1t/ha/year. The averaged value for energy potential was 8toe/ha/year.

Table 5.1.2: Annual herbaceous energy crops

	Sweet sorghum	Fiber sorghum	Kenaf	Rapeseed
Sowing season	May T > 15 °C	May T > 15 C	April – July	Sep-Dec (early var.) March-April (late var.)
Herbicide	Pre-sowing Post-emergent	Pre-sowing Post-emergent	Pre-sowing Post-emergent	Pre-sowing Post-emergent
Plant density (plants/ha)	70,000-286,000	70,000-286,000	170,000 –320 000	130,000
Irrigation (mm)	250-500	250-500	300-400	-
Fertilisation (kg N/ha)	0-240	30-50	0-120	30-100
Flowering season	September	September	July (early var.) - Sep. (late var.)	March – April
Harvesting season	September - October	September	November – January	June – October
Dry matter yields (t/ha)	13-45	27	7.6-23.9	3-8
Biofuel type	Bioethanol	Bioethanol, solid	Solid	Bioethanol, solid

Table 5.1.3a: Perennial herbaceous energy crops

	Cardoon	Giant reed	Elephant grass	Switchgrass
Propagation material	Seeds	Rhizomes, stem cuttings	Rhizomes, stem cuttings, seeds	Seeds, rhizomes
Sprouting season	April – May	March	April	March
Herbicide	Pre-planting	Pre-planting	Pre-emergent in the first 2 years	pre-planting
Plant density (plants/ha)	10,000 –50,000	12,500-28,500	28,500-40,000	4,000,000
Irrigation (mm)	-	400	60-700	200
Fertilization (kg N/ha)	0-100	40-120	40-240	0-150
Flowering season	Spring	September – October	August - September	June – July
Harvesting season	June - July	February	February	December – February
Dry matter yields (t/ha)	17-30	20-30	11-34	19 – 30
Biofuel type	Solid Biodiesel	Solid	Solid	Bioethanol Solid

Table 5.1.3b: Perennial woody energy crops

	Eucalyptus	Black locust
Propagation material	Seedlings, Stem cuttings	Seedlings, Stem cuttings
Herbicide	Post-planting	post-planting
Plant density (plants/ha)	10,000-40,000	10,000-20,000
Rotation cycle (y)	2-3	2-3
Dry matter yields (t/ha)	18 – 24	14
Biofuel type	Solid	Solid

Results per research topic

Agronomic aspects

So far all the crops studied have performed good adaptability to Greek climatic conditions as well as high yields in terms of fresh biomass and dry matter.

Productivity varied with site, climate, soil, species and agricultural management but commercial yields of over 20 t d.m. ha^{-1} y^{-1} (400 GJ ha^{-1} y^{-1}) appear feasible in most of the tested Greek regions.

Fuel characterization

Among the annual crops, sweet sorghum is considered as a promising one for bioethanol production and *Brassica carinata* and *Brassica napus* for biodiesel production.

All other tested crops (annual and perennial) present efficient solutions for heat and electricity generation when they are carefully integrated in the local cropping systems.

Environmental aspects of biomass production

Environmental impacts of energy crops are anticipated to be lower than those associated with current row crop production and greater than those of fallowed, pasture or set-aside lands.

- Soil erosion

The perennial herbaceous crops tested so far offer excellent soil holding capacity because of their robust root system provide soil coverage during almost all the rainfall period (cardoon and giant reed), subsequently limiting runoff and sediment losses, stabilizing soil by their permanent rooting system, improving water infiltration and reducing impacts by water (Kort, 1998). Additionally, they favour soil development processes by improving soil organic matter, soil structure and soil water and nutrient-holding capacity.

The cultivation of annual herbaceous energy crops is expected to have similar erosion impacts as traditional food crops but they can be avoided by following more appropriate culture techniques such as less tillage and machinery movement.

- Ground and surface water pollution

Energy crops are generally less demanding for agrochemical inputs than conventional crops. As a consequence pollution of soil and water resources will be eliminated (Ranney, 1994b). During the experiments, insecticides and fungicides use was low for energy crops than conventional food crops. In addition, perennial crops required herbicides only during the establishment phase.

- Water consumption

Some energy crops under consideration have very high water use efficiency, which is very important for southern EU regions facing serious irrigation water shortages. Others, like eucalypts and giant reed, can tolerate long periods of drought while cardoon is an entirely rainfed crop.

- Biodiversity and wildlife habitat manipulation

Large-scale cultivation of energy crops can result in pest and disease outbreaks. Multi-species production systems could reduce the risks associated with pests, diseases and nutrient depletion and could also aid in increasing biodiversity of plant and animal species in a predominantly agricultural area (Hohenstein, 1994)

Conversion to energy technologies

Generation of electricity from biomass is made with known technologies, but there is room for considerable improvement and expansion especially in terms of efficiency and control of emissions. Expanding the biomass electric industry to a large scale requires an assurance of feedstock supply and considerable technology transfer to utilities and investors. Putting fossil fuels and biomass feedstocks on a level playing field by internalising environmental externalities in fossil fuel costs would very likely increase the economic attractiveness of energy crop biomass feedstocks.

Economic and social dimensions

Significantly higher yields per unit of land area than natural stands have been achieved. As a result, cost effectiveness over conventional crops can be improved. Obtaining higher yields would tend to reduce the production cost per unit since harvesting costs and land rental costs per unit become less for every extra unit produced. Despite the undoubted benefits of growing energy crops, they have to compete with traditional land uses, and landowners would only grow them if a greater profit would be possible (Sims, 1998).

Any shift of the current land use towards energy crop production will strongly depend on the respective profitability on farm level for the farmers. This in turn will be related to European and national programs for food crops and other agricultural and land use policies.

Annual herbaceous energy crops offer the advantage of using standard farming equipment and familiar management techniques. A major disadvantage of annual crops' cultivation is the high cost input requirements compared to respective perennial crops.

On the other hand perennial crops require less annual management and inputs, providing higher net profit for the farmers.

5.3 CRITERIA FOR THE SELECTION OF PROMISING ENERGY CROPS

Based on the above described ten years' research and development activities some criteria were set for the selection of the most promising options for bioenergy schemes fuelled with energy crops in Greece.

- Adaptability under different soil-climatic conditions.
- Cultural practices do not differ from the ones used so far for the conventional crops in the local agricultural system.
- No additional machinery is required.
- Adequate yields can be produced with less inputs (water, fertiliser, chemicals) than conventional crops.

5.4 POTENTIAL ENERGY CROPS: CARDOON AND GIANT REED

In this thesis, two perennial crops are examined - cardoon and giant reed. Both crops have been evaluated in experimental plantations for several years (Mardikis, 2000). The author was the scientist responsible for the experiments conducted in central Greece from 1994-1997. During this period, she worked in the field establishment, management of the crop and data recording. She was collecting data at monthly intervals from the plantations concerning:

- Fresh biomass and dry matter yields per plant part (soil leaves, stem leaves, capitulas, stems and branches)
- Height
- Number of stems and branches

- Number of capitulas

She was also co-author in all the technical project reports and in a scientific paper on cardoon (Dalianis, 1996a, Panoutsou, 1997a). For giant reed, the author collaborated with the scientists involved in the experiments and reporting (Christou, 1998, Christou, 2000a, Christou, 2000b, Christou, 2000c, Dalianis, 1994a) and further elaborated on their data in the models used in the thesis.

It must be mentioned that data from a long-term study on cardoon and giant reed grown in Rhodope in a monoculture environment on cropland to produce biomass are not available since both plantations have been tested at an experimental level only, in Rhodope (giant reed) and in central Greece (cardoon and giant reed). However, the experiments conducted so far show that the two crops can be used in dedicated feedstock supply systems addressing technical, economic and environmental issues of concern to farmers, landowners and the rural community.

After reviewing the current state on energy crops in Greece, the author decided to examine in depth the utilisation of cardoon and giant reed, two well adapted, high yielding perennial energy crops. Several benefits are expected to derive from their inclusion in the rotation. With their vigorous and robust rooting systems they contribute to the improvement of soil organic matter levels (Dalianis, 1995, Panoutsou, 1996). In addition, being perennial crops reduces the potential for nitrate leaching since the need for external inputs of fertilisers is small compared to conventional crops currently cultivated in the area (winter cereals, corn, cotton, etc.).

Following, there is an extensive presentation of the experimental methods and the results achieved so far in Greece. As stated above, the data concerning cardoon represent the author's ***original*** contribution to the technical work of the thesis (field experiments, data collection and statistical analysis, scientific interpretation of the results). The respective data for giant reed are evaluated by the author in this chapter and used later in the modelling of economic and socio-economic aspects.

Finally, it should be emphasized that all the methods and results presented below are at experimental – demonstration scale since no commercial projects on energy crops exist in the country.

5.4.1 Cardoon

Cardoon (*Cynara cardunculus*, L.), a perennial herbaceous species, is a kind of thistle, traditionally cultivated in some places of the Mediterranean area, for human consumption of its leaf petioles and for cheese making (Fernandez, 1991). Like most thistle species, it is very well adapted in summer drought conditions and as a winter crop it needs low water inputs since it reaches its maximum biomass yields by exploiting the available rainfalls during the autumn and the winter period. Due to this fact and to a dense rooting system, *it offers protection against soil erosion in sloping* and marginal lands (Dercas, 1996, Panoutsou, 1997b).

After harvesting the crop in the summer, a new cycle starts with the onset of rains from underground buds. The plant takes a rosette like form until the following spring when it develops stems. Later on this season branching development occurs in the top of the plants and several capitulas are formed per stem. During summer the aerial parts dry while the subterranean parts, roots and remnant buds found in the bottom of the stalk remain alive (Dalianis, 1996a).

Possible novel utilisation of the crop is use of the stalks as a fibre or energy raw material of the seeds as an oil source and of the aerial rosette leaves produced in winter as green fodder. The lifetime of the plantation is 15 years.

The results presented below are based on an EU funded project (AIR CT 93-1089) for which the author has been contributed as research assistant and project manager thus contributing the Greek data and analysis of the experiments.

Experimental data concerning yields and adaptability

A series of experiments were conducted in central Greece (1994 - 1997) to examine the adaptability and the yielding potential of cardoon under different cultural practices. In general, the crop was found to grow well under local climatic conditions and high biomass productivity was found.

Three experiments were established on February 1994, in the area of Vagia, central Greece, one of the largest plains in the country. Emergence was more than 90%. Plants survived through very cold climatic conditions during winter 1995 (Panoutsou, 1997a). The control of weeds was not very difficult since after its establishment the crop suppresses most of the weeds on the field due to its big canopy. In more detail, the three experiments were:

A. Green forage: The aim of this experiment was firstly to study fresh biomass production for animal feeding during autumn and winter periods and secondly to evaluate growth and final biomass yields in relation to green forage cuttings. For this purpose the effect of four winter cuttings (November - February) on growth and productivity of the crop has been examined, compared to plants with undisturbed growth.

Methods and Materials

The experiment was located on a hill, in the plain of Thebes, central Greece. *Cynara cardunculus* L., cv Bianco di Spagna, was sown on March 1994. The experimental layout was a randomized complete block design in five blocks. The five treatments were:

- C_0: control (no cutting-undisturbed growth)
- C_1: November cutting
- C_2: December cutting
- C_3: January cutting
- C_4: February cutting

Distances between rows and inside the row were 0.80 m. The plantation was entirely rainfed. Nitrogen fertilization was applied on November, every second year, at a rate of 50 kg/ha.

During the first and the second growing periods, one harvest per month has been made from November to February and the following parameters were recorded: i) crop height and ii) fresh and dry biomass yields. Representative samples of each plant part (stems and branches, soil leaves, stem leaves and capitula) were taken from the field and were oven dried in 85^0C, for approximately 3 days, to determine dry matter.

At the end of the first (August 1995) and the second (August 1996) growing period a final harvest was made. It must be noted that biomass production in the end of the establishment year (August 1994) was not significant. Therefore, we consider August 1995 as the first productive growing period. Four representative plants were selected in each plot. According to the proposed protocol the following determinations were made: a) maximum height (the height of the tallest stem), b) number of stems, c) number of capitula and d) the weight of the following plant fractions: leaves on the soil, leaves on the stems, stems, branches and capitulas.

Samples of stems and branches, soil leaves, stem leaves and capitulas were taken in paper bags from the field and were oven dried in 85^0C, for app. 3 days, in order to determine dry matter. Statistical analysis of the collected data were estimated with Statgraphics 6.

Results

Height: Crop height, observed at each cutting date (November-February) did not present any statistically significant difference for the two examined growing periods.

On the 1994-95 growing cycle height ranged from 56 cm (November) to 122 cm (February) and on the 1995-96 cycle, it ranged from 55 cm (November) to 118 cm (February) (figure 5.4.1a).

The corresponding values for the final crop height are shown in figure 5.4.1b. In the end of each growing period, final crop height for the control treatment (C_0), reached at 266 cm and 239 cm in 1995 and 1996, respectively.

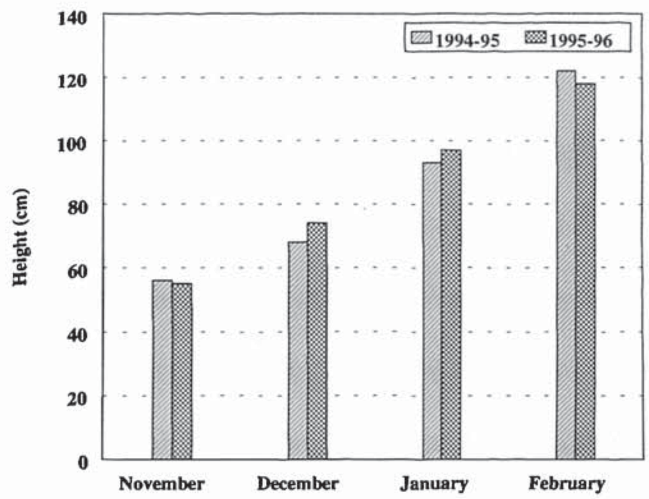

Figure 5.4.1a: Effect of green forage cuttings *(C0: control, C1: November cutting, C2: December cutting, C3: January cutting, C4: February cutting)* on the height of *Cynara cardunculus* L. averaged over different cutting dates and growing periods.

At this stage, green forage cuttings showed a statistically significant effect on final crop height, especially among the C_0 (control) and the C_3 (January) and C_4 (February) treatments.

It must be mentioned that in both years final crop height was lower in the late cuttings. This is due to the fact that regrowth in November and December was enhanced by higher rainfalls occurring at the time than regrowth on February.

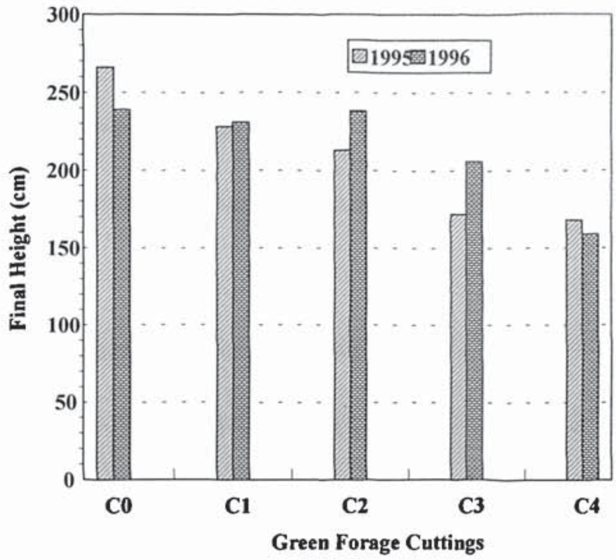

Figure 5.4.1b: Effect of green forage cuttings *(C_0: control, C_1: November cutting, C_2: December cutting, C_3: January cutting, C_4: February cutting)* on final crop height of *Cynara cardunculus* L. for the first (1995) and the second (1996) growing period.

Yields

Effect of green forage cuttings

During the first growing period, the highest biomass yields were recorded in the February cutting (C_4) and they reached up to 149.34 t/ha fresh biomass and 11.98 t/ha dry matter. Plants remained green all this period and no yellow leaves were yet observed.

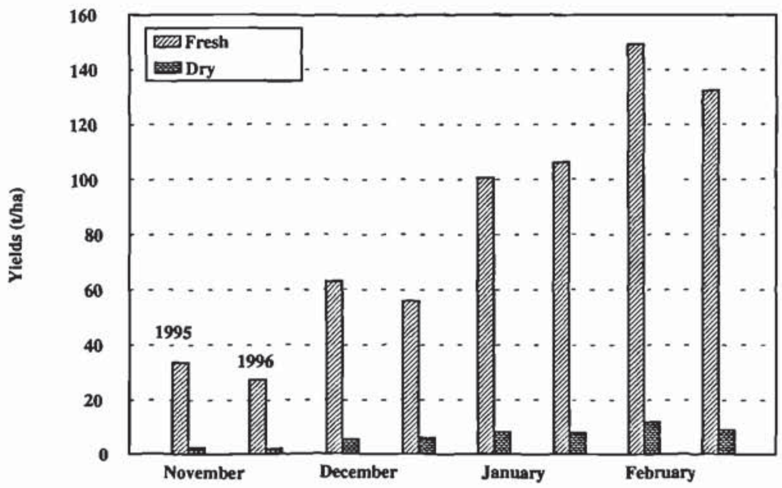

Figure 5.4.1c: Average fresh and dry biomass yields of *Cynara cardunculus* for the first (1995) and the second (1996) growing period.

It is worthwhile to mention that the plantation has been proved cold resistant, since it survived, with no damage at all, through a very cold and snowy 20-day period in January.

During the first part of the second growing period, until December, plant growth was slightly lower, due to delayed rainfall in the area. Afterwards, the growth rate was similar to that of the first year. However, this delayed growth resulted in slightly lower fresh and dry biomass yields.

Total fresh and dry matter yields reached at 132.32 t/ha and 9.12 t/ha, respectively. The slight reduction, observed in the yields during the second year was mainly due to the low rainfall rates, which occurred in winter.

From all the aforementioned results it is clear that in both years dry matter accumulation shows a very low rate till February and it reaches up to 8%.

Final biomass yields

In the first growing period (1995), fresh biomass yields ranged from 43.45 t/ha in the C_0 treatment to 25.07 t/ha in the C_4 treatment. Dry matter yields ranged from 35.65 t/ha, to 18.58 t/ha, respectively.

In the second growing period (1996), fresh biomass yields ranged from 40.58 t/ha in the C_0 treatment to 26.6 t/ha in the C_4 treatment. Dry matter yields ranged from 33.43 t/ha to 18.94 t/ha, respectively.

In both periods, a progressive reduction in both fresh biomass and dry matter yields was observed in the late cuttings (January, February).

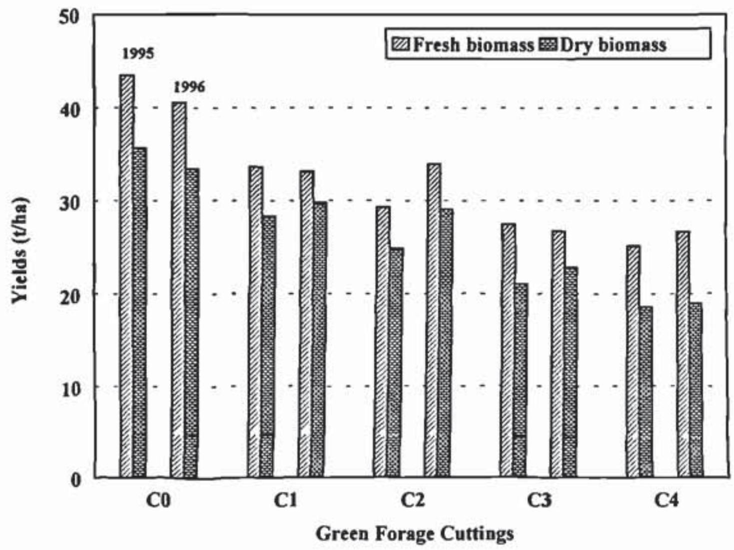

Figure 5.4.1d: Fresh and dry biomass biomass yields averaged over four green forage cuttings *(C_0: control, C_1: November cutting, C_2: December cutting, C_3: January cutting, C_4: February cutting)*, for the first (1995) and the second (1996) growing period.

In the following figures, fresh and dry matter is shown for each plant part separately, in comparison to the total yields. From them it is clearly shown that stems and capitulas represent the highest percent of both fresh biomass and dry matter yields. It must be also mentioned that soil leaves in 1996 presented a higher value. This is due to the fact that the harvesting date in this period was delayed compared to the previous one and this resulted in higher amount of soil leaves and lower amount of stem leaves.

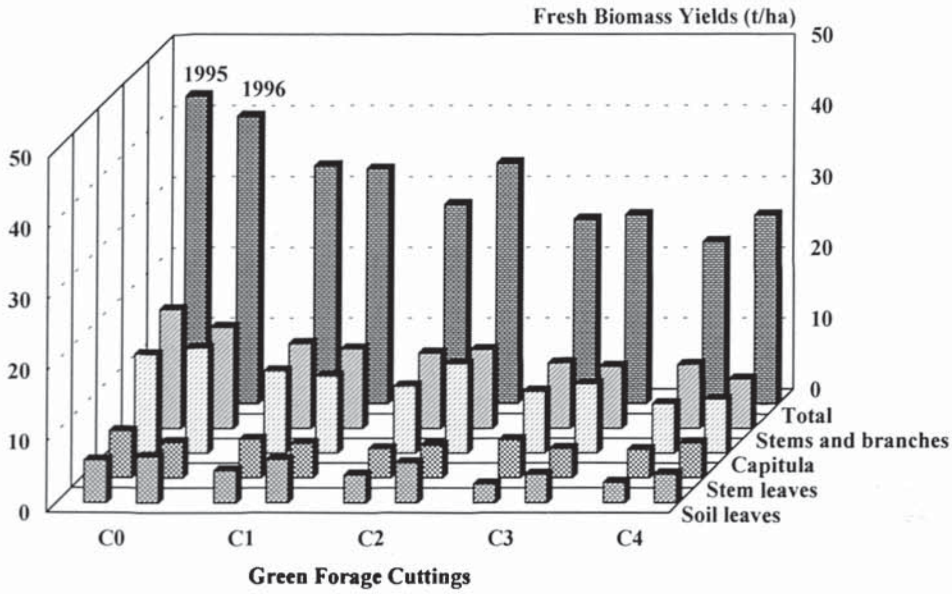

Figure 5.4.1e: Fresh weight of each plant part averaged over four green forage cuttings *(C_0: control, C_1: November cutting, C_2: December cutting, C_3: January cutting, C_4: February cutting)* in the final harvest, for the first (1995) and the second (1996) growing period.

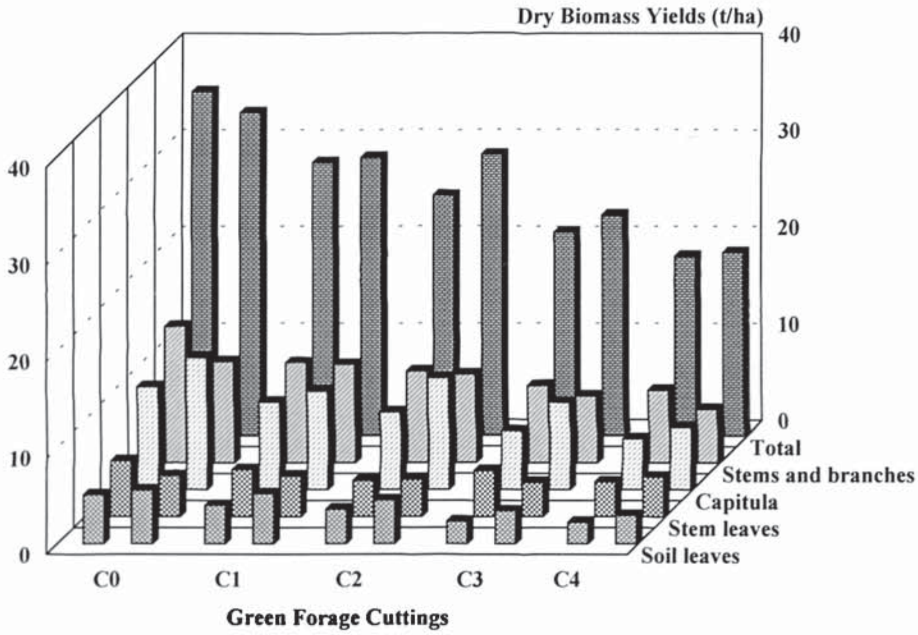

Figure 5.4.1f: Dry matter of each plant part averaged over four green forage cuttings (*C_0: control, C_1: November cutting, C_2: December cutting, C_3: January cutting, C_4: February cutting)* in the final harvest, for the first (1995) and the second (1996) growing period.

B. Plant density: The aim of this experiment was to examine the effect of plant density on growth and biomass productivity of *Cynara cardunculus* L. under Greek climatic conditions. For this purpose five plant densities, from 10,000 plants/ha to 50,000 plants/ha have been examined.

Methods and materials

The experiment was located on a hill, in the plain of Thebes, central Greece. *Cynara cardunculus* L., cv Bianco di Spagna, was sown on February 1994.

The experimental layout was a randomized complete block design in five blocks. Each plot size was 7.5 x 4.8 m. Five plant densities have been applied inside the rows:

- D_0: 10,000 plants/ha
- D_1: 20,000 plants/ha
- D_2: 30,000 plants/ha
- D_3: 40,000 plants/ha
- D_4: 50,000 plants/ha

Distances between rows and inside the row were 0.80 m. The plantation was entirely rainfed. Nitrogen fertilization was applied on November, every second year, at a rate of 50 kg/ha.

At the end of the first (August 1995) and the second (August 1996) growing period a final harvest was made. It must be noted that biomass production in the end of the establishment year (August 1994) was not significant. Therefore, we consider August 1995 as the first productive growing period. Four representative plants were selected in each plot. According to the proposed protocol the following parameters were recorded: a) maximum height (the height of the tallest stem), b) number of stems, c) number of capitulas and d) the weight of the following plant fractions: leaves on the soil, leaves on the stems, stems, branches and capitulas.

Samples of stems and branches, soil leaves, stem leaves and capitulas were taken in paper bags from the field and were oven dried in 85^0C, for app. 3 days, in order to determine dry matter. Statistical analyses of the collected data were estimated with Statgraphics 6.

Results

Height: Plant density did not have any statistically significant effect on the final crop height of *Cynara cardunculus*, both in the first and in the second growing period. The maximum height was observed in the D_0: 10,000 plants/ha treatment and it was 2.58 m and 2.52 m for 1995 and 1996, respectively.

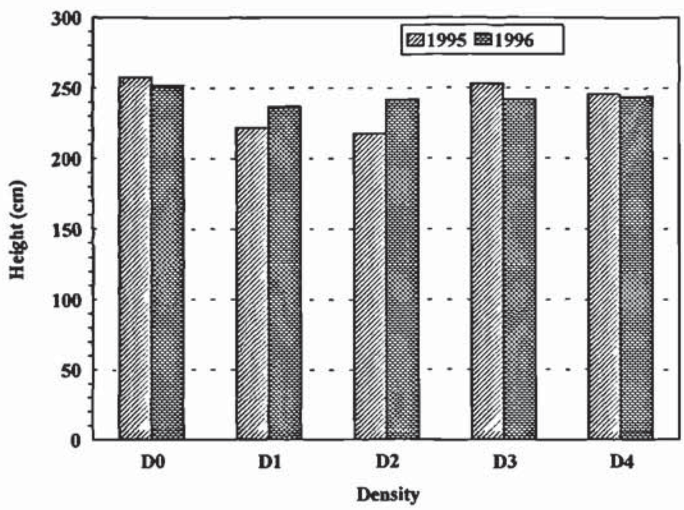

Figure 5.4.1g: Effect of plant density *(D_0: 10,000 plants/ha, D_1: 20,000 plants/ha, D_2: 30,000 plants/ha, D_3: 40,000 plants/ha and D_4: 50,000 plants/ha)* on the final crop height of *Cynara cardunculus* L, for the first (1995) and the second (1996) growing period.

Number of stems:

In 1995, plant density had a significant effect on the number of stems per plant. It was observed that D_0 was superior to others in the number of stems and branches (21.5/ plant) while D_1, D_2, and D_3 were quite similar (11.7, 14.2 and 11.5 respectively). D_4 had the lowest number of all (9.4/plant).

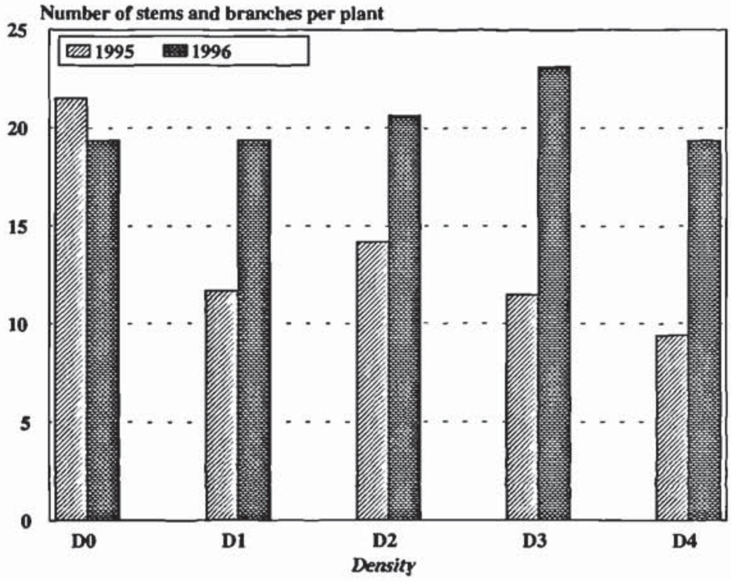

Figure 5.4.1h: Effect of plant density *(D_0: 10,000 plants/ha, D_1: 20,000 plants/ha, D_2: 30,000 plants/ha, D_3: 40,000 plants/ha and D_4: 50,000 plants/ha)* on the number of stems and branches per plant of *Cynara cardunculus* for the first (1995) and the second (1996) growing period.

On the contrary, in 1996, plant density didn't show any statistically significant effect. The average number of stems per plant ranged from 19.38 (D_0: 10,000 plants/ha) to 20.63 (D_2: 30,000 plants/ha).

Number of capitulas: In 1995, the number of capitulas was higher for D_0 (19.5/ plant) than for D_1, D_2 and D_3 (11.7, 12.8, 10,5 respectively) while it showed the lowest value for D_4 (8.7/ plant). However, in 1996 there was a significant increase in the number of capitulas in all the density treatments. Average number of capitulas per plant ranged from 18.44 (D_0: 10,000 plants/ ha) to 23.75 (D_4: 50,000 plants/ ha). It is clearly shown that plant density didn't have a statistically significant effect on the capitulas number during the growing period.

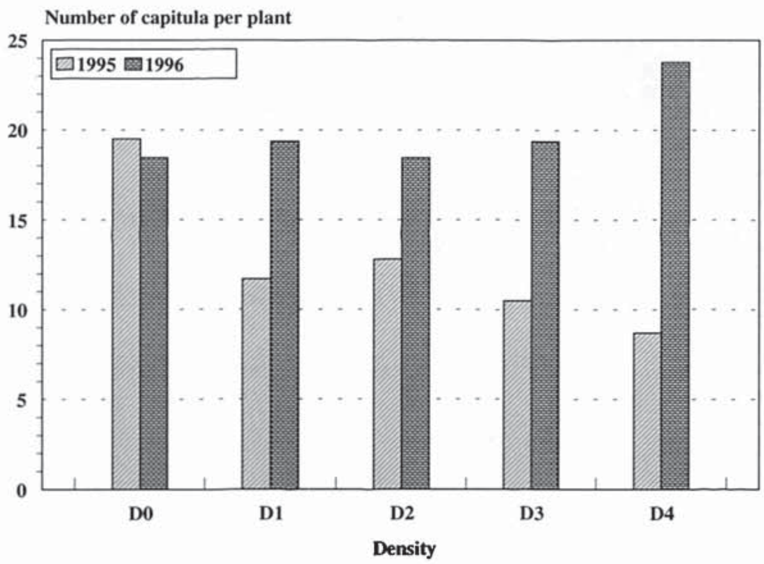

Figure 5.4.1i: Effect of plant density *(D_0: 10,000 plants/ha, D_1: 20,000 plants/ha, D_2: 30,000 plants/ha, D_3: 40,000 plants/ha and D_4: 50,000 plants/ha)* on the number of capitulas per plant of *Cynara cardunculus* for the first (1995) and the second (1996) growing period.

Yields: Plant density showed a statistically significant effect both on fresh biomass and dry matter yields. In the end of the first growing period (1995), total fresh and dry biomass yields ranged from 25.5 t/ha- 48.5 t/ha and from 16.96t/ha- 31.67 t/ha, respectively.

In 1995, the high density (D_4: 50,000 plants/ha.) resulted in almost double fresh and dry weight than the low one (D_0: 10,000 plants/ha).

In 1996, due to a severe damage of some plots, biomass yields, especially in D_3 treatment, were much lower. Furthermore, it must be pointed out that although fresh biomass yields were lower than 1995, dry matter was approximately the same. This is due to the very hot and dry summer, which resulted in low plant humidity levels at harvest time.

Fresh and dry biomass yields for each plant part separately is shown in figures 5.4.1j and k. Plant density showed also a statistically significant effect for the different plant parts as it showed for the final biomass yields.

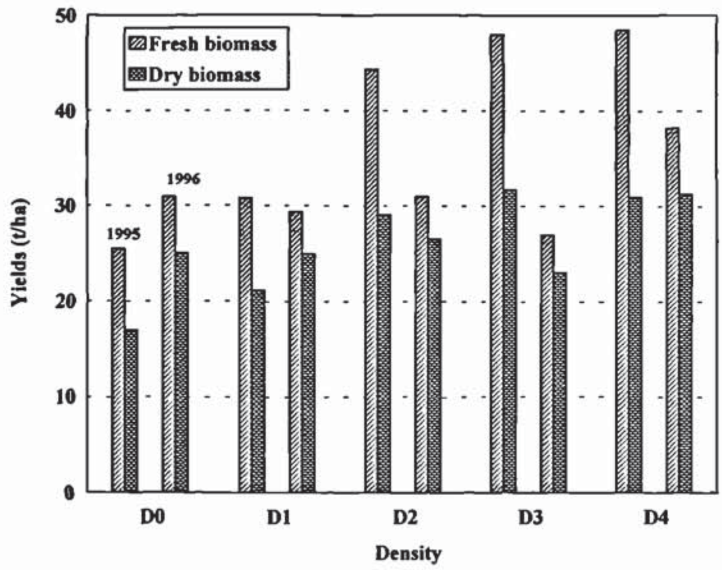

Figure 5.4.1j: Effect of plant density *(D_0: 10,000 plants/ha, D_1: 20,000 plants/ha, D_2: 30,000 plants/ha, D_3: 40,000 plants/ha and D_4: 50,000 plants/ha)* on the final fresh and dry biomass yields of *Cynara cardunculus* for the first (1995) and the second (1996) growing period.

From the figures it is clear that total yields variation in relation to plant density was mainly caused by the yields of stems and capitulas. Both soil and stem leaves remain almost stable. It should be pointed out that the delayed harvesting date in 1996, resulted in higher amount of soil leaves and lower amount of stem leaves.

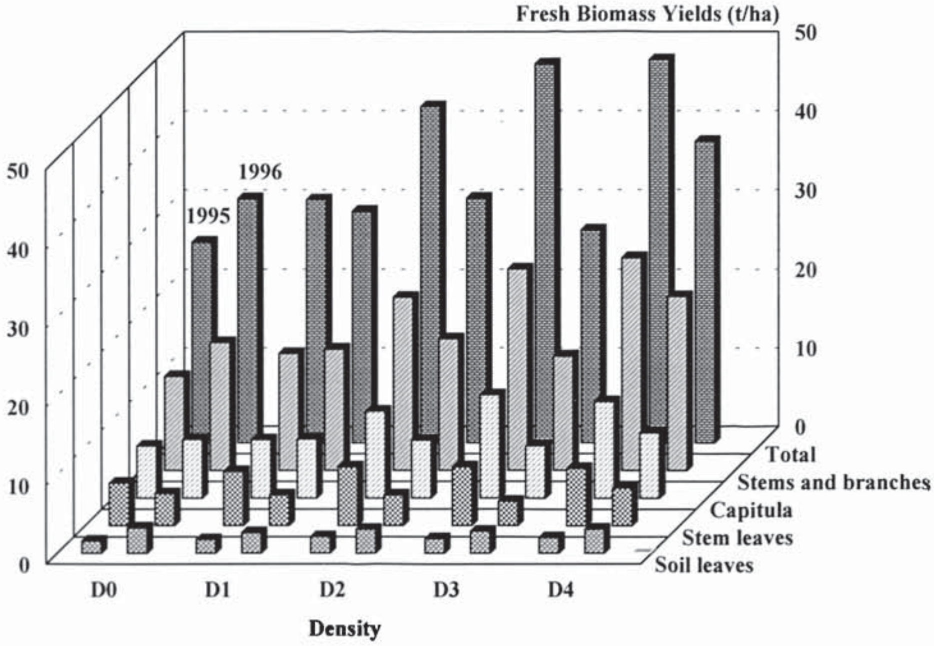

Figure 5.4.1k: Effect of plant density *(D_0: 10,000 plants/ha, D_1: 20,000 plants/ha, D_2: 30,000 plants/ha, D_3: 40,000 plants/ha and D_4: 50,000 plants/ha)* on fresh biomass yields of different plant parts of *Cynara cardunculus*.

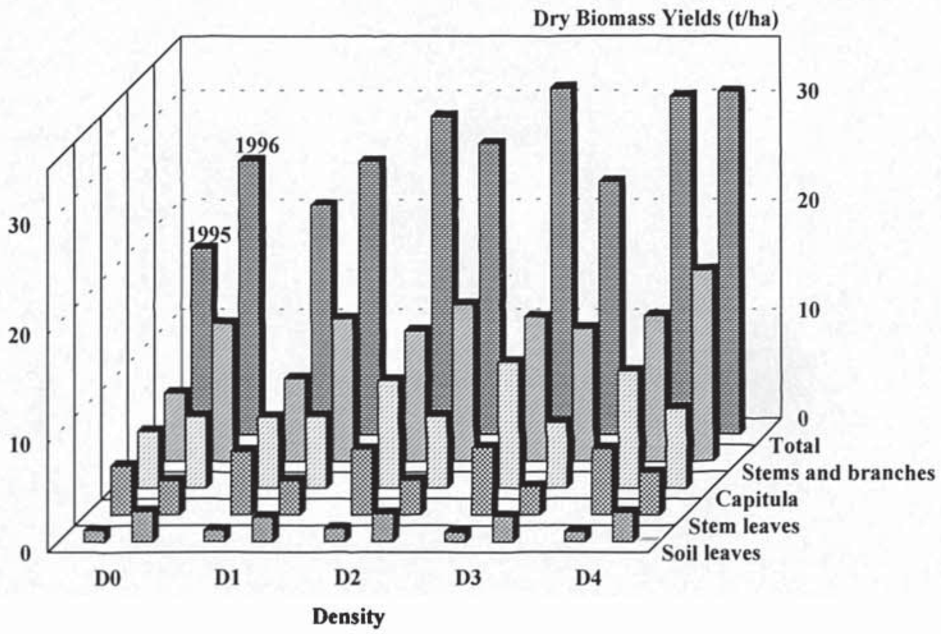

Figure 5.4.11: Effect of plant density *(D_0: 10,000 plants/ha, D_1: 20,000 plants/ha, D_2: 30,000 plants/ha, D_3: 40,000 plants/ha and D_4: 50,000 plants/ha)* on dry biomass yields of different plant parts of *Cynara cardunculus*.

C. Nitrogen fertilisation and plant density: The aim of this experiment was to study the effect of N top fertilization and plant density on growth and productivity of *Cynara cardunculus* L., under Greek climatic conditions.

Methods and materials

The experiment was located on a hill, in the plain of Thebes, central Greece. *Cynara cardunculus* L, cv Bianco di Spagna, was sown on February 1994. The experimental design was a 2x3 factorial experiment in a randomised complete block design in 4 blocks. Each plot size was 7.5x4.8 m. The plantation was entirely rainfed.

Three nitrogen fertilization rates were applied on November 1994:

- N_0: control- no fertilization
- N_1: 50 kg/ha
- N_2: 100 kg/ha

The two examined plant densities inside the row were:

- D_0: 42 cm
- D_1: 81 cm

At the end of the first (August 1995) and the second (August 1996) growing period, a final harvest was made in order to estimate comparative results for the two growing cycles. It must be noted that biomass production in the end of the establishment year (August 1994) was not significant. Therefore, we consider August 1995 as the first productive growing period. During this, four representative plants were selected in each plot. According to the proposed protocol, the following parameters were determined: a) maximum height (the height of the tallest stem), b) number of stems, c) number of capitulas and d) the weight of the following plant fractions: leaves on the soil, leaves on the stems, stems, branches and capitulas.

Samples of stems and branches, soil leaves, stem leaves and capitulas were taken in paper bags from the field and were oven dried in 85^0C, for app. 3 days, in order to determine dry matter. Statistical analyses of the collected data were estimated with Statgraphics 6.

Results

Height: Final crop height ranged from 270 cm for the (N_0) treatment to 274 cm for the high fertilization rate (N_2) in 1995, and from 253 cm for the high fertilization rate (N_2) to 257 cm for the low fertilization rate (N_1), in 1996. Data recorded indicate that N fertilization had no statistically significant effect on the final crop height of *Cynara cardunculus* L.

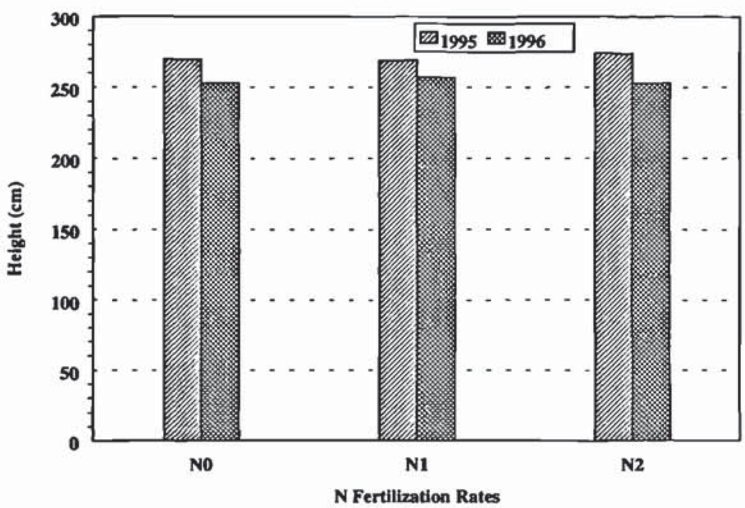

Figure 5.4.1m: Effect of N fertilization rates *(N_0: control no fertilization, N_1: 50 kg/ha and N_2: 100 kg/ha)* on the final crop height of *Cynara cardunculus* L., for the first (1995) and the second (1996) growing period.

Number of stems: In 1995, N fertilization rates showed a statistically significant effect on the number of stems per plant. It was observed that N_1 was superior to others in stems and branches (17.5/plant) while the corresponding values for N_0 and N_2 were 12.75 and 15.4, respectively.

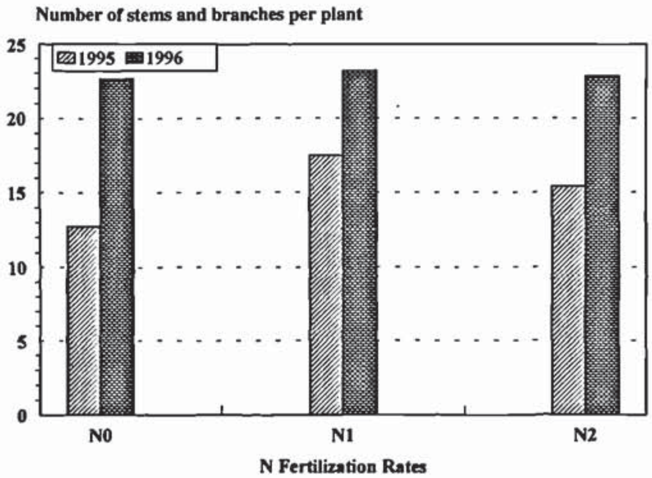

Figure 5.4.1n: Effect of N fertilization rates *(N_0: control- no fertilization, N_1: 50 kg/ha and N_2: 100 kg/ha, on November 1994)* on the number of stems of *Cynara cardunculus* L., for the first (1995) and the second (1996) growing period.

On the contrary, in 1996, N fertilization didn't have any statistically significant effect on the number of stems. However, a significant increase in the number of stems and branches per plant was observed in the end of the second growing period. Average number of stems per plant ranged from 22.66 (N_0: control- no fertilization) to 23.24 (N_1: 50 kg/ha).

Number of capitulas: In both the growing periods, the number of capitulas was higher for the N_1 treatment (17.25/plant in 1995, 17.77/ plant in 1996) than for N_0 and N_2 (12.13/ plant in 1995, 14.84/ plant in 1996 and 14.3/ plant in 1995, 16.02/ plant in 1996, respectively). It must be noted that the number of capitulas slightly increased in 1996, for the N_0 and N_2 treatments.

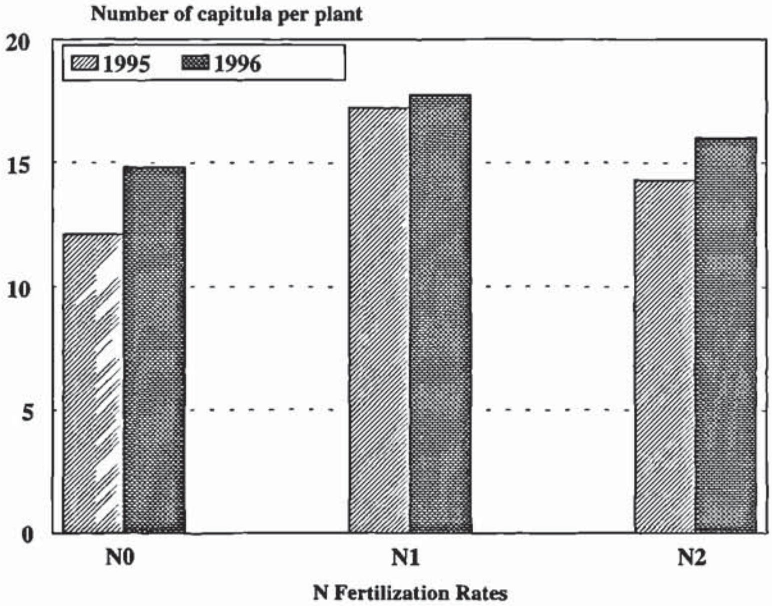

Figure 5.4.1o: Effect of N fertilization rates *(N_0: control- no fertilization, N_1: 50 kg/ha and N_2: 100 kg/ha, on November 1994)* on the number of capitulas of *Cynara cardunculus* L., for the first (1995) and the second (1996) growing period.

Yields: Nitrogen fertilization had a slightly significant effect on final biomass yields. A statistically significant difference was observed between N_0 (no fertilization) and N_2 (high fertilization rate).

In 1995, fresh and dry biomass yields ranged from 35.57 t/ha (N_0 treatment) - 40.15 t/ha (N_2 treatment) and 29 t/ha (N_0 treatment) - 33.65 t/ha (N_2 treatment), respectively. In 1996, N_1 treatment was proved the more productive in terms of fresh biomass yields (38.65 t/ha) and N_0 treatment in terms of dry matter (30.82 t/ha). Fresh and dry biomass yields for the other treatments ranged from 34.89 t/ha - 35.44 t/ha and 26.27 t/ha - 30.43 t/ha.

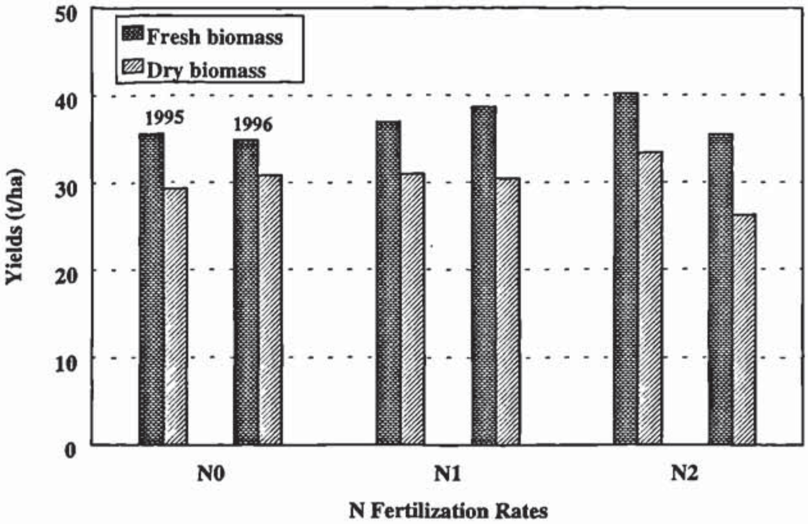

Figure 5.4.1p: Effect of N fertilization rates *(N_0: control- no fertilization, N_1: 50 kg/ha and N_2: 100 kg/ha, on November 1994)* on fresh and dry biomass yields of *Cynara carduncululus* for the first (1995) and the second (1996) growing period.

Fresh and dry biomass yields for each plant part are shown in the following figures. It has been estimated that high N fertilization rate was slightly superior in biomass productivity for stems, soil leaves and stem leaves while capitulas yields were higher for low N fertilization rate.

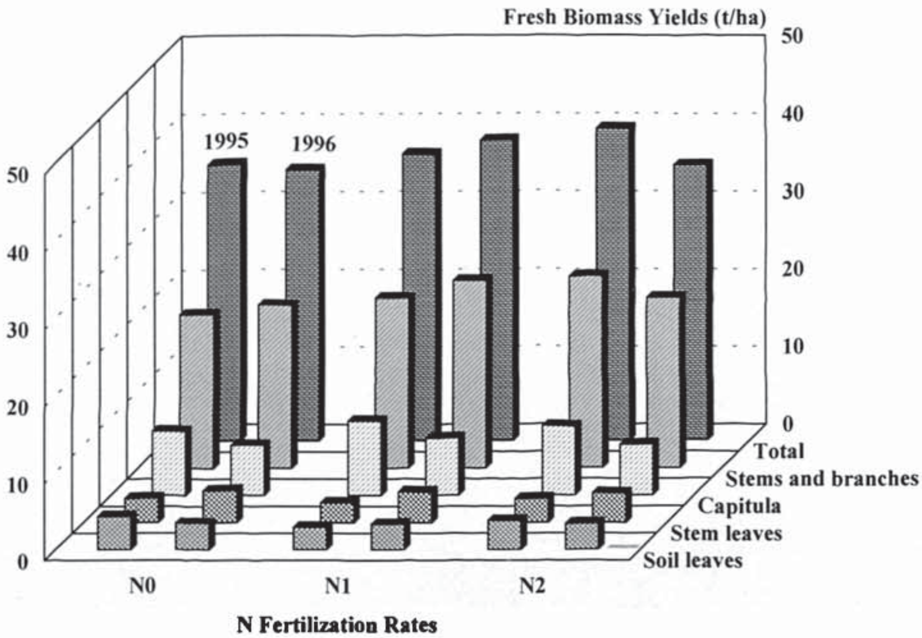

Figure 5.4.1q: Effect of N fertilization rates *(N_0: control- no fertilization, N_1: 50 kg/ha and N_2: 100 kg/ha, on November 1994)* on fresh biomass yields for different plant parts of *Cynara carduncululus* for the first (1995) and the second (1996) growing period.

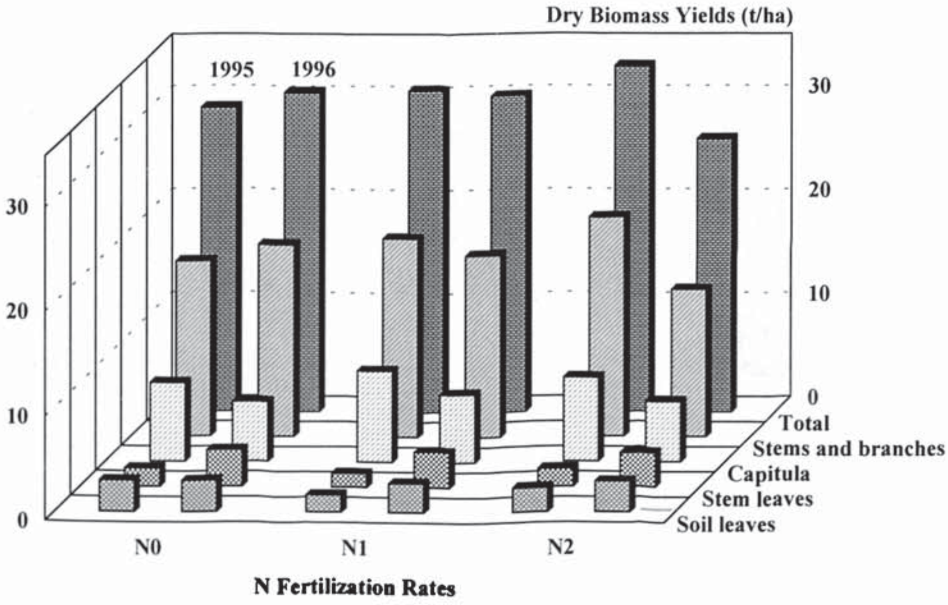

Figure 5.4.1r: Effect of N fertilization rates *(N_0: control- no fertilization, N_1: 50 kg/ha and N_2: 100 kg/ha, on November 1994)* on dry biomass yields of different plant parts of *Cynara cardunculus* for the first (1995) and the second (1996) growing period.

Calorific values ranged from as low as 3,474 kcal/kg for leaves and receptacles to 5,912 kcal/kg for the seeds. The latter was due to the high oil content of the seeds. Significant differences have been observed for the different proximate analysis variables among the various plant components. It was found that leaves and receptacles, which as it was stated had the lower calorific values, have the higher ash content, about 14 %. For the other plant components ash content ranged from 3.32 to 5.36 %. Respective values for the energy potential ranged from 6.9 to 12.9 toe/ha (Dalianis, 1994b, Dalianis, 1996a).

5.4.2 Giant reed

Giant reed (*Arundo donax* L.) is a native of the Mediterranean countries and, therefore, naturally adapted to south EU climatic conditions. Giant reed is considered to be one of the most promising grass species for non-food uses, on account of favourable characteristics including high biomass yielding potential (40-75 t/ha/year fresh matter) (Dalianis, 1994a, Christou, 1998); with simultaneous low agrochemical inputs; high quality of solid biofuel and various environmental benefits such as soil protection.

Giant reed is reported to tolerate various types of soils, from heavy clays to loose sands and gravely soils. Giant reed grows well in and in warm temperate and tropical regions where it can produce 40-75 t /ha /year fresh matter (Boose, 1999, Christou, 1998, Jodice, 1994).

The plant regrows every year from rhizomes; therefore a number of cultivation techniques (such as ploughing, disking, sowing, etc.), typical of annual crops are avoided. However, the Arundo cultivation needs rather complex and expensive planting operations, because it does not have sexual reproduction, and only rhizomes or cuttings can be used for vegetative multiplication of the plant (Jodice, 1998). In this study stem cuttings were used for estimation of establishment costs. The lifetime of the plantation is 15 years.

The crop can overcome severe draughts achieving satisfied yields under water-limited conditions. It is also considered to be one of the most cost-effective energy crops, since it is perennial and annual inputs after establishment are very low. However, establishment and harvesting costs are high due to the lack of mechanization. Irrigation and/or fertilization costs can be relatively low depending on soil-climatic conditions. It is reported that giant reed is not susceptible to any serious disease and, as a consequence, inputs should be very low. Due to its high moisture content, harvesting should be carried out in late winter in order to reduce the moisture content of the stems.

The results presented below are based on a series of experiments conducted by scientists of the Biomass Department of the Centre for Renewable Energy Sources in Greece, in the framework of the EU funded project FAIR CT 96 2028: Arundo donax network.

Propagation experiments

The purpose of this work was to determine the most successful and cost-effective establishment method by the evaluation of three propagation materials (stem cuttings, rhizomes and whole stems) and two plant densities.

Methods and materials

An experimental field was established in the plain of Kopais in central Greece (Aliartos). The field coordinates were latitude 38.23°, longitude 23.06° and altitude 110m. The texture of soil was sandy/loam (SL) for the layer 0-58cm, clay/loam (CL) for the 58-82cm one and sand (S) down to 92cm. The carbon content for the upper layers was 0.5- 0.7%.

The experimental layout was a randomised complete block design with five treatments in four blocks. Each plot covered a total area of 20m^2. The propagules were rhizomes, with 2 to 3 visible well-formed axillary buds, stem cuttings, 15cm in length, with one node, and whole stems, 4m in length.

The propagules were planted horizontally at 10cm depth, without any prior treatment. Distances between rows were 80cm but within rows they varied depending on the treatment. The five treatments to be studied were:

T_0= rhizomes at 50cm (density: 25,000 rhizomes/ha),

T_1= rhizomes at 100 cm (density: 12,500 rhizomes/ha),

T_2= stem cuttings at 50 cm (density: 25,000 s.c./ha),

T_3: stem cuttings at 100cm (density: 12,500 s.c./ha), and T_4: whole stems (4m in length) laid down in the furrow (density: 2,500 stems/ha).

The planting was carried out at the beginning of May when temperatures raised and soil moisture was high due to frequent rainfalls in April and May. Furthermore, in the second year the treatments T_2, T_3 and T_4 were re-established because of the very low survival rate. During the first two growing periods meteorological data were recorded on a daily basis.

Shortly after planting, irrigation was applied, in order to supply the plants with sufficient amounts of water for their successful rooting. Watering of plants continued until September. 90 and 139mm in total were applied in the first and second growing periods, respectively).

During the growing periods, sprouting capacity for each treatment and growth data (such as, number of shoots per square meter, height of plants and basal stem diameter) were collected at monthly intervals from three plants randomly chosen. Moreover, at the end of each growing period (February) harvests were carried out, in a larger area, in order to estimate biomass productivity for each treatment.

Results

Growth characteristics: Rhizomes showed a very high success in sprouting reaching in most cases the 100%. On the contrary, stem cuttings showed a nearly 100% failure in establishment, in spite of the well watering and the high air temperatures (Table I). The trial was repeated in the following year (1998) and the failure in establishment was confirmed once again.

Despite the total failure of the stem cuttings, whole stems had 75% establishment rate in the first year and 100% in the second one. It has to be noted, however that the percentage refers to the number of whole stems that resprouted and not to the number of buds in each stem. It was observed that the new shoots were developed from buds in the middle and upper parts of the stems.

During both growing periods, plants derived from rhizomes had exhibited better growth characteristics than the plants derived from stem cuttings or whole stems (Table 5.4.2a).

Table 5.4.2a. Growth characteristics for the five treatments at the end of the first and the second growing periods.

	Sprouting Capacity		Number of shoots/ plant		Number of shoots/m²		Height of plants (cm)		Shoot diameter (mm)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
T_0	94	-	4.0	8.1	9.9	20.2	325	391	17.5	16.4
T_1	100	-	7.1	10.3	8.9	12.9	390	440	17.3	17
T_2	2	0	3.8	36.5	0.2	2.9	162	430	10.6	19.8
T_3	2	0	4	33	0.1	3.3	166	478	11.2	19.8
T_4	75	100	2.4	28.9	0.5	7.7	154	312	7.9	13.8

The plants in the denser plantation had produced fewer shoots per plant in both growing periods, however, the number of shoots per m^2 was similar for T_0 and T_1 (9.9 and 8.9, respectively) in the establishment year. In the following year, shoot numbers were considerably increased in the T_0 treatment, due to the high increase of the shoot numbers per plant in this year. For the T_2 and T_3 treatments, the number of shoots per plant was similar to T_0 (4 shoots/plant), but the number of shoot per m^2 was extremely low due to extremely low plant population.

Concerning the final plant height, a considerable differentiation between the treatments was observed in both growing periods. The plants produced by the rhizomes were considerably higher (325 cm for T_0, 391 cm for T_1) than the plants produced by stems and stem cuttings (162 cm for T_2, 166 cm for T_3 and 154 cm for T_4) in the first year. In addition, the plants produced by stems and stem cuttings were much thinner (8-11mm basal shoot diameter) than the respective ones from rhizomes (17-18mm).

Throughout the second growing period (1998), an extreme increase was recorded regarding the most of the growth characteristics, especially for the plants deriving from stems and stem cuttings. More than 30 shoots per planted propagule were measured, for T_2, T_3 and T_4 treatments, while for the T_0 and T_1 only 8 and 10 respectively were produced. In contrast to the number of shoots per plant, a higher number of shoots was produced per square meter in the T_0 and T_1 treatments (20 and 13, respectively), than in the T_2, T_3 and T_4 treatments (3, 3 and 8 shoots/m^2, respectively).

The plants were higher at the end of the second year in comparison with the respective height in the establishment year. The plants produced by rhizomes increased their height by 12-20%, while the height of plants produced by stems and stem cuttings was increased by 102 and 165 – 188% respectively. The final height ranged from 312cm (T_4) to 478cm (T_3). The basal shoot diameter was slightly decreased in T_0 and T_1, while it was dramatically increased (75 – 87%) in the other three treatments. The basal shoot diameter ranged from 14 mm (T_4) to 20 mm (T_2 and T_3 treatments).

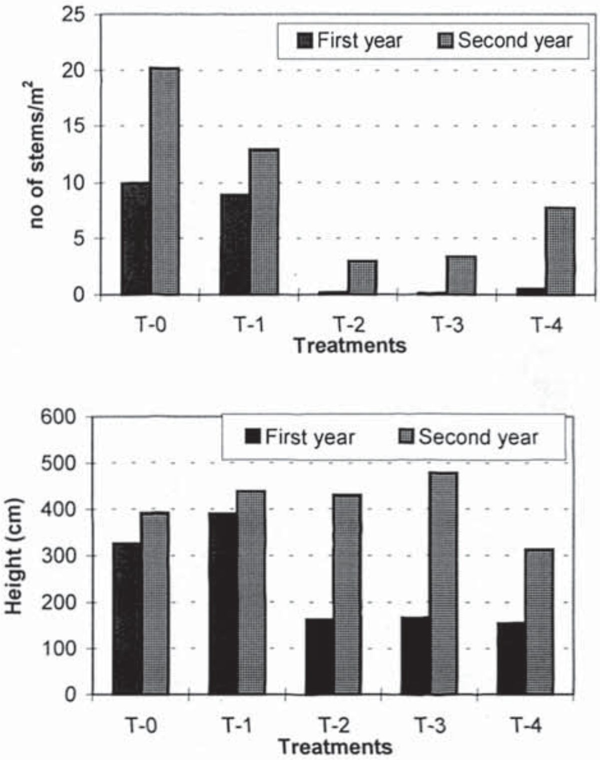

Figure 5.4.2a: Shoot numbers per m^2 (up) and height (down) for the five treatments at the end of the two growing periods.

The evolution of height for the five treatments during the second growing period is presented in Figure 4. Sigmoid curves were fitted for each treatment. The estimated equations for the T_0, T_1, T_2, T_3 and T_4 treatments, respectively, were:

Apparently, the well-established plants that derived from stems and stem cuttings, had benefited of the absence of competition for nutrients and light and produced very high and thick shoots in the second growing period.

Biomass yields: In the establishment year, final harvest was carried out only in the T_0 and T_1 treatments due to the very poor establishment of the other treatments. Total dry matter in T_0

and T_1 treatments was similar, 12 and 13 t/ha, respectively. Stem fraction was the 66.7 and 69.2% of the total dry matter T_0 and T_1, respectively.

In the second growing period T_1 treatment produced higher total dry matter yields (22 t/ha) than T_0 (16 t/ha), mainly due to the increase of the number of shoots produced by each plant. The treatments T_2, T_3 and T_4 were less productive (8, 8 and 13t/ha of dry matter, respectively). Fresh and dry matter yields and yields components, for both growing periods, are presented in Table 5.4.2b and Figure 5.4.2c.

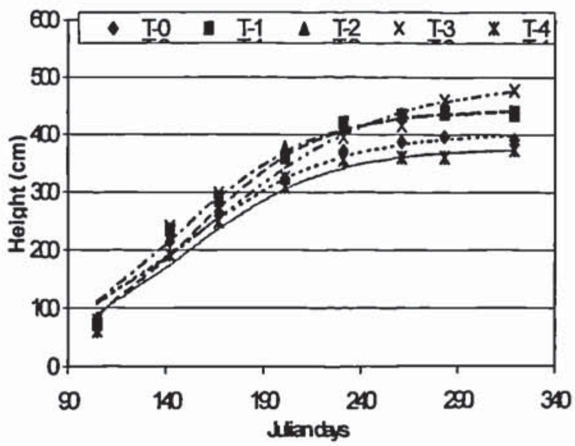

Figure 5.4.2b: Evolution of height for the five treatments during the second growing period.

Table 5.4.2b: Fresh biomass and dry matter yields and yield components for the five treatments at the end of the first and second growing periods.

		T_0	T_1	T_2	T_3	T_4
SFM	1st	17	20	-	-	-
(t/ha)	2nd	30	44	15	14	27
LFM	1st	7	6	-	-	-
(t/ha)	2nd	3	3	0.7	0.4	1.3
TFM	1st	24	26	-	-	-
(t/ha)	2nd	33	46	16	15	28
SDM	1st	8	9	-	-	-
(t/ha)	2nd	15	21	7	8	12
LDM	1st	4	4	-	-	-
(t/ha)	2nd	0.2	1.3	0.3	0.2	0.8
TDM	1st	12	13	-	-	-
(t/ha)	2nd	16	22	8	8	13
Moisture	1st	50	52	-	-	-
(% d.m.)	2nd	50	52	52	48	54

S: Stem, L: Leaf, T: Total, F: Fresh, D: Dry, M: Matter

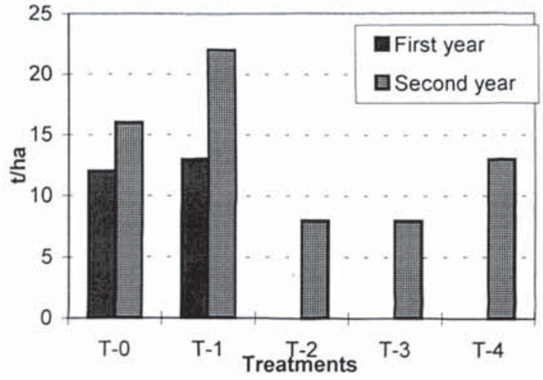

Figure 5.4.2c: Fresh biomass (up) and dry matter yields (down) for the five treatments at the end of the first and second growing periods.

Other biomass productivity experiments

In several other productivity experiments that have been conducted so far, the final plant height of two years old plants was 5.80 m while fresh and dry matter biomass yields for autumn cuttings were 58.56 t/ha and 31.47 t/ha, respectively (Mardikis, 2000). Calorific value of 17.1 MJ/kg was determined and based on this value energy potential up to 12.9 toe/ha/year was estimated.

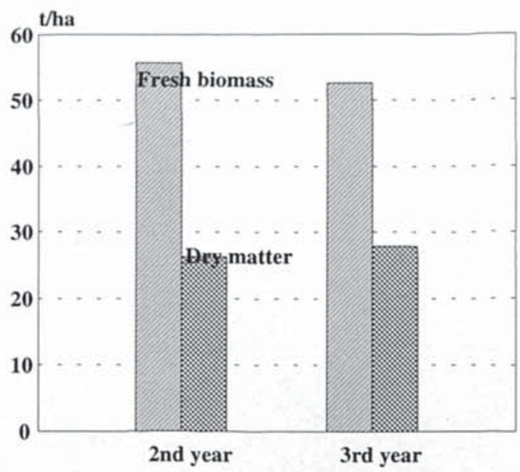

Figure 5.4.2d Yields of giant reed at the 2^{nd} and 3^{rd} growing period. (Panoutsou, 1997b)

It is notable that these high yields were obtained from unimproved wild populations and conventional cultural methods.

This indicates the great biomass potentiality of this energy crop for the future.

5.5 CONCLUSIONS

In conclusion, both cardoon and giant reed show very good potential as energy crops, from environmental and agricultural point of view. Experimental results conducted in selected agricultural areas in Greece presented yields up to 25 tonnes dry biomass per hectare.

In addition, both plants were proved highly resistant to pests and diseases and competed effectively against weeds and pests. As a result, the annual inputs after establishment are very low. As for irrigation cardoon is a non irrigated crop with few water requirements during the establishment stage while giant reed gave good yielding potential, up to 31 dry t/ha with an irrigation of approximately 400mm per year (which is similar to other conventional crops in the region such as corn).

In addition, both crops, via their robust form and perennial nature, with aerial inputs providing ground cover during winter, both plants offer protection against soil erosion.

In the following chapter, a thorough analysis of the economic, the agricultural and the energy sectors will be presented at national, regional and local level. Based on that the context under which the under study bioenergy scheme will operate will be defined.

CHAPTER 6. SITE SELECTION

Site selection is considered a critical factor for the implementation of bioenergy schemes. The main parameters affecting the final choice are:

- Availability of raw material, or good potential for energy crops.
- Sufficient energy needs so that the market for the final product is evident.
- Social aspects, which can be improved by bioenergy deployment such as unemployment, unstable incomes in the farming community, lack of rural development.

The site selected for this thesis, Rhodope, northern Greece, presents most of the above characteristics (Panoutsou 1998b, e, Kypriotis 2000).

However, prior to the final selection, a thorough analysis was conducted of the main parameters affecting bioenergy development namely economy, agriculture and energy in order to set the framework under which a potential bioenergy scheme would operate.

This analysis firstly set the economic scene for Greece and then the situation in the Prefecture of East Macedonia and Thrace (Ref. E.M&Th) where Rhodope (the selected site) belongs. This enabled a comparison of this region's performance with the rest of Greece. It also helped explain why E.M&Th was chosen for the study. Rhodope (one of the five nomoi[1] of E.M&Th) is the case study region and as such, is the main subject of this regional review. Rhodope was chosen because of its potential for the development of bio-energy schemes (Liapis, 1993, Kypriotis 2000, Panoutsou, 2000).

The analysis required collection of data about the following sectors:

- Population statistics
- Labour force
- Industrial activity

[1] Nomos (plural: nomoi) is the administrative geographical division of Greece. There 51 nomoi in the country.

- Energy sector

Population statistics

Details about the resident population of the chosen region and of the country were collected. In addition to the total population statistics, information was collected on how the population is broken down by age- known as age distribution. From this it can be seen whether the selected region has a young population or an ageing population. A rough percentage breakdown by age groups for both the region and nationally was formed.

The migratory trends of the population were also presented. This means the age group and gender of population that is more likely to move around the country. In this way the depopulation state can be assessed over a given time period and what age group and which gender left the region.

Labour force participation

The proportion of residents of the region registered as economically active, self-employed or unemployed is presented. This is important to make assessment on the labour resource both in the region, but also within the country as a whole.

Industrial activity

The key industrial sectors, which are examined, are manufacturing, construction and services and the agriculture sector. A breakdown of their economic activity in monetary and percentage terms is presented for both the selected region and the country.

Agriculture sector

Since the agriculture sector will be the supplier (and in some cases the transporter) of the biomass feedstock, it will be a major sector affected by the commercial deployment of a bioenergy scheme. To assess the impact on the agriculture sector data on the number, size distribution and type of farms in the selected region are required.

Energy sector

In addition to the agriculture sector, the energy sector will be the other main area most affected by the development of a bioenergy scheme. To assess how the bioenergy scheme will fit into the energy sector of the selected region, information on the distribution of fuel sources, distribution of end users and energy consumption by sector is presented at national, regional and local level.

6.1 NATIONAL LEVEL ANALYSIS

The current economic situation

During the last four years the Greek economy has shown significant signs of recovery, while the central goals of the revised Convergence Program as already mentioned, were mostly achieved. This progress in the macroeconomic indices was also evident during the current year and with only one-month to go, estimates can be made according to the latest available data.

Table 6.1.1 Basic Macroeconomic Aggregates (% yearly changes)

	1994	1995	1996	1997	1998	1999
GDP	1.7	1.8	2.6	3.5	3.7	4.1
Investment	- 1.8	6.8	9.4	11.7	13.2	14.4
Inflation rate	10.9	8.9	8.2	5.6	3.7	2.5
Unemployment rate	9.6	10	10.3	10	9.7	9.2
General Government Deficit (as % of GDP)	10.3	9.8	7.6	4.2	2.4	2.1
General Government Primary Surplus (as % of GDP)	3.9	3.3	4.4	5.6	6.4	6.1
General Government Gross Dept (as % of GDP)	109.6	111.3	112.6	109.9	107	101
Average Depreciation	7.1	3.5	1.1	1.7	0	0
Average interest rate of Treasury Bills	19	15.5	12.9	10.2	8.9	

Source: 1994-96: NSSG, 1997-99: Estimates and Forecasts of the Directorate of Macroeconomic Analysis

Economic activity: As it concerns the economic activity, for 1997, GDP growth reached 3.5% supported by high private and public capital spending. In 1998 and 1999 GDP growth rates presented similarly increasing trend reaching up to 3.7% and 4.1%, respectively.

One of the main supporting factors for the acceleration of growth in these years is the significant decline in interest rates. Interest rates of newly issued treasury bills in the end of 1999 were 4% compared to 9.5% of September 1997, 11.2% in December 1996 and 20.3% in December 1993.

Labour force Participation: Seasonally adjusted unemployment in Greece at the end of 1999 was 523,400 or 11.73 % of the workforce (National Statistics on employment and unemployment, 2000).

Despite strong output growth, unemployment has risen sharply in 1998 and 1999. Indeed, the labour force grew faster than employment mainly reflecting the rising participation of women in the labour market and the reversal of the 'discouraged worker effect' of earlier years.

Further complicating the analysis of employment/ unemployment data is the existence of many illegal workers in Greece. Since the early 1990s, a large number of immigrants from the former communist block have entered the country - an estimated 500 to 700 thousand persons, representing over 10% of the labour force.

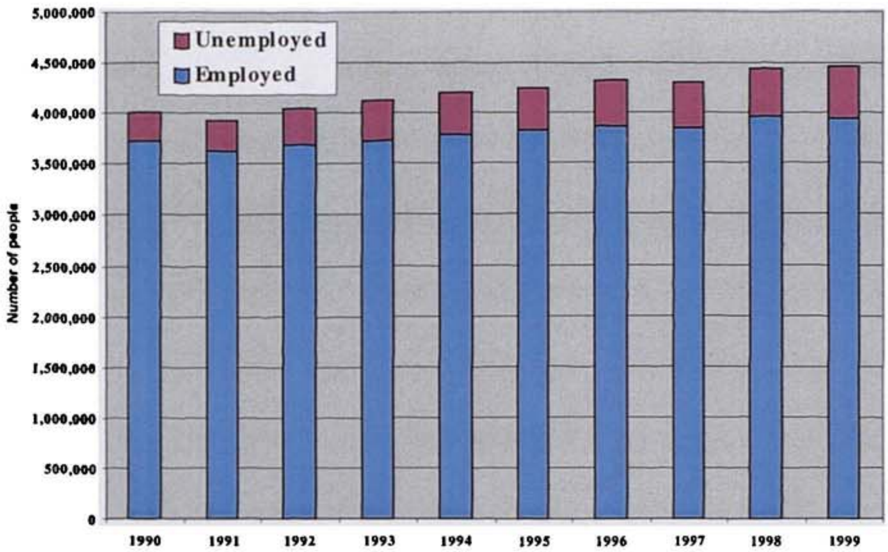

Figure 6.1.1: Employed and unemployed in Greek labour force

This large number of immigrants, most of whom work without permits and for wages which are below the minimum wage, have helped keep down growth in labour costs in Greece during the past several years, thus providing a boost to economic activity, particularly in the construction and agriculture sectors. In 1998, the Government introduced a registration programme for these workers, and through June 1998 about 375 thousand illegal workers had registered with the labour authorities. As a result of the 1998 legalisation programme for a large number of illegal immigrants up till the April 1999 deadline 373,000 residence permits ('white cards') had been requested and 225,000 immigrants had also asked for an employment permit ('green card'), with 167,000 having been approved up till mid-2000 and 3,000 having been turned down.

In mid-2000, 55,000 requests were still under examination. Legalised immigrants do not seem to have displaced Greek workers, but have rather helped prevent or alleviate bottlenecks in certain geographical areas or sectors (agriculture, construction, household services) thus contributing to both GDP growth and to labour cost restraint.

As overall employment declined somewhat in 1999, following the sharp increase in 1998, the unemployment rate rose to 12% in 1999 (11.7% for the second quarter of 1999 on the basis of the Labour Force Survey), and was the second highest in the European Union.

Another important aspect of unemployment trends is the analysis by sectors.

- The primary sector (agriculture and mining) presented a dramatic decrease from 40.8% of the total labour force in 1970, to 30.3 % in 1980, 23.9% in 1990 and 17 % in 1999.
- The industry and energy sectors, presented almost 5% increase in the decade 1970-1980, then a 2.5% decrease till 1992 (27 %), while from 1993 there is continuous decline reaching to 22.9 % (1998, 1999).
- On the contrary, in the services sector, there is a constantly rising trend, which leads from 34.2 % in 1970 to 51 % in 1992 and to 60.1 % in 1999.

Also of note is the analysis of unemployment by sex. Women participation in labour force has risen from 38.9% in 1998 to 39.2% in 1999. However, unemployed women still represent 61.4% of the total unemployed (1999) while the respective figure for men was 17.9%.

Table 6.1.2: Labour force per sector (as % of total), during 1970, 1980, 1990, 1992 – 1995 and 1998,1999.

	1970	1980	1990	1992	1993	1994	1995	1998	1999
Agriculture & Mining	40.8	30.3	23.9	21.9	21.3	20.8	20.4	17.8	17
Industry & Energy	25	30.2	27.7	27.1	24.2	23.6	23.2	22.9	22.9
Services	34.2	39.5	48.3	51	54.5	55.5	56.4	59.2	60.1

Finally, long term unemployment (more than 12 months) accounts for the highest percentage in unemployed reaching to 58.5% of the total unemployed.

Consumer expenditure: Results of the Greek private final consumption expenditure for 1995 showed that almost 37% of the consumption expenditure is on the *food, beverages and* *tobacco sector*, while 14% is on *gross rent, fuel and power sector* and 13.5% on *transport and communication.*

Table 6.1.3: Private Final Consumption Expenditure by object in million GRD (1995).

Commodity or Service	Greece
Furniture, Furnishings and Household Equipment	1,167,282
Gross Rent, Fuel, and Power	2,213,670
Food, Beverages and Tobacco	5,785,170
Clothing and Footwear	1,018,040
Medical care and Health expenses	768,848
Transport and Communication	2,134,836
Recreation, Entertainment, Education and Culture	852,776
Miscellaneous Goods and Services	1,873,096
ALL EXPENDITURE	15,813,718

Energy Sector: From the figure below, it is evident that the highest percentage of energy consumption in Greece is on the domestic sector, which presents a steadily increasing trend.
The stated-owned Public Power Corporation (DEH) dominates the electricity market. DEH is vertically integrated in all aspects of the electricity sector- generation, transmission, distribution and supply- as well as lignite mining. Greece liberalised the electricity market in February 2001, in accordance with the relevant EU Directive.
Though the provisions of the 1999 law are a step towards opening the electricity sector, effective competition is likely to remain limited. The measures leave DEH with significant monopoly power, as the corporation remains the exclusive supplier of the more profitable, captive small consumer market. At the same time, the sectors structure, in combination with the existing regulatory framework and the relative isolation of the Greek network, both geographically and technically, impede market entry. Competition from imports, for instance, is virtually precluded, due to demanding conditions on supply authorisations, while competition through domestic entry is likely to develop only very slowly. The key constraints for electricity companies include access to transmission and distribution, and price discrimination in favour of large industrial customers. To foster the creation of competing generating companies a more radical reform of the sector will be required, involving the splitting of DEH into several independent and competing generation companies. Under current plans, partial privatisation is expected to improve DEH's efficiency.

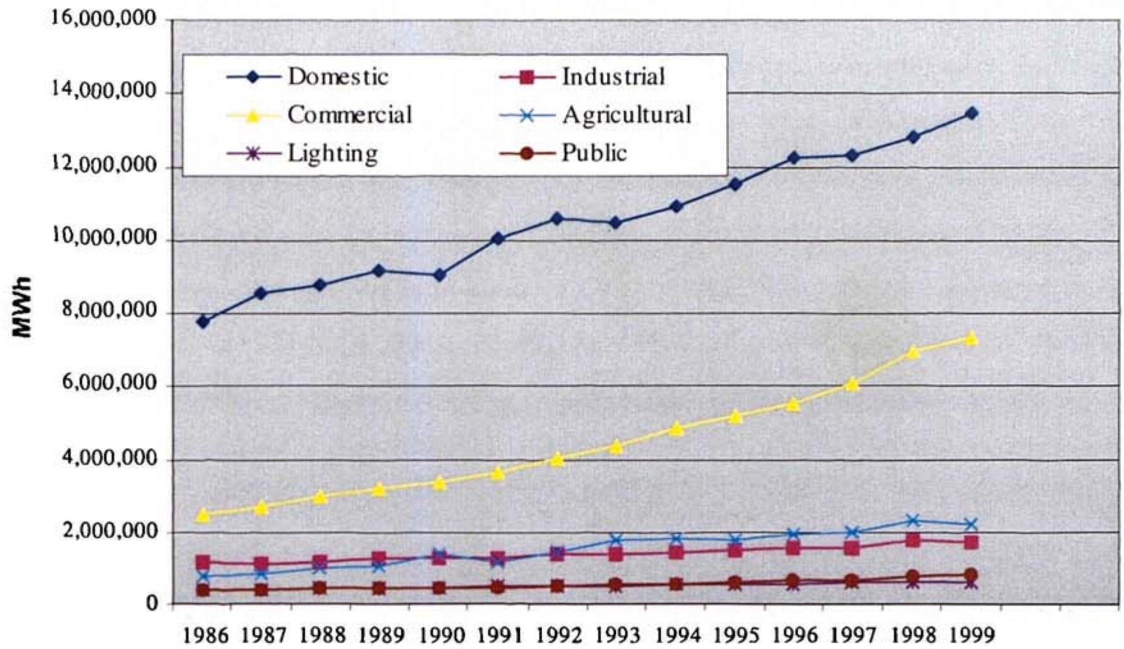

Figure 6.1.2: Sold electricity (in MWh) per sector in Greece (1986 - 1999). DEH, 2000.

Agriculture: Agriculture still remains an important sector of economic activity in Greece, accounting for 7.2% of GDP and 17% of civilian employment in 1999. Agriculture's contribution to GDP has been declining, while agricultural employment has shrunk by 5 percentage points as a share of total employment since the early 1990s. Agriculture has remained the most heavily- subsidised sector. In 1999, it received budgetary transfers estimated at 51% of the sectors value added (3.7% of GDP). Moreover, the amount of support has increased since the early 1990s. Nearly 75% of total support (2.8% of GDP) comes from the EU's Common Agricultural Policy transfer schemes. Cotton, wheat, olive oil and tobacco are the most heavily protected products, attracting nearly 80% of total budgetary transfers. The rest of CAP transfers aim at the restructuring of production under the EAGGF Guidance Fund. Most of the national budgetary transfers (around two-thirds) are earmarked for investment, including improvements of rural infrastructure and matching grants for farm modernisation programmes eligible for EU support. A significant part of national transfers also consists of support to young farmers, early retirement, and preservation of the countryside. In addition to such direct budgetary transfers, substantial indirect support comes from national sources to fund a non-contributory scheme for farmers' pensions.

The sector suffers from structural weaknesses that are reflected in poor international competitiveness. Structural impediments to enhance productivity are mostly due to the large number of small inefficient farms, with the average farm size being just 25% of the EU average.

Agriculture has also become very intensive with a heavy use of fertilisers and pesticides, which has led to a levelling of yields, a declining quality of farmland, and signs of environmental damage (Ministry of Agriculture, 1999). In addition, easy access to water resources (through, for instance, unlicensed artesian wells) and low prices has encouraged waste of water resources.

As agriculture accounts for 85% of the country's water consumption, water shortages are looming.

Long-standing structural weaknesses are exacerbated by distortions arising from the EU's CAP. For example, generous support granted to cotton and wheat cultivation sustains strong demand for well-irrigated farmland, thus boosting land prices and rentals. The latter can reach up to 50% of a farmer's income.

At this point it should be mentioned that cotton and wheat are the conventional crops that are comparatively evaluated with energy crops under economic terms in the selected region (see Chapter seven).

6.2 PREFECTURE LEVEL ANALYSIS: EAST MACEDONIA & THRACE

Greece is administratively divided in seven prefectures. The region of Rhodope belongs to the prefecture of East Macedonia and Thrace. The Eastern Macedonia and Thrace (EM&Th) Region covers the north-eastern part of Greece, with boundaries to the north with Bulgaria and eastwards with Turkey. Its area of 14,514 sq. km is divided into five prefectures: Kavala, Drama, Xanthi, Rhodope and Evros. Total population is 570,496 (Census 1991).

Rhodope has been chosen because of its potential for the development of bioenergy schemes and information on East Macedonia and Thrace as a whole has been provided to enable a context in which the selected region operates to be clearly seen. It is one of the five nomoi of the prefecture, in the northern part of Greece.

East Macedonia and Thrace has a varied topography consisting of mountains, valleys, and several coastal plains. For this research, Rhodope has been chosen as the basic unit of analysis because the agricultural sector represents a high percentage (30%) of the GDP, which is 98 million GRD. Secondly, it is geographically a representative area of the prefecture.

Agriculture remains an important economic factor for the region, employing 42.8% of the working population.

The manufacturing sector has a high level concentration of firms in clothing, textiles, food packaging, wood, paper and metal processing. A significant peculiarity of the EM&Th Region is that it is the only oil-producing Mediterranean region in the EU. Offshore oil wells are located near the island of Thassos. The region counts the highest level of unemployment in Greece.

The particularly favourable complex of development incentives in EM&Th, supported by the Community Support Framework and the Regional Development Plans, offer significant investment opportunities mainly for the establishment of new technology based firms, high tech products and tourism.

Regional GDP: During the last 25 years, statistical data for Eastern Macedonia and Thrace show a continuous growth of the GDP and employment in the sectors of manufacturing, construction, transport, banking, and other services.

During the period 1991-1995, the region suffered from de-industrialisation, in terms of number of firms (8,7%) and employment. The decline was inverted in 1995, when started the implementation of the first investment plans. The country as a whole followed a similar decline and the relative figures were more intense (-22,1%).

Table 6.2.1: East Macedonia and Thrace GDP by industrial sector in 1986, 1988, 1991, 1993 and 1994 (in million GRD and as % of total).

Sector	1986	1988	1991	1993	1994
Agriculture, Forestry and Fishing	73,262	93,672	151,004	155,974	187,619
	(29.5)	(29)	(28.1)	(23.1)	(24.9)
Mining and Quarrying	18,577	19,470	38,677	42,616	45,892
	(7.5)	(6)	(7.2)	(6.3)	(6.1)
Manufacturing	37,343	46,470	73,295	96,371	103,008
	(15)	(14.5)	(13.6)	(14.3)	(13.7)
Electricity, Gas and Water	3,973	4,666	5,849	6,425	6,933
	(1.6)	(1.5)	(1)	(1)	(0.9)
Construction	26,417	32,288	56,802	68,549	73,142
	(10.6)	(10)	(10.6)	(10)	(9.7)
Services	89,167	124,741	212,105	305,653	337,610
	(35.8)	(39)	(39.5)	(45.2)	(44.7)
TOTAL	248,739	321,307	537,372	675,588	754,264

Agriculture: The prefecture has a large number of unique bio-habitats and is characterised as one of the major water vessels of the country. It produces a series of agricultural products, such as wheat, potatoes, melons and cucumbers. Based on the agricultural products of the area a significant agro-industry has been developed. The degree of mechanised agriculture is higher than the country's average, while the average farming size is smaller than 5 hectares.

Industry: During the last 20 years a new industrial space has been created, including new firms and new production practices. All prefectures of Eastern Macedonia and Thrace present an increase of industrial employment, up to 47,2% for the decade 1978-88. The geographical concentration of investments led to the creation of clusters: food industry in Rhodope and Evros, textiles industry in Xanthi and Rhodope, and clothing in Rhodope and Evros.

Main branches in the big industry, according to the number of firms, are: clothes, foods and beverages, non-metallic ores, textiles, furniture, elastics-plastics, wood and cork. Accordingly, the branches of food-beverages, textiles and clothing dominate SMEs.

Services: The tertiary sector is a significant welfare resource for the region. On stable prices (1970), the production of the tertiary sector was increased by 17,4%, almost equal to the half of the respective national change (30,3%). This increase was not distributed equally between the five prefectures of the region. The structure of the tertiary sector is similar to that of the whole country: the commercial activities dominate, followed by the transport and communications.

Dynamic activities in the tertiary sector are banking, insurance, land sub-contracting services, and public administration, followed by health services and education.

Employment – Unemployment: According to the data of OAED (Organisation for the Employment of Labour Force), the unemployment in the Region of EM&Th has increased from 9.2% in 1992 to 12.8 % in 1999. Totally, there are 31,400 unemployed; 51% of them are looking for a job for longer than 12 months, while the 46, 27% have lost their jobs during the last year.

Almost 45% of unemployment consists of young labour force looking for a job for the first time, while long-term unemployment concerns mainly women and young people.

Table 6.2.2: Labour force in the East Macedonia and Thrace prefecture during 1992 - 1999.

	1992	1993	1994	1995	1996	1997	1998	1999
Labour force	254,300	262,700	254,500	258,700	268,800	254,500	242,500	245,400
Employed	234,800	242,100	233,500	232,200	240,600	230,500	220,800	214,000
Unemployed	19,500	20,600	21,000	26,600	28,200	24,000	21,800	31,400
Unemployed (%)	7.7	7.8	8.3	10.3	10.5	9.4	9.0	12.8

Energy Sector: The domestic sector presents the higher consumption in the prefecture of East Macedonia and Thrace. The same increasing trend exists for both the agricultural and the commercial sector but in a much lower level.

The annual electricity consumption in the prefecture for 1996 was 5,600 GWh (3,000 GWh in the domestic sector, 530 GWh in the industrial and 520 GWh in the agricultural). The respective figures for the country were: 12,000 GWh in the residential sector, 12,000 GWh in the industrial and 2,000 GWh in the agricultural. In figure 5 the energy consumption as percentage for each sector is presented both for the East Macedonia and Thrace prefecture.

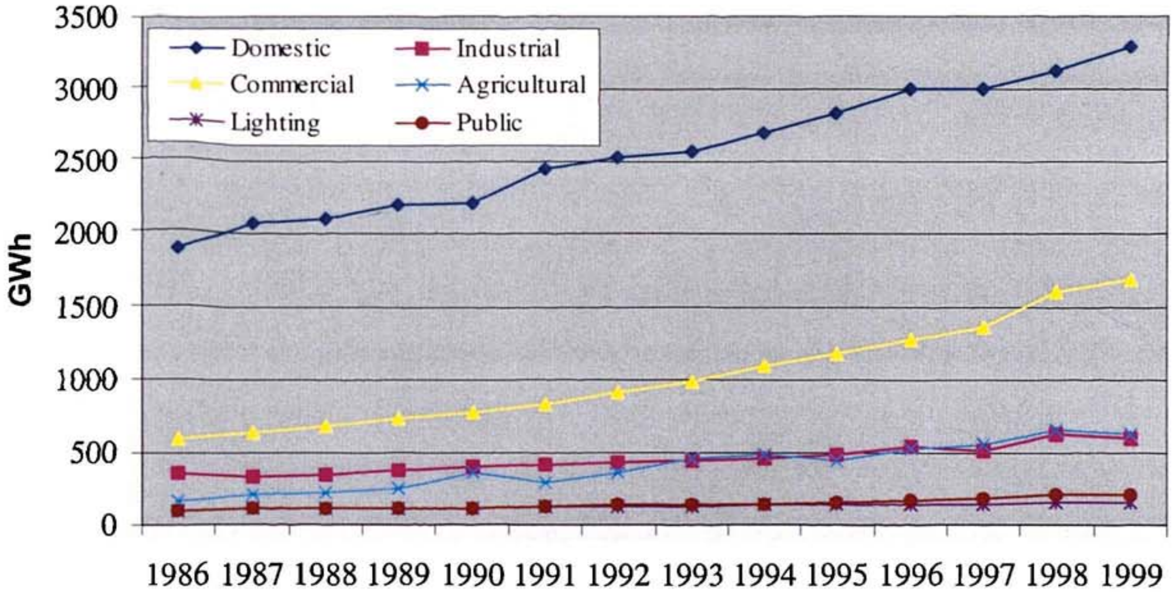

Figure 6.2.1: Sold electricity (in GWh) in the East Macedonia and Thrace prefecture (1986 -

1999). DEH, 2000.

6.3 BIOENERGY IMPLEMENTATION IN RHODOPE, NORTHERN GREECE

The selected region is Rhodope (northern Greece) with its capital town Komotini.

Aston University

Illustration removed for copyright restrictions

Map 1: Geomorphology of the Greek territory

It is situated in the northeast of Greece, in the middle of Thrace, bounded by the Thracian Sea to the south, the prefecture of Xanthi to the west, the Greek-Bulgarian frontier to the north and the prefecture of Evros to the east. It had a population of 108,000 in 1991 (Census, 1991) and covers an area of around 2,500 sq. km, approx. 2% of the territory of Greece. Of this total area, 966 sq. km are lowlands, 814 sq. km are semi-mountainous, and 763 sq. km are mountainous highlands (Lapis A., 1993).

Rhodope has two climatic zones, Mediterranean in the south (hot summer and mild winter) and continental in the north (warm summer and very cold winter with snow and low temperatures reaching minus 10^0 C), with the Rhodope Mountains marking the division between them. The annual temperature varies widely, and rainfall is very unequally distributed over the year, two thirds of the total annual precipitation falling in the first and last quarters and one third in spring and summer. The prevailing north and northeasterly winds cause very low temperatures (down to -10^0 C) in the winter.

This region presents certain characteristics (Kypriotis, 2000), which favour the potential development of energy crop bioenergy schemes:

- agriculture is intense both in terms of land use and active population,
- the agricultural sector is from the most important economic activities of the region whilst facing economic difficulties (Commercial and Industrial Service of Rhodope, 2001),
- the unemployment rate is higher than the national average, especially among the young people (National Statistics on Employment and Unemployment, 2000), and
- the climatic conditions favour the use of heat produced in a bioenergy scheme (Panoutsou, 1998e, Panoutsou, 2000a).

Table 6.3.1: Population by age and sex in Rhodope (Census of population, 1991)

Age group	Male (numbers)	% Male	Female (numbers)	% Female	Total Persons	% Persons
0 – 14	9,925	20.8	9,642	18.9	19,567	19.8
15 – 24	6,204	13	6,923	13.6	13,127	13.3
25 –34	6,575	13.8	6,849	13.4	13,424	13.6
35 – 44	6,481	13.7	6,772	13.3	13,253	13.4
45 – 54	6,711	14.1	7,082	13.9	13,793	14
55 – 64	6,800	14.2	6,905	13.5	13,705	13.9
65 +	5,058	10.6	6,819	13.4	11,877	12
All ages	47,754	100	50,992	100	98,746	100

Rhodope has a population of 98,746 people (47,754 males and 50,992 females), which is 18 % of the population of East Macedonia and Thrace prefecture, with an average population density of 2.6persons/ km^2. Almost 33 % of Rhodope's population is aged under 25, thus having a relatively young population.

The main industrial activities in Rhodope are agriculture, food processing, and other services. Komotini town is the local commercial and administrative centre as well as the key location for the industry. The region has four cotton ginning industries which exploit more than 70% of the cotton produced in the prefecture and it also contains a number of food industries, two wood processing industries and a paper industry.

Economic Situation: Agriculture and services are the main components of the GDP in Rhodope for the last nine years (1986 -1994).

Table 6.3.2: Rhodope GDP (total and by sector) for the period 1990-1999(as % of total and in million GRD).

Year	GDP	Agriculture		Industry		Services	
	million GRD	%	million GRD	%	million GRD	%	million GRD
1986	39381	47.2	18,553	15.8	6231	37	14599
1990	92829	33	30634	15	13924	52	48271
1991	116102	33	38314	16	18576	51	59212
1992	131691	27	35557	18	23704	55	72430
1993	145923	26	37940	17	24807	57	83176
1994	169715	26	44126	18	30549	56	95040
1995	205490	28	57537	18	36988	54	110965
1996	228454	22	50260	23	52544	55	125650
1997	257435	20	51487	26	66933	54	139015
1998	278437	20	55687	27	75178	53	147572
1999	297115	20	59423	27	80221	53	157471

However, Table 6.3.2 indicates some interesting figures about the development trends in the region. The share of the agricultural sector to the GDP was dramatically reduced during the aforementioned period from 47.2 % in 1986 to 20 % in 1999. The services sector presented an increasing trend reaching to 53 % in 1999 from 37 % in 1986.

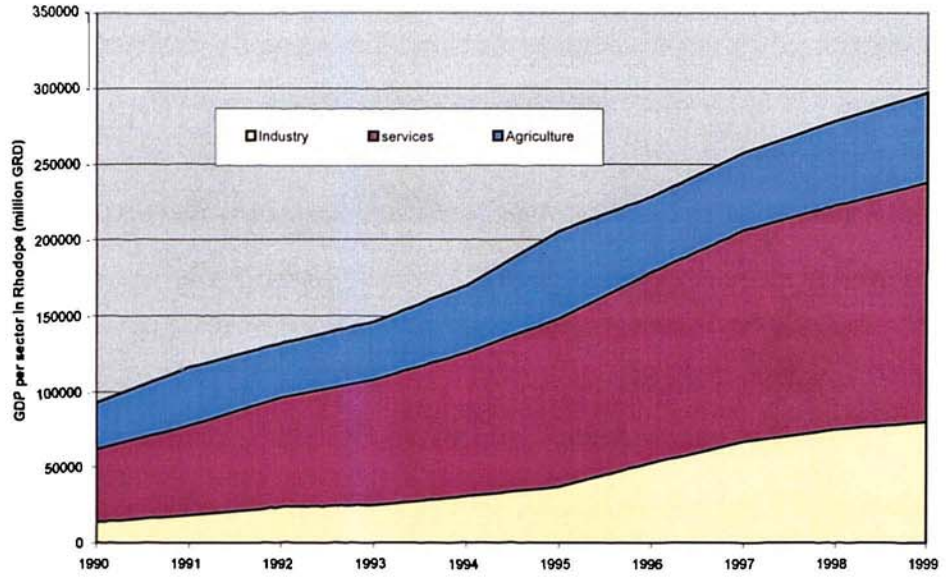

Figure 6.3.1 GDP growth per sector in Rhodope.

Table 6.3.3: Economically active population per sector in Rhodope (Census 1991).

Sector	Male	Female	Total
Agriculture	16,130	7,640	23,770
Minerals and chemicals	39	2	41
Engineering	2,125	953	3,078
Energy	96	6	102
Construction	1,369	14	1,383
Commercial	2,907	897	3,804
Transport	1,079	67	1,146
Finance	468	352	820
Other services	3,520	2020	5,540
No profession	597	312	909
Total	28,330	12,263	40,593

Employment: In 1991, 59% of the economically active population in Rhodope were occupied in agriculture (57% of male employment and 62% of female). The second employer is the services sector, which accounts for 28% of all employment.

The energy sector is very small indeed. The self- employed account for 48% of all employment in Rhodope compared to the national average of 30%. It is likely that the self-employed will be concentrated in the agriculture sector mainly.

The unemployment in Rhodope was higher in the 20 - 34 years group accounting for 58 of the total figures in the region. This means that there is spare labour for the development of bioenergy schemes.

Table 6.3.4: Unemployment numbers by age group and sex in Rhodope.

	< 20	20-34 years	35-54 years	55+ years	Total
Male	321	824	326	60	1531
Female	186	574	123	11	894
Total	507	1398	449	71	2425

Migratory Trends: Relatively high migratory trends are presented in the region, especially in the young people from 15 - 34 years old.

Table 6.3.5: Migratory Trends

Age Group	Male (%)	Female (%)
0-14	17.5	20.92
15-24	36.09	39.42
25-34	22.91	17.92
35-44	11.31	8.21
44-54	5.8	5.66
55-64	3.54	3.82
65+	2.85	4.05

Agriculture:

Conventional crops: The total cultivated land area of Rhodope is 86,000 ha. From this 34,000 ha (43% of the total cultivated land) are cultivated with cereals, 30,000 ha (34%) with industrial crops, 9,000 ha are vines and the rest are cultivated with several kinds of vegetables and fruit trees.

The main differences and similarities between the national and local cropping systems are clearly observed in figure 6.3.1. Cereals occupy a similar percentage of the cultivated land area (34% in Greece, 43% in Rhodope), dominating in the agricultural system. Similarities also exist in vegetables, which occupy 3% of the cultivated area both at national and at local level.

However, sharp differences exist in cotton (9% in Greece, 34% in Rhodope), in trees (24% in Greece, 1.5% in Rhodope) and in vineyards (3.6% in Greece, 0.14% in Rhodope).

Based on the aforementioned statistical data Rhodope can be characterized a typical Greek region in terms of cereals but it presents quite a large variation in terms of other crops, compared to the national level.

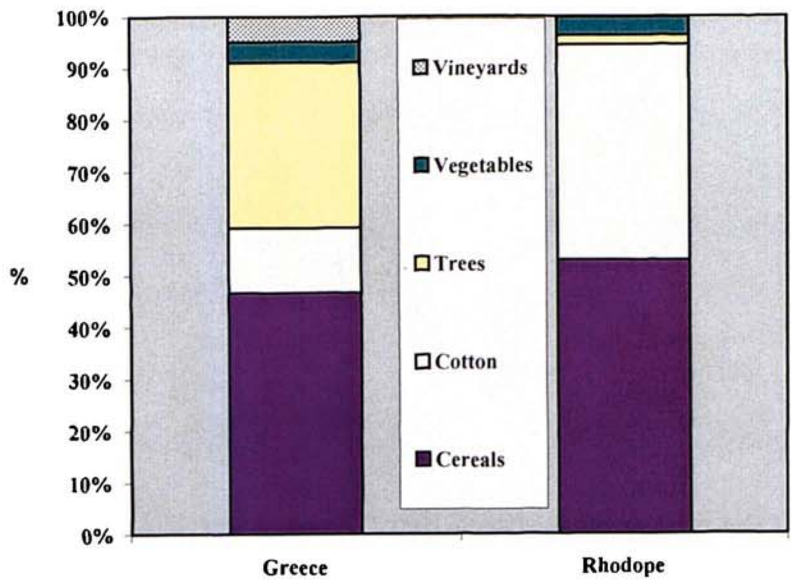

Figure 6.3.2: Crops cultivated area (%) at national and at regional level (nomos Rhodope).

The most important crops in the region are cereals (durum and soft wheat and barley). Therefore, the comparative economic analysis for the possible insertion of energy crops in the region is going to be based on the net incomes obtained by farmers from those crops.

Farm size: The total number of farms in the county is 16,300. However, it must be stressed out that 67% of them are less than 5 ha, 23 % are up to 10 ha and only 10 % are larger than 10 ha (Table 6.3.6).

Table 6.3.6. Farm size in Greece and in Rhodope.

Size of farm holdings	Farms (%) Greece	Rhodope
0.1 - 0.9 ha	3	15
1 - 2.9 ha	16	28
3 - 4.9 ha	16	24
5 - 9.9 ha	25	23
>10 ha	40	10

The respective figures for Greece indicate that 40% of the farms are more than 10 ha, 25% are from 5-10 ha while the rest 35% is from 0.1-5 ha. These figures show that farming size in Rhodope is relatively smaller than the average Greek farm.

Energy: Power supply for Thrace and more specifically for Rhodope is done from the large lignite station of Ptolemaida, which is located 400 km west from the region.

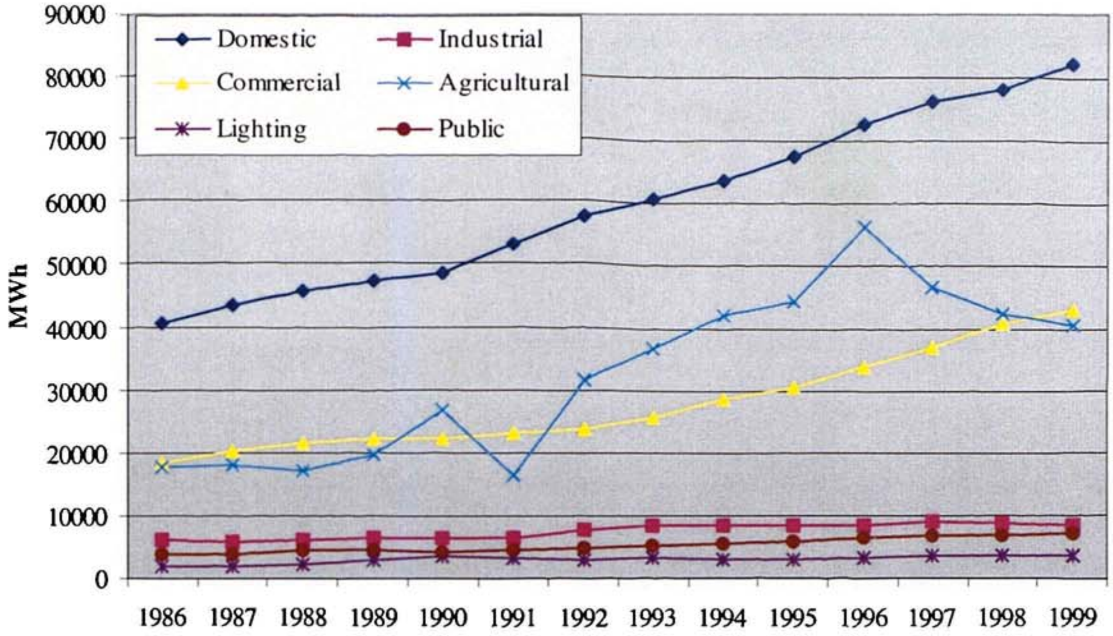

Figure 6.3.3: Sold electricity (in MWh) in Rhodope (1986 - 1999). DEH, 2000.

The annual electricity consumption in 1996 was 241 GWh (73 GWh in the residential sector, 57 GWh in the industrial and 56 GWh in the agricultural). The respective figures for the country were: 12,000 GWh in the residential sector, 12,000 GWh in the industrial and 2,000 GWh in the agricultural. In figure 6.4.2 the energy consumption as percentage for each sector is presented both for the country and the region of Rhodope.

6.4 CONCLUSIONS

An analysis was conducted at three levels, national-regional-local, for the main aspects affecting the development of a bioenergy scheme, namely economy, agriculture and energy. Rhodope, the site selected for this study presents the following features:

- In economic terms, the local GDP accounts for 0.8% of the national GDP and 15.6% of the regional GDP. During the period 1990- 1999 the local GDP presented a rapid increase and almost tripled (92,829 million GRD in 1990 and 297,115 million GRD in 1999).

  The local economy is based on agriculture, industry and services. In the first one dramatic reduction in percentage is observed during the last fifteen years (47.2% in 1986 to 20% in 1999). In real terms however, there is a steady increase from 18,553 million GRD in 1986 to 59,423 million GRD in 1999. The industry sector presented an increase both in percentage of total and in real terms reaching from 6,231 million GRD in 1986 to 80,221 million GRD in 1999. However, the highest contribution to the triplication of the local GDP is due to the services sector, which from 14,599 million GRD in 1986 reached up to 157,471 million GRD in 1999. The aforementioned figures indicate that Rhodope is currently a rapidly developing REGION where bioenergy could as well contribute towards sustainable energy production using indigenous resources.
- The energy sector at the moment is based on power supply from a 400km away lignite station while heat demand in the area is covered by diesel and wood (for the domestic sector) and natural gas for the industrial (Commercial and Industrial Service of Rhodope, 2001). We can therefore assume that the use of bioenergy for local heating applications would contribute to less fuel imports, both locally and nationally, as well as environmentally friendly energy generation.
- Concerning the agricultural sector, the local agricultural system is dominated by wheat (almost half the cultivated area) and cotton. Both crops are heavily subsidised (Ministry of

Agriculture in Greece, 2001, OECD, 2000) thus causing respective distortions in the farm income. Therefore, the introduction of energy crops could present an interesting alternative land use (Panoutsou, 2000a).

In the following chapter, the economic evidence supporting the introduction of the selected energy crops to agricultural system of Rhodope is examined comparing them with the conventional ones (wheat, barley and cotton).

CHAPTER 7. THE ECONOMICS OF ENERGY CROPS (CARDOON AND GIANT REED) PRODUCTION COMPARED TO SELECTED CEREALS AND COTTON IN RHODOPE

Energy crops introduction into regional agricultural systems strongly depends on their competitiveness with the existing crops in the area (Panoutsou, 2000a).

Farmers raise the question '*is there a guaranteed market for this product?*' immediately when new crops are suggested. It is evident that they are going to grow energy crops only if they earn an equal or a higher net income than that of the replaced conventional ones. Another vital consideration is the potential to diversify their production, e.g. supply another additional market. In the case of the energy crops under study, cardoon and giant reed, the additional market might be that of boarding material.

Based on these arguments and on the information provided in the previous chapters, the aim here is to present thorough economic analyses concerning the introduction of energy crops in the agricultural system of Rhodope.

This is accomplished by examining alternative land uses, through financial evaluation of the main conventional crops (soft, durum wheat, barley, cotton) in comparison to cardoon and giant reed, two high yielding perennial energy crops, which present promising options for energy production in the area (Panoutsou, 2000a).

Rhodope has an area of 250,000 ha. From this 76,000 ha (30%) are mountainous areas, 82,000 ha (32%) are semi-mountainous areas and 95,000 ha (38%) are plains (Panoutsou 1998a, e). The total cultivated land area is 86,000 ha while forests extend up to 85,000 ha. There are also 64,000 ha of permanent grassland.

From the total agricultural land, 41,000 ha (47% of the total cultivated land) are cultivated with cereals, 36,000 ha (41 %) with industrial crops- mainly cotton, 9,000 ha are vines and the rest are cultivated with several kinds of vegetables and fruit trees.

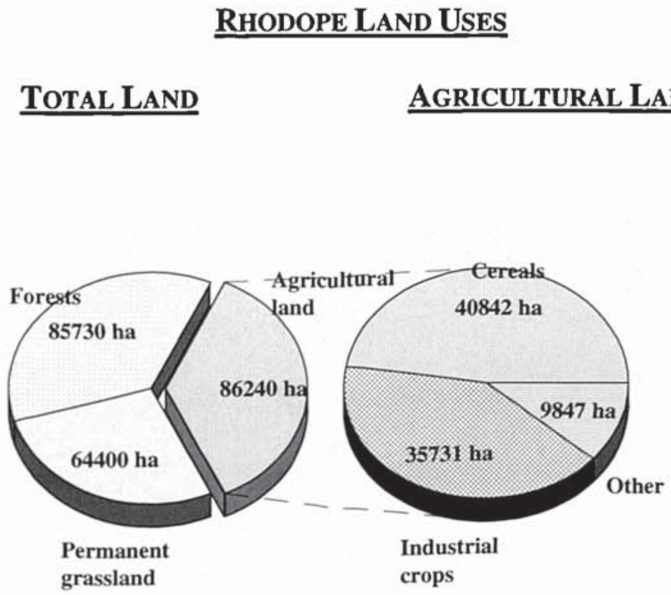

Figure 7.1 Land use in Rhodope

Most farms in the area are small mixed arable farms with an average area of 3.5 ha (National Statistical Service of Greece, 2000). The crop mix is usually cereals and cotton. Since both crops are highly subsidised, especially cotton, (Ministry of Agriculture in Greece, 2001) it is evident that the local farm income is distorted by the amount of support given and is not estimated by the real costs and revenues deriving from current market prices.

Under the existing cropping framework in the area, local farmers are facing an uncertain situation due to:

- constantly changing subsidisation policy leading to farm income instability, and
- lack of alternative cropping solutions.

These factors along with the relatively small farming area lead most of them to seek other solutions or give up farming and seek employment in other sectors (e.g. tourism).

Since most farmers base their family income on the revenues of the small mixed farms it is clear that their main aim is to maximise their profits rather than taking risk for something "new".

Taking this into account, this study investigates the relative advantages and/ or disadvantages of using energy crops as alternatives (to earn equal or higher farm incomes) to the current agricultural system by comparing the conventional crops with the new ones.

The output of this comparative analysis will assist in defining the breakeven for biomass crops along with a sensitivity analysis for the risk of the potential implementation.

In addition it will contribute to the determination of an accepted selling price for the produced feedstock so as to be competitive with the other fuels used in the region for small/medium heat generation and in other regions for lignite power generation (heavy fuel oil, gasoline, lignite, natural gas, fire wood, straw).

7.1 COST ANALYSIS OF THE MAIN CONVENTIONAL CROPS IN RHODOPE

In order to find economic evidence for potential energy crops' introduction, this section analyses the economics of conventional crops in the region, namely cereals and cotton.

Cereals, as shown in figure 7.1, are grown in almost half the cultivated land area of Rhodope region. The national figure for cereals is around 1,000,000 ha (2.5 % of the total cultivated area) (National Statistical Service of Greece, 2000).

Under current subsidisation policy in Greece, farmers growing cereals receive annual area grants of 480 Euro/ ha and 145 Euro/ ha, for durum wheat and soft wheat/ barley, respectively, according to the new revised Common Agricultural Policy.

Cotton is cultivated in 7,200 ha accounting for 8.4 % of the total cultivated area, while the respective national figure is 4,000,000 ha (10% of the total).

Biomass crops, at the moment can receive an establishment grant (50% of their establishment costs) according to EC Regulation 1251/1999 for set aside land. However, in Greece there are no such crops established since there is no market for them at present. This subsidy can be justified in the future only if circumstances are favourable in terms of market and other forces. For example, a lot of activities take place at international and European levels on carbon trading. Energy crops present important options for absorbing the released carbon thus producing alternative forms of energy.

Subsidies distort the economics of conventional and biomass crops. Therefore, in making comparisons between conventional and biomass crops, estimates of costs and profits are made with and without the subsidies. Such calculations also show the policy implications of subsidies more clearly.

In table 7.1.1 detailed estimation is provided for the income generated by durum wheat, soft wheat and barley on both irrigated and non-irrigated land (barley is cultivated only in non-irrigated land). Cultivation techniques are similar for all four.

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

Yields: Depending mainly on the climatic conditions and on the amount of irrigation in late spring, yields for cereal crops in the region are 2.5 t/ha for non-irrigated and 5 t/ha for irrigated land, respectively. Barley is only cultivated in non-irrigated land.

Cotton presents yields up to 3 t/ha.

Land rent: The amount of required irrigation affects the choice of land and its opportunity cost or rent, which in the specific case is double the non-irrigated land cost.

Variable expenses and *labour:* These cost items differ also due to the cost of water and the extra labour required for irrigation.

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 Rhodope 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. This is the case for cereals while for cotton the selling price used includes subsidies.

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.

The farm income analysis is used to evaluate the performance of the farm in a particular year. Current prices are used, and a depreciation allowance is included to account for that portion of longer-term capital investment used up in the year being considered. The analysis provides an estimate of the return to capital invested and to the farmer's labour, and this may then be compared with the return to alternative cropping patterns of to off-farm opportunities (Gittinger, 1995).

By estimating the profit before subsidies we have a clear picture of the situation without distortions.

Afterwards, we add the current amount of subsidy given and we have the farming income for the examined conventional crops. At this point we should emphasize that most farmers are used to counting this figure as their revenue and not the profit before subsidies, when discussing potential alternative crops.

It is clear from the appraisal in Table 7.1.1 that all crops are uneconomic for farmers in the region. Their net profit before subsidies is negative, with a slight difference between irrigated and non-irrigated crops (-193 EURO/ha and -229 EURO/ha). As expected the profitability of crops is modified by the addition of subsidies.

In the case of cotton the profit before subsidy is - 163 Euro/ha while the respective production costs are almost double those of the cereal crops examined.

However, the profit after subsidy is the highest among the examined crops (398 Euro/ha). The reason for this is that current EU policy framework which favours cotton cultivation (up to a certain area limit per region) by setting a high subsidy per ton (561 Euro/ton).

This subsidy for cotton is regulated by the following EC Directives: 1964/87, 1201/89 and 1554/95.

An EC top production limit is defined and in case of surpluses both target price and the minimum price for farmers are respectively reduced. For the period 2000- 2001, the top production limit for Greece is 782,000 tons.

Table 7.1.1: Income from durum wheat, soft wheat, barley and cotton [1](Euro/ha)

	D. wheat ([2]irrigated)	D. wheat (non-irrigated)	S. wheat ([2]irrigated)	S. wheat (non-irrigated)	Barley	Cotton
Cultivated Area (ha)	**19,093**		**13,203**		**4,751**	**7,200**
Yields (t/ha)	5	2.5	5	2.5	2.5	3
Selling price (Euro/ton)	162	162	162	162	162	440
Gross income (GI)	*810*	*405*	*810*	*405*	*405*	*1,320*
- Variable expenses[3]	268	128	268	128	128	660
- Labour[4]	52	42	52	42	42	140
- Other expenses[5]	131	131	131	131	131	131
- Land rent[6]	360	180	360	180	180	360
- Equipment rent[7]	153	153	153	153	153	153
- Depreciation (incl. Interest) of irrig. equipment[6]	39	-	39	-	-	39
Total production costs (TPC)	*1003*	*634*	*1003*	*634*	*634*	*1483*
= Profit before subsidies (GI- TPC)	*- 193*	*- 229*	*- 193*	*- 229*	*-229*	*- 163*
+ Subsidy	480	480	145	145	145	561
= Profit after subsidy	*287*	*251*	*-48*	*-84*	*- 84*	*398*
Farm income 1(own labour, equip.ent, land)	*852*	*626*	*517*	*291*	*291*	*1,051*
Farm income 2 (hired equipment)	*699*	*473*	*364*	*138*	*138*	*898*
Farm income 3 (hired land, hired eq.) equipment)	*339*	*293*	*4*	*-42*	*-42*	*538*

[1] Most figures were available in GRD and have been converted to Euro at 340 GRD per Euro.
[2] Potential irrigation, if necessary in order to secure yields in case of extended dry period during spring and early summer.
[3] Variable expenses consist of the following:

		Durum and Soft wheat irrigated			Durum, Soft wheat and barley non-irrigated			Cotton		
		annual q'ty/ha	cost/ unit	cost/ha	Annual q'ty/ha	cost/ unit	Cost/ha	Annual q'ty/ha	cost/ unit	cost/ha
1	Seeds	150	0.24	36	150	0.24	36	10	14.7	147
2	Fertilisers	300	0.21	63	300	0.21	63	650	0.29	191
3	Pesticides/Herbicides	100	0.29	29	100	0.29	29	100	1.82	182
4	Irrigation water	2000	0.07	140				2000	0.07	140

[4] Cereals cultivation is mechanised to a great extent. Labour is only needed in relatively small quantities during harvesting. The cost of unskilled man-hour is equal to 3 EURO.
[5] Includes financial and other expenses
[6] Land rent reflects current market prices for irrigated and non- irrigated land in the area. The same is true for the cost analysis of energy crops (below).
[7] It is assumed that most of the necessary equipment is hired. This is common practice in the area because farm sizes are too small to justify ownership of expensive equipment. In the case of irrigated wheat it is assumed that the farm owns the irrigation equipment.

Durum wheat gives positive profit ranging from 251 EURO/ha to 287 EURO/ha. On the contrary, soft wheat remains uneconomic in both irrigated and non-irrigated land (-84 EURO/ha to -48 EURO/ha). Barley is also uneconomic. This is due to the fact that durum wheat gets a triple amount of subsidy, compensating the negative profit before subsidy in both irrigated and non-irrigated land.

Cotton, on the other hand, is highly profitable under current subsidization policy. However, the allowed cultivation area is already covered in Rhodope region and any additional area results in lower subsidies

In addition to the appraisal of Table 7.1.1, three assumptions are examined for the farm income generated by the three cereal crops.

- In this assumption we estimate the farm income considering that the farmer uses his own land, labour and equipment.
- The farmer uses his own land and labour but hires the equipment.
- The farmer uses own labour but rents the land and hires the equipment.

As it is clearly indicated from the above assumptions the three crops generate positive farm income, after subsidies, almost in all the examined cases. It should also be emphasized that all the used values have a certain amount of distortion because of the subsidies used.

In detail, when the farmer uses his own land, labour and machinery, farm income ranges from 291 Euro/ha for non-irrigated soft wheat and barley to 517 Euro/ha for irrigated soft wheat as well as 626 Euro/ha and 852 Euro/ha for durum non-irrigated and irrigated, respectively.

However, it should be stressed out that in this case the positive incomes derive from a quite 'unrealistic' assumption which does not take into account these main economic values. We put them here as a reference, but we mainly think that the following assumptions (2 and 3) are more realistic.

Farm income is slightly modified when farmer hires the equipment. Lower values range from 138 Euro/ha in the case of non-irrigated soft wheat and barley to 699 Euro/ha for irrigated durum wheat. Finally, negative farm income (-42 Euro/ha) is observed in the cases of non-irrigated soft wheat and barley when the farmer rents the land and hires the equipment. Under the same assumption, irrigated soft wheat presents marginal farm income (4 Euro/ha) while figures for durum wheat, non- irrigated and irrigated, are 293 Euro/ha and 339 Euro/ha, respectively.

As presented above, cereals' cultivation is, in most cases, uneconomic for farmers. Therefore, questions arise concerning their drives to continue cultivating these crops since they generate low or no profit at all.

Cotton, on the other hand is highly favoured under the current policy framework and no other crop can be considered competitive to it. If it were feasible, most of the farmers would cultivate cotton. However, there is a top production limit for cotton, which is already covered in Rhodope.

Based on the above, farmers' alternative land use options are, at the moment, either cultivating cereals or leaving the land fallow and for a certain area get paid for set aside.

Since the aim of this thesis is to justify the role of dedicated energy crops for alternative land uses, possible scenarios for fitting these "new" crops in the local agricultural system with conventional crops should carefully take into account the existing situation in the agricultural sector.

7.2 THE ECONOMICS OF ENERGY CROPS PRODUCTION: CARDOON AND GIANT REED

Both cardoon and giant reed are perennial crops. Crop establishment is made in autumn by seed for cardoon and in spring by stem cuttings for giant reed (Panoutsou, 2000a).

During the first year (establishment) the cropping practices are common with all the conventional crops and consist of land preparation, sowing/planting and maintenance (fertilising, herbiciding). From the second year till the end of the plantations lifetime they only need fertilising to maintain high yields and harvesting[8].

A complete N-P-K (Nitrogen-Phosphorous-Potassium) prescription is applied in autumn for cardoon (Fernandez, 1996, Curt, 1998) and in spring for giant reed. Giant reed normally requires irrigation to maximise yields (Jodice, 1998, Christou, 2000b).

The costs of producing the energy crops under study were categorised in two major groups: i) establishment and, ii) recurring costs. Cost analysis was conducted using the following template:

Table 7.2.1: Sequence of cropping practices observed for cardoon and giant reed plantations.

	Cardoon	**Giant reed**
Economic life	15 years	15 years
Harvest cycle	Annual	Annual
Time of harvest	July	Winter
Establishment cost (at the outset)		
Pre-plant herbiciding	Yes	Yes
Ploughing, disc harrowing	Yes	Yes
Sowing /Planting	Seed (2 kg/ha)	20,000 plants/ha
Herbiciding	Grass herbicide	Grass herbicide
Initial Irrigation	Yes	Yes
Annual Activities		
Fertilizing (nitrogen)	50 kg/ha	50 kg/ha
Irrigation	No	Yes
Harvesting	Yes	Yes

The main cost elements for both crops are: growing, land rent and harvesting. Growing includes such costs as ploughing and harrowing (land preparation), crop establishment (sowing or planting) as well as the cost of seed/ stem cuttings, fertiliser and irrigation when required.

[8] Harvesting is uneconomic during the establishment year.

Harvesting costs cover the cost of labour and machinery for cutting, chipping and forwarding biomass within the field. Cost of working capital and other costs are also taken into account in the appraisal (Rahmani et al., 1998).

For all the cultivation techniques the costs cover labour, machine depreciation and fuel. All the estimates of the energy crops costs were made on a dry ton basis.

Finally, exit costs (grubbing up) for the cultivation are incorporated in the establishment costs.

Table 7.2.2. Establishment and recurring costs for cardoon and giant reed (Euro/ha/year)

	Cardoon		Giant reed	
Plantation Lifetime		***15***		***15***
Establishment costs	***Euro/ha***	***%***	***Euro /ha***	***%***
Ploughing	130	15.6	130	4.6
Harrowing	130	15.6	130	4.6
Herbiciding	130	15.6	130	4.6
Initial fertilising	63	7.6	63	2.2
Sowing/ Planting	200	24	2010	71
Initial irrigation	38	4.6	60	2.1
Exit costs (Grubbing up)	142	17	308	10.9
(a) Total Establishment costs	***833***	***100***	***2,831***	***100***
(b) Annual equivalent of establishment costs[9]	***113***		***332***	
Recurring costs (in all years ex. Harvesting)				
Land rent	180	26	360	39.6
Irrigation	0	0	38	4.2
Fertilisation	73	10.6	73	8
Harvesting	86	12.4	86	9.5
Cost of working capital	151	21.9	151	16.6
Other costs (incl.depreciation of trav. Gun)	201	29.1	201	22.1
c) Total recurring costs	***691***	***100***	***909***	***100***
Total annual equivalent cost (b+c)	***804***		***1,241***	

Since both the energy crops under examination are perennial it is evident that the highest amount of investment is required during the establishment year (Year 1).

In detail, establishment costs for cardoon are estimated at 833 Euro/ha while the corresponding figure for giant reed is 2,831 Euro/ha. This significant difference results from the different planting methods. Cardoon is sown with a conventional sowing machine, while giant reed is planted with rhizomes or stem-cuttings and therefore requires special machinery.

[9] In cost analysis the establishment costs are annualised and the annual equivalent [$e = ci / 1 - (1+i)^{-n}$, where c= purchase cost, i= discount rate and n= item lifespan] is added to the recurring costs in order to estimate the total annual equivalent cost.

The highest recurring cost is land rent, which accounts for ***26%*** and ***39.6%*** of total annual expenses for cardoon and giant reed, respectively. The total annual equivalent cost, including an annuity share of establishment expenses, is estimated at 804 Euro/ha for cardoon while it is significantly higher for giant reed, reaching up to 1,241 Euro/ha. This is due to the establishment with stem cuttings, which requires more effort in time and money.

Table 7.2.3: Annual cost analysis of energy crops cultivation (at farm gate)

		Cardoon		Giant reed	
		Euro/ha/yr	%	Euro/ha/yr	%
Labour		***28***	***4***	***63***	***6***
	Skilled [10]	22	3	56	5
	Unskilled [9]	6	1	7	1
Land		***180***	***30***	***360***	***30***
	Land rent	180	30	360	30
Machinery		***121.9***	***14***	***121.1***	***10***
	Tractor	107	13	108.5	9
	Tr.Gun	0.9	0	0.8	0
	Harvester	12	1	11.8	1
Variable inputs		***118***	***14***	***337.5***	***28***
	Seeds / Cuttings	25	3	249.2	21
	Herbicides	21	3	17.8	1
	Fertilisers	69	8	67.7	6
	Water	3 [11]	0	2.8	0
Energy		***6***	***1***	***6.2***	***1***
	Diesel	6	1	6.2	1
Cost of Working Capital		***151***	***18***	***151***	***13***
Other		***201***	***18***	***201***	***13***
TOTAL COST		**803.9**	**100**	**1240**	**100**

A different cost layout, by breaking total cost by production factor, was also used to analyse the economic cost of the two perennial energy crops (Table 7.2.3):

- ***Labour***: is further categorised as skilled and unskilled. The labour required for each stage (establishment, annual) and cultivation technique has been calculated.
- ***Land***: land rent is estimated as the opportunity cost of land based on current activity (fallow land, cereals cultivation). Usually, this cost of land value is determined by soil

[10] The man-hour cost of skilled labour is 5 EURO while for the unskilled labour is 3EUR; labour of establishment activities has been annualised and added to labour requirements of recurring activities.
[11] Annual equivalent of initial irrigation cost.

productivity combined with economic forces that affect demand for land resources in the region.

- ***Machinery***: rent of tractor, harvester and travelling gun has been added to the cost analysis.
- ***Variable inputs***: include seed/stem cuttings for crop establishment, fertilisers and pesticides for increased production, irrigation water, etc.
- ***Energy***: mainly diesel for machinery operation.

Cost of working capital and overheads are also added to the agricultural costs.

The cost of working capital and other costs are also quite high but this is easily justified since it is essential for the farmer to have sufficient capital for the establishment of the crops.

Land is the more costly production factor in both crops accounting for a third of the total expenses while the plantations are much less demanding in terms of labour (4% and 6% of the total for cardoon and giant reed, respectively).

Especially for giant reed variable inputs are high costly mainly due to the cost of stem cuttings which accounts for 21% of the total cost for producing the crop.

7.3 CARDOON AND GIANT REED IN RHODOPE'S AGRICULTURAL SYSTEM

Both cardoon and giant reed are 'new crops' for the local agricultural system. Their successful introduction will be subject to a number of barriers, legislative, agricultural and economical.

Table 7.3.1. Barriers for energy crops introduction in Rhodope's agricultural system

Barriers	
Legislative	Common Agricultural policy has only one directive for support to perennial energy crops and future prospects for additional support schemes are limited.
Agricultural	Introduction of these crops requires a sufficient amount of resources within the region in terms of labour, land and equipment. Therefore their cultivation should be complementary, in time, with the existing conventional crops.
Economic	Incomes in the regional agriculture are low except of those generated by cotton crop. However, any 'new' crop should ensure profitability levels at least equal to the ones of the current land use.
Non technical	Residues are still the most promising biomass alternatives and potential claims for land use to cultivate energy crops versus food crops, represent a strong disadvantage for energy cropping.

Table 7.3.1 summarises the most important ones.

Legislative: Within Agenda 2000, there is no specific proposal for a non- food policy. Nevertheless, the proposal on support of arable crops entails provisions relating to non-food. In detail:

The proposal on support for producers of arable crops. Member States agreed to retain compulsory set-aside at a default rate of 10% of a producer's claimed area from 2000 to 2006. The Council of Agriculture Ministers, acting by a qualified majority on a proposal from the Commission, will still be able to set a different rate each year if they agree to do so in the light of market developments.

Industrial and Energy crops on set-aside

The continuation of the principle that industrial crops, including biomass crops such as SRC, miscanthus, etc., can be grown on set-aside, whether voluntary or compulsory, was readily accepted and endorsed as part of the revised arrangements. Member States will continue to be able to pay establishment grant of up to 50% of the costs associated with establishing multi-annual crops intended for biomass production such as SRC on set-aside land.

Agricultural: As mentioned at the beginning of this chapter the agricultural system of Rhodope is dominated by cereals (41,000 ha) and industrial crops (36,000 ha, of which 7,200 ha is cotton). Therefore, there is adequate conventional machinery, which could be used in the energy cropping, too.

Taking into account that the local farming model is based on small mixed arable farms with low profit any "introduction" of new crops should be planned efficiently by using conventional machinery as well as by employing farmers in an evenly distributed timing on an annual basis.

Additionally, since both energy crops will be used as raw material for bioenergy schemes, continuity of supply in the power plant should be ensured without requiring big storage facilities. At the moment there are no such plants under operation in Greece. However, from examples existing in other countries (Denmark, UK) storage facilities are considered essential for the continuous supply of raw material (The Centre for Biomass Technology, 1998- ARBRE, 2001)

The information collected so far from RTD programmes (Mardikis, 2000, Panoutsou, 2000c, Biomass Department, 2000) regarding their feasibility for electricity and/or heat generation, indicates that the crop harvesting time is a critical factor influencing the supply of adequate raw material quantities at the proper time.

In our case mild climatic conditions favour the successive harvest of energy crops throughout the year. Under the prevailing soil-climatic conditions, it has been reported that cardoon and giant reed complete their growing cycle and reach physiological maturity in successive periods of time. In order to take advantage of this successive harvesting attitude we suggest a two-crop energy cropping system, which will ensure:

- A year round feedstock supply with lower storage requirements,
- efficient use of conventional machinery, giving the opportunity to increase the working hours with even time distribution within the year,
- efficient use of labour throughout the year, and
- enhancement of biodiversity, which has a twofold importance a) from the eco-agricultural point of view we avoid single cropping systems and the relative risks, while, and b) from the energy conversion point of view, two types of feedstock will be produced to supply a thermochemical conversion unit, ensuring thus an unhindered feeding of the unit.

Cardoon is harvested during the summer (from July to September), as soon as it is dry, and always before seed dissemination. At this time moisture content of the harvested material is very low (about 15%). The harvesting procedure will be carried out in two operations: the first consists of cutting the biomass with a swath- mower machine followed by the baling operation with a roll baler machine.

Table 7.3.2. Time schedule for labour and conventional machinery for harvesting in Rhodope

	J	F	M	A	M	J	J	A	S	O	N	D
Cardoon							■	■	■			
Giant reed	■	■	■									
Durum, soft wheat						■						
Barley						■						
Corn								■				
Cotton									■	■		

Giant reed usually flourishes from mid-September to mid-October, under south European climatic conditions. It can be harvested from January to early spring, before new growth occurs. Moisture content of the harvested material is about 45- 50%. Giant reed plants can be harvested with conventional equipment used for maize. The proposed energy cropping system, with farmers growing both cardoon and giant reed, would complement other crops very well in terms of timing and harvesting. Giant reed would be harvested in the period January to March, when no other crops are harvested. Cardoon would be harvested in the period July to September, following the harvest of durum, soft wheat and barley in June. Corn harvest in August would be done within the same period as cardoon while cotton harvest in September and October would overlap in time with cardoon harvest.

From Table 7.3.2 we can figure that farmers will have less demand for labour during harvesting and the conventional machinery, already existing in the region, will be efficiently used without much higher requirements for additional machines. The storage facilities for the energy crop derived biomass will be smaller and the raw material will be kept there for a period of time avoiding big losses in dry matter.

Economical: The produced biomass would firstly be introduced to the small/medium heat generation of the region. To achieve this, a reasonable price, per energy unit, should be set. In order to define under what prices energy crops biomass can compete the existing fuels for the heat market, a comparative analysis is presented in the following table:

Table 7.3.3: Market prices of common and potential fuels for the heat market (Euro/GJ)

Fuels	Market price including taxes for fossil fuels	Price (Euro/GJ)
Lignite	0.012 – 0.015 Euro/KWh	3.419 – 4.273
Heavy fuel oil	0.123 Euro/lt	3.160
Gasoline	0.646 Euro/lt	19.84
Natural Gas	15 Euro/ KWh	4.273
Fire wood	108 Euro/odt	5.6
Straw (for animal feeding)	80 Euro/ odt	4.2
Energy crops	57 – 80	3 – 4.2

It is evident from the above table that energy crops price could be competitive if it ranges between 3 Euro/GJ (heavy fuel oil) to 4.2 Euro/GJ (straw).

On the other hand and in relation to the existing crops, biomass crops could be cultivated mainly in abandoned marginal land or they could replace cereals. In the latter case, it is necessary for the farmer to secure a profit at least equal to the one gained from the current use of land.

For example, in order to substitute cardoon for soft wheat net profit from cardoon should be comparable to the corresponding figure from soft wheat. Strictly speaking the producer will be willing to introduce a new crop in his land if the expected returns are higher than those of the best alternative cultivation that he may be facing (Soldatos, 1996).

This statement assumes expected return maximising behaviour. Other considerations such as aversion to risk or implications of replacing annual by perennial crops are not so important in the area.

The main reasons for this, as explained also in previous chapters, is that farmers rely on small pieces of land to earn an annual income and adding the lack of alternative opportunities in the region forces them to seek 'profit maximisation' solutions.

Table 7.3.4: Net profit and profit after subsidies (Euro/ha/year)

Crops		Yields	Selling price (Euro/odt)	Gross income	Total production costs	Net Profit	Subsidy	Profit after Subsidies
Durum wheat	Irrigated	5	162	810	1003	- 193	480	287
Durum wheat	Non-irrigated	2.5	162	405	634	- 229	480	251
Soft wheat	Irrigated	5	162	810	1003	- 193	145	- 48
Soft wheat	Non-irrigated	2.5	162	405	634	- 229	145	- 84
Barley	Non-irrigated	2.5	162	405	634	-229	145	-84
Cardoon low price	Non-irrigated	20	57	1140	804	336	57[12]	393
Cardoon high price	Non-irrigated	20	80	1600	804	796	57	853
Giant reed low price	Irrigated	20	57	1140	1240	- 100	166[12]	66
Giant reed high price	Irrigated	20	80	1600	1240	360	166	426

As may be seen from table 7.3.4, in all cases net profit from cardoon is higher than net profit from soft wheat (both irrigated and non-irrigated) and therefore, it seems reasonable to assume that substitution of the conventional crop may take place if the selling price of cardoon can be secured.

It is also clear in the same line of thought that giant reed becomes economic only in the high price scenario.

Non-technical barriers

Energy balances: Biomass produced for energy is expected to substitute fossil fuels in the energy market. In order to assess the comparative advantages/disadvantages in terms of energy and environmental aspects, comprehensive life cycle assessments that compared biofuels with fossil fuels appeared in the beginning of 1990's. Several studies have been conducted but in the case of cardoon and giant reed which are examined in this thesis there are no specific results or studies so far.

However, just for the aspect of energy balances we can state the following based on the cultural practices used for each crop. No data are available at the moment and in order to present concise and accurate results one should do a detailed life cycle assessment study for

[12] Annual equivalent of 50% of the establishment costs according to EC Regulation 1251/1999 for set aside.

the specific region. In the following table the cultural practices for both crops are presented. It is clear that cardoon is less energy demanding than giant reed since it does not require irrigation or plantation management annually thus being established by seeds. However, as previously mentioned detailed assessment is required for each case and region to present accurate results and conclusions for these two crops.

Table 7.3.5 Cultivation practices for cardoon and giant reed

	Cardoon	Giant reed
Establishment (at the outset)		
Pre-plant herbiciding	Yes	Yes
Ploughing, disc harrowing	Yes	Yes
Sowing /Planting[13]	Seed (2 kg/ha)	20,000 plants/ha
Herbiciding	Yes	Yes
Initial Irrigation	Yes	Yes
Annual Activities		
Fertilizing (nitrogen)	Yes	Yes
Management of the plantation[14]	No	Yes
Irrigation	No	Yes
Harvesting	Yes	Yes

Both are expected to provide better results in terms of emissions (CO, CO_2, N_2O), and ozone depletion. As states by Reinhardt (Reinhardt, 2000), *biofuels show the greatest advantages if* they substitute coal as a fossil energy carrier, followed by fuel oil and finally natural gas. The results are influenced more significantly by the differences between the substituted fossil energy carrier than by the conversion technology (heat, power, combined heat and power plant).

Biomass alternatives. The major barriers for energy cropping in general, are restrictions or prior claims on use of land (food, energy, housing, commerce, industry, leisure or designations as areas of natural beauty, special scientific interest, etc.), as well as the environmental and ecological effects of monoculture perennial plantations. Such considerations include loss of

[13] Cardoon is sown with common machinery while giant reed requires more time and energy since it is established either by rhizomes or by stem cuttings.

[14] Giant reed requires proper cleaning between the rows of the plantation in order to keep the rhizomes from expanding without control. Cardoon on the other hand does not require such management.

biodiversity, concern about water resources where irrigation is required and the impact of intensive agriculture, including release of greenhouse gases from fertilisers.

In the case examined in this thesis, local farmers would be much more concerned for the first aspect namely land use (as this is directly connected with their revenues) and very little with the environmental and ecological aspects. Since no adverse environmental hazards exist in the region for soil or water resources.

Additional disincentives for energy cropping, but from the 'end users' point of view this time, are the availability of cheaper, alternative biomass resources (wastes and residues).

At the moment in Greece, like in some other Member States, there is currently a lack of end user demand and there is no marketing infrastructure dealing with biofuels. This hinders further bioenergy development.

Public resistance to genetically modified organisms is also seen as a hindrance in using such techniques to improve yields and decrease use and cost of inputs such as chemical pesticides and herbicides.

7.4 SENSITIVITY ANALYSIS

As it is previously mentioned (Mardikis, 2000) both energy crops under study have been cultivated at experimental/ demonstrative scale but no data exist for such large scale plantations. Since validation of the results is practically impossible at the moment, sensitivity analysis is used below, as a method to explore the effects of variation in input parameters on the outcomes. Two types of parameters were analysed in the sensitivity of analysis of profit, yields and land cost.

Yields: The base case scenario that is used in the economic appraisal is 25 odt/ha/year for both cardoon and giant reed. In the following figure yield fluctuations up to 20% have been considered and the respective profit is estimated.

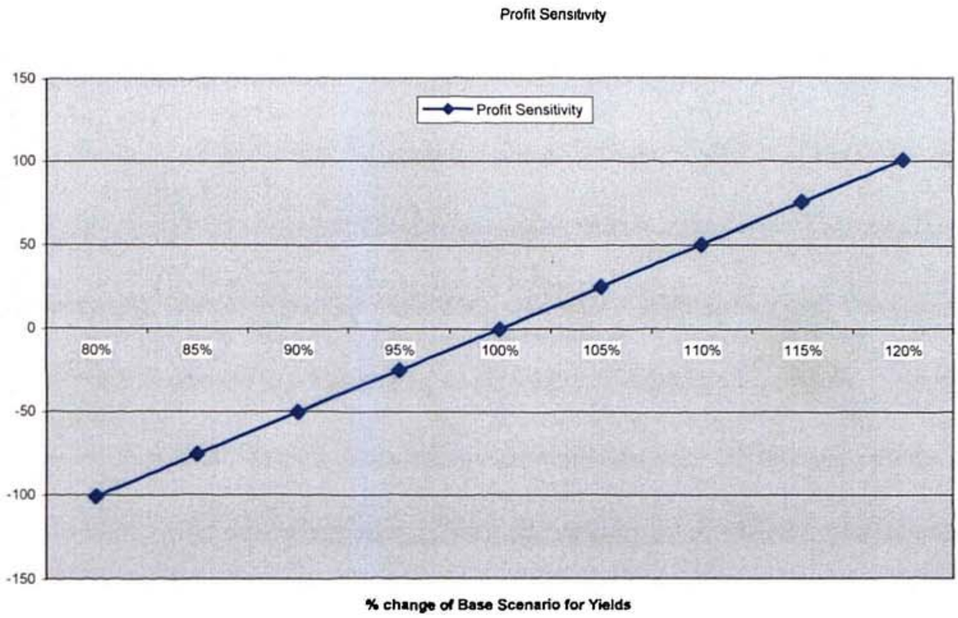

Figure 7.4.1. Profit sensitivity in relation to yields of cardoon and giant reed.

From the sensitivity analysis in relation to yields, it is evident that when yields drop by 20% from the base case (25 odt/ha/year) profit drops 100%, respectively and in the same line it doubles when they increase up to 20% (Figure 7.4.1)

Therefore, all the RTD efforts currently ongoing all over EU and in several experimental fields in Greece are essential so that the level of yields is maintained. In addition, the respective efforts and future activities should aim to 'sustainably' maximise the yielding potential of these crops by selecting better varieties and by exploiting all available resources (waste water irrigation, organic fertilisers, etc.).

Land cost: The type of land used for energy cropping is considered another critical factor to the estimation of profit. Land rent or the opportunity cost of land is a major cost element in most crops' economic analyses.

Since both energy crops are still not introduced in the local agricultural system, in our base case scenario we estimated land rent with the market prices for low fertility land. However, if the crops are successfully introduced in the future, the claims for land will be increased and inevitably "more expensive- higher quality" land will have to be used.

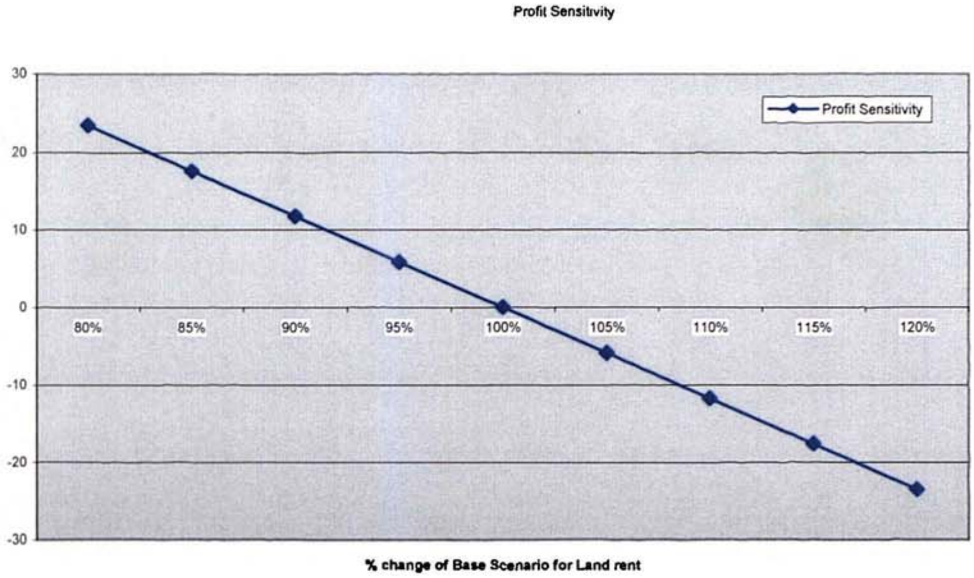

Figure 7.4.2. Profit sensitivity in relation to land rent of cardoon and giant reed.

Therefore, a sensitivity analysis was conducted to define the profit fluctuations with several types of land. Profit, in this case is slightly modified in relation to percentage changes of land rent. A twenty percent reduction or increase in the land rent results in 23.5% change of profit. From the above we can conclude that yields are the most critical factor for the economic viability of the examined energy crops and efforts should be targeted towards their maintenance and, wherever feasible, their maximisation.

7.5 CONCLUSIONS

Establishment of biomass energy crops in the local agricultural system of Rhodope presents advantages in the following aspects:

- the crops can be introduced as supplementary activity for the agricultural system and fit properly in with the conventional crops, wheat, barley and cotton

- they could stabilise farm incomes and provide alternative land uses, only if equal treatment was applied in terms of subsidies. This implies that either all subsidies should be removed (which at the moment seems impractical) or a sufficient amount of them should be redirected towards the development of energy farming.
- they will provide local energy production, as well as decrease imports of fossil fuels

Table 7.5.1 Profit before and after subsidy for the conventional crops under study (Euro/ha/year)

Crop	Profit before subsidy	Subsidy	Profit after subsidy
D. wheat (irrigated)	- 193	480	287
D. wheat (non-irrigated)	- 229	480	251
S. wheat (irrigated)	- 193	145	- 48
S. wheat (non-irrigated)	- 229	145	- 84
Barley	- 229	145	- 84
Cotton	- 163	561	398

The economic analyses conducted in this chapter indicated that the under study conventional crops in Rhodope result in negative profit, before subsidy is added. This means that there is much field for discussion and suggestion for viable alternative solutions.

Furthermore, based on the economic analyses of the two perennial energy crops and the current market prices for other fuels in Rhodope region we can state that they can both be viable solutions (especially cardoon). ***With a selling price of 57 Euro/odt, the respective incomes are 393 Euro/ha/year and 66 Euro/ha/year for cardoon and giant reed.***

However, given the present situation in the agricultural system, which is distorted by subsidies, these crops do not present attractive alternatives for farmers without any financial incentive.

In the analyses of this chapter we tried to estimate farmers perceptions for energy crops, under monetary terms trying to maximise their profits, and made comparisons with the income they gain from conventional crops. As mentioned '..they are going to grow energy crops only if they earn an equal or a higher net income than that of the replaced conventional ones.'

However, an important obstacle, which further complicates the analysis is that, every farmer in the region knows the exact amount of subsidies he will get for each hectare of his land. Psychologically, if you tell farmers that they are going to get half subsidy of cereals, 'suspicious minds' would object to the idea even if the farming income is the same with previous crops. In addition, if all their money is derived from subsidies then they would have to claim for the highly subsidised crops.

Finally, another important parameter for energy crops to become competitive in the future is the level of food, feed and fibre prices so that the competitive markets for these crops have less market potential. All these prices depend on market conditions and whenever concerns arise about energy prices growing faster than the other products it is evident that energy crops will become more profitable.

After defining the economics of cardoon and giant reed as well as factors affecting their potential introduction to energy systems, in the following chapter, both economic and socio-economic evaluation of an energy crop based scheme is conducted.

The aim of this thesis is to not only analyse the competitiveness of energy crops in the local agricultural system but to define their viability as potential fuel for a small-scale energy schemes.

CHAPTER 8. ECONOMIC AND SOCIO-ECONOMIC EVALUATION OF AN ENERGY-CROP BASED BIOENERGY SCHEME

As clearly indicated by the results of the previous chapter, both the energy crops under study can present economically viable solutions for the local agricultural system in Rhodope. Especially cardoon provides an 'acceptable' level of farm income even without any subsidies.

Given that and the information presented in chapter four for renewables and bioenergy in Greece, the respective bioenergy scheme selected to be further evaluated in the local context is a *district heating plant fuelled with cardoon.*

Small-scale renewable energy schemes are identified as the most promising in the Greek energy market, especially in the remote parts of the country (Panoutsou, 1998e). Energy crop fuelled district heating plants for villages in northern regions would increase the share of renewables in the primary energy supply thus providing alternative sources of income to the local agriculture.

In this chapter, the main considerations in determining the economic feasibility and the broader socio-economic value of the overall bioenergy scheme are:

(a) the attractiveness of bioenergy crops for farmers which depends on the income from such crops in comparison with alternative uses of land, subject to other aspects such as risks and exit costs of moving out of perennial crops if there are problems,

(b) the production of energy at competitive costs and

(c) the wider socio-economic benefits.

The methodological approach of BIOSEM (FAIR Programme. 1996a) is followed, starting with the investment appraisal, evaluating two of the abovementioned considerations, of the bioenergy scheme and then proceeds to the evaluation of the wider socio-economic benefits (income and jobs).

The investment appraisal was necessary to ensure that the resources used in the construction and operation of the plant, were allocated correctly. Viability was only possible with financial support and this was taken into account. If the plant is not viable over an acceptable period of investment time, then it is extremely unlikely that the plant would be built. To test the viability of the plant, the RECAP model was used.

RECAP, developed as part of the UK government's New and Renewable Energy Programme (Renewable Energy Crop Analysis Programme, 1997) analyses all the costs associated with the production and conversion of energy crops to heat and/ or power. With given feedstock and power/ heat selling prices, RECAP calculates both the Internal Rate of Return (IRR) and Net Present Value (NPV) for both the producer and the farmer, and the Net Margin (NM) for the farmer. The IRR and NPV give an indication of the economic viability of the investment in the bioenergy plant and in the production of the biomass feedstock. In addition, the level of net margin generated by the biomass crops can be compared with the net margin generated by existing land uses. This gives the farmer a quick assessment of whether biomass crop production can be a realistic alternative income source.

RECAP also allows a number of grants to be modelled. These include crop production grants and capital grants for the plant construction or price support for electricity sold to the grid.

Table 8.1.1 in the next paragraph provides details of the investment appraisal undertaken by RECAP (Table 6.1.1). The full set of tables of the BIOSEM methodology is provided as an Annex in the end of this chapter along with the socio-economic evaluation.

The author used RECAP and the BIOSEM methodology by contributing the Greek data to it as a scientific project manager of the BIOSEM project (FAIR Programme. 1996a).

8.1 INVESTMENT APPRAISAL OF THE BIOENERGY SCHEME

The bioenergy scheme examined here is a small-scale (1 MW_{th}) district heating plant fuelled with cardoon biomass.

Table 8.1.1. Main features of the bioenergy scheme and outputs of the investment appraisal.

Variable	Value (incl. Subsidies)	Value (without Subsidies)	Units
Cardoon price[1]	57	57	Euro/odt
Energy crop subsidies[2]	57	0	Euro/ha/y
Farmers Net Margin/ Opportunity Cost[3]	145	145	Euro/ha/y
Farmers Interest Rate[4]	10	10	%
Interest Rate for Conversion Plant[5]	10	10	%
Capital Costs[6]	575,000	575,000	Euro
Operating Costs[7]	100,572	100,572	Euro
Nominal Plant Output	1	1	MW
Conversion Efficiency to Heat	80	80	%
Plant Operating Life	20	20	Years
Labour hours required per year	700	700	Hours/y
Annual Plant Operating hours	4,000	4,000	Hours/y
Conversion Plant Subsidy[8]	280,000	0	Euro
Construction Time	1	1	Year
Plant Biomass Fuel Consumption	0.32	0.32	Tonnes/h
Heat Price[9]	0.041	0.041	Euro/kWh_{th}
OUTPUTS			
Total Cost	***2,625,240***	***2,625,240***	***Euro***
Average per year Total Cost	***132,043***	***132,043***	***Euro***
Revenue	***3,560,000***	***3,280,000***	***Euro***
Average per year Revenue	***171,250***	***153,750***	***Euro***
Farmers Net Margin	***242***	***242***	***Euro***
Average Annual Profit (before Interest)	***40,923***	***40,923***	***Euro***
Average Annual Profit (after Interest)	***3,365***	***3,365***	***Euro***
Farmers NPV	***7,099***	***6,837***	***Euro***
Farmers IRR	***10***	***10***	***%***
Bioenergy Plant NPV	***156,984***	***- 97,561***	***Euro***
Bioenergy Plant IRR	***19***	***7***	***%***

In the above table the outputs of the investment appraisal are presented considering separately the financial calculations (which include subsidies) and the economic calculations (which exclude them).

[1] The price used for cardoon is estimated at Chapter seven based on comparative prices for other fuels (utilised for heat generation) in Rhodope.
[2] Annual equivalent of 50% of the establishment costs according to EC Regulation 1251/1999 for set aside.
[3] Average farm income from cereals non irrigated (see table 7.2.1).
[4] Common interest for agricultural investment projects (Agricultural Bank of Greece, 2000).
[5] Common interest for renewable energy investment projects (OPE, 1997).
[6] Maximum allowed capital cost as set in the submission form for subsidisation or renewable energy projects (OPE, 1997).
[7] Operation costs as set in the submission form for subsidisation or renewable energy projects (OPE, 1997).
[8] 45% subsidy as set for biomass district heating in as set in the submission form for subsidisation or renewable energy projects (OPE, 1997).
[9] Heat price is calculated as 70% of the heat price when the district heating plant uses heating oil. This is the case in a commercial district heating plant in the area of Kozani, northwest Greece. The oil prices used were of March 2001. It is clear, however, that this price as well as the viability of the plant is strongly influenced from any fluctuations in oil prices. Sensitivity analysis is presented afterwards.

The viability of the district heating plant is strongly influenced by two major factors, the fuel (energy crop) price and the heat-selling price. Following we estimate the economic viability of the bioenergy scheme, using the criteria of Net Present Value (NPV) and Internal Rate of Return (IRR). The NPV may be interpreted as the present worth of the income stream generated by the energy crops' cultivation and by the district heating plant itself. The IRR is interpreted as the discount rate that makes the net present value of the cash flow equal to zero. It is the maximum interest that a project could pay for the resources used if a project is to recover its investment and operating costs and still breakeven (Gittinger, 1995). It is the rate of return on capital outstanding per period while it is invested in the project (Merrett and Sykes, 1973).

Attractiveness of bioenergy crops for farmers: Although farmers in the area are looking for alternative land uses, their decisions will be based on the net potential annual income which should be equal or a little higher than the current one in order to decide changing to energy cropping. In addition, the energy crop price will be based on the prices of other fuels used for heat purposes in the region (Table 7.3.4). Based on the boundaries we use as base case for cardoon a price of 57 Euro/odt.

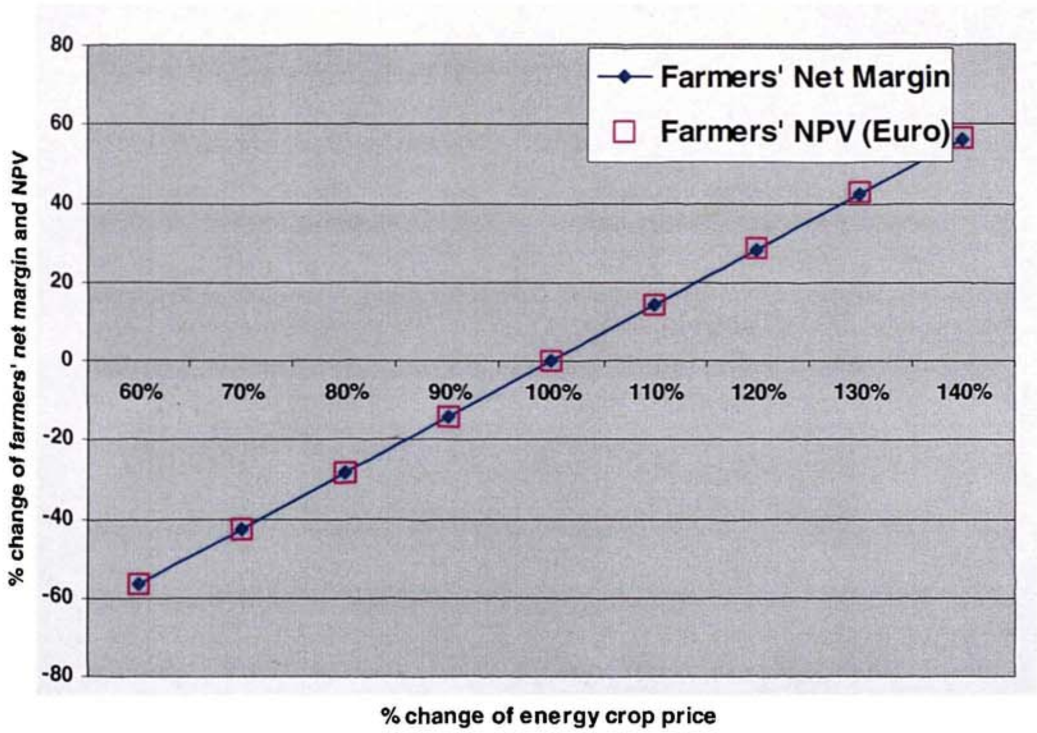

Figure 8.1.1. Percentage change of the farmers' Net Margin and NPV with the change (%) of the base price (57 Euro/odt).

Both farmers' net margin and NPV are linearly affected by changes in the energy crop's selling price. Farmers will appreciate the higher price of course.

It is worthwhile to mention that farmers' net margin for the above-examined cases ranges from 105 to 378 Euro/ha/year. Values above 150 euro/ha/year can be considered acceptable ones compared to incomes obtained in Rhodope by non- irrigated soft wheat and barley (Table 7.3.4). The latter are negative, so it is likely that farmers will agree to change their activity to energy cropping starting with a price of 45.6 Euro/odt.

Table 8.1.2. Changes in farmers' Net Margin and farmers' NPV with the change (%) of the base price (57 Euro/odt.

Price (Euro/odt)	% change from the base case scenario	Farmers' Net Margin (Euro)	Farmers' NPV (Euro)
28.5	- 50	71	2,062
34.2	- 40	105	3,069
39.9	-30	139	4,077
45.6	- 20	173	5,084
51.3	-10	207	6,091
57	0	242	7,099
62.7	10	276	8,106
68.4	20	310	9,113
74.1	30	344	10,121
79.8	40	378	11,128

Since the subsidy included in the financial calculations, is considerably low (57 Euro/ha/year) no changes are observed in the economic calculations where it is excluded (Table 8.1.1).

a) Production of energy

Financial calculations: In real terms, the most likely energy crop price will be that one for which the district heating plant will be economically viable.

For this reason we present below, a comparative sensitivity analysis for the Internal Rate of Return (IRR) and the NPV of the conversion plant making the following assumptions:

- the energy crop's price, using 57 Euro/odt as base case scenario, and
- the heat-selling price.

In order to estimate the latter we use as indicator the production costs of 1 kWh_{th} at a district heating plant fuelled with oil. The heat price from biomass is set as 70% of the aforementioned price, as is the case in the district heating plant of Kozani, northwest Greece, currently under operation.

Since oil prices present significant fluctuations during the year, we use as base case oil prices of March 2001 (0.47 Euro/lt) and we run a sensitivity analysis for the medium and the lower case (0.41 and 0.35 Euro/lt) of the same year.

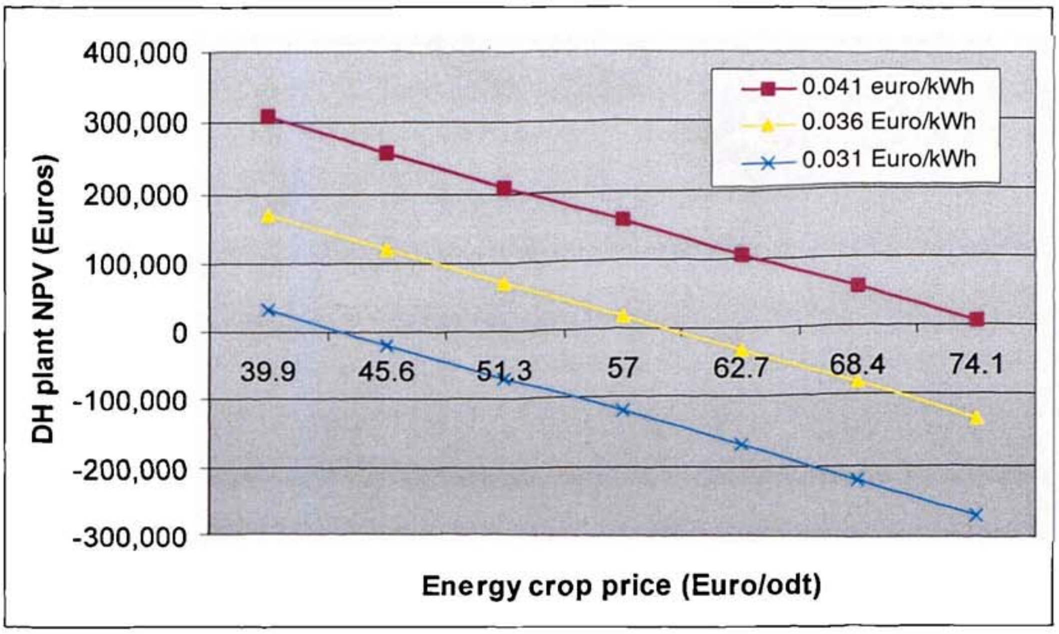

Figure 8.1.2. Net Present Value (NPV) of the district heating plant at different energy crop and heat selling prices.

The NPV of the conversion plant is positive and in some cases presents high values when the heat price is 0.041 Euro/kWh, a price based on the higher oil price (0.47 Euro/lt).

Even with the medium heat-selling price, an energy crop price below 57 Euros/odt presents positive values for the district heating plant.

Table 8.1.3 Oil prices, production cost of 1 kWh_{th} from oil and biomass heat prices (in Euro)

Oil prices/ lt	Production costs/ kWh_{th} from oil	Biomass heat price/ kWh_{th}
0.47	0.058	0.041
0.41	0.051	0.036
0.35	0.044	0.031

Values change dramatically when the heat price falls to 0.031 Euro/kWh and then the plant is not economically viable for the energy crop prices, which also offer an acceptable farmers' net margin. However, the latter case of heat price derives from an oil price of 0.35 Euro/lt, which is considered very low under current market prices.

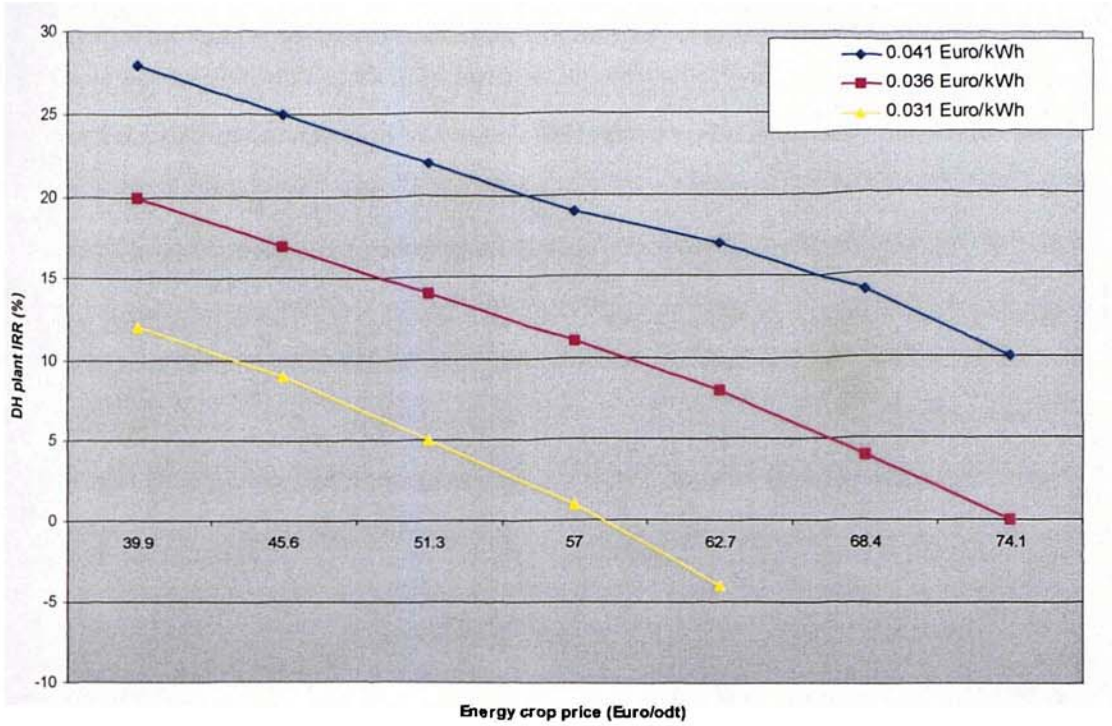

Figure 8.1.3. Internal Rate of Return (IRR) of the district heating plant at different energy crop and heat selling prices.

Therefore, we can assume that the plant will be able to sell at higher prices, ensuring both its viability and adequate income for the local farming community.

Economic calculations: Current policy (OPE, 1997) supports renewable energy investments with a 45% subsidy on capital cost. This, as seen in Table 8.1.1, is critical for the examined district heating plant.

With no subsidy, NPV presents negative value (- 97,561 Euro) while the plant's IRR falls from 19% to 7%.

It is evident that in this framework the investment is not attractive under economic terms, therefore the resources could be allocated elsewhere, creating profit.

8.2 SOCIO-ECONOMIC EVALUATION

Before presenting the socio-economic evaluation a short outline of socio-economic modelling and the applied BIOSEM technique is presented.

What is socio-economic modelling?

Socio-economic impact assessments can be broadly defined as 'the systematic advanced appraisal of the impacts on the day to day quality of life of people and communities when the environment is affected by development or policy change' (Bowles 1981).

Socio-economic impact studies are commonly used to evaluate the local, regional and national implications of implementing particular development decisions. Typically they are measured in terms of specific employment and income gains from a capital investment in to a given region. To date, however, they have rarely been used in the evaluation process of regional renewable energy programmes.

It is likely that socio-economic impact studies have been ignored because of the difficulties in quantifying the majority of socio-economic effects. Aside from local employment and income effects, the majority of gains or benefits associated with decentralised power tend to be of an intangible nature; they are therefore difficult to quantify (Table 8.2.1). As a result of this, there have been very few socio-economic impact studies for renewable energy technology development and deployment, despite the fact that for some technologies, the local value added component can be quite significant.

There has, in recent years, been much concern over the problems of rural depopulation, largely caused by falling or static agricultural incomes in real terms. Bioenergy plants serve two very useful purposes.

Firstly, energy crops and/or the productive use of residues represent alternative sources of income to the farming community; secondly, the processing or conversion of these resources in to an energy product (heat, power) will generate income and employment benefits to the wider rural community. Whilst there is recognition for the potential benefits, the actual benefits need to be quantified.

BIOSEM aims to do this by quantitatively and qualitatively analysing the economic effects of local biomass production (including energy crops cultivation) and utilisation with respect to rural diversification. The methodology acknowledges the existence of other key benefits (including social, supply and macroeconomic effects), but the BIOSEM model used here concerns itself with demand side effects and the repercussions they have on the supply side. The reasons for this are:

- Practicability: some of the above benefits, in terms of social, macro and supply side, are broad and it is not possible to assess them due to the lack of data.
- Importance: their contribution to the analysis of a small-scale local bioenergy scheme is of less significance and indirect since a small bioenergy scheme involves mainly the agricultural and energy sectors of a region.

Table 8.2.1. Types of socio-economic benefits (BIOSEM, 1997)

Major type	Example
Social	Increased Standard of Living • Environment • Education • Lighting • Domestic Productivity Cohesion & Stability • Migration effects (urbanisation trends) • Regional Development/ Diversification
Macro	Export Potential Security of Supply Increased rate of growth Reduced Reliance upon Imports Risk Diversification
Supply Side	Increased Productivity Enhanced Competitiveness Labour and Population Mobility Avoids Mismatches between Supply & Demand Improved Infrastructure Economies of Speculation
Demand Side	Employment Income Induced Investment Support for Related Industry

The Demand Side

Impacts on the demand side constitute the major feature of the majority of socio-economic impact assessments. There are many reasons for this. Most notably, they are relatively easy to define and the scale of the investment's impact can be quantified with reasonable accuracy (whether it be investment during the construction phase or the additional output and employment supported during the operational stage). Indeed in the short to medium term these effects are likely to dominate the project's overall impact.

From Table 8.2.1 the demand side effects are primarily quoted in terms of employment and regional income and can be categorised as follows:

- Key and associated ***direct*** effects

Key direct effects arise specifically from the actual development, such as direct plant employment, whilst associated direct effects result from activities related to the development as a whole, e.g. transport for workers.

- Key and associated ***indirect*** effects

Key and associated indirect effects are due to increased activity in the supply chain, which provides materials and services needed by the key direct and associated activities, e.g. increased levels of work in the engineering sector which provides components for the development.

- Key and associated ***induced*** effects

Key and associated induced effects are a consequence of the successive expenditure rounds generated by the additional incomes generated by the existence of the development. This is an important multiplier effect, which is often used to establish 2^{nd}, 3^{rd} and 4^{th} order employment and income effects.

- ***Displacement*** effects

Displacement effects can be very significant and occur when the development reduces the level of demand for competing activities.

The BIOSEM technique

The analysis of the above effects should form the basis of any socio-economic impact study. The BIOSEM technique will be an evaluative framework, which can identify and analyse the multiplier or 'knock-on effects' from local expenditure derived from a local investment. The technique will need to analyse the short and long term impact on forward and backward linkages within the local economy's demand and supply chains. This is because the technologies in these sectors will not only affect output supply and input demand, but also the local employment levels and income generation. Subsequent changes in the demand and supply of other related activities could similarly result in adjustments being made in their own production techniques and employment and income distributions. The BIOSEM technique is a standard methodology for quantifying the impacts of a regional investment in a bioenergy plant on the employment and income of the key industries, namely agriculture and energy.

8.3 BIOSEM TECHNIQUE ANALYSIS

To implement the BIOSEM technique, the user will need to consider the following points:

- the definition of the area or region to be covered (likely to be determined by the availability of economic data);
- the availability of data for the region and for the production of biomass fuel and the construction and operation of the plant;
- the economic conditions prevailing in the rural region;
- the size of the bioenergy plant;
- the type and availability of biomass feedstock;
- the nature of the energy produced (heat and or power); and
- the availability of a market for the energy.

In addition, it is very important from the outset that the programme should first establish the financial viability of both the biomass fuel production activity and the bioenergy plant. In the real world farmers would not switch to, and project developers would not invest in, unprofitable projects so all subsequent income and employment effects would be meaningless.

The first three points of the technique are thoroughly presented in the following sections so that the framework under which the 'future' bioenergy plant will operate is clear in terms of economic activities and figures, agriculture, labour and energy aspects.

The criteria for the selection of the proposed bioenergy scheme are based on information presented in the two previous chapters (six and seven). According to that analysis, district heating for remote villages in the northern part of the country (where heat demand lasts for six to seven months) is one of the most promising bioenergy implementation schemes identified so far. In addition, there is a large number of small and quite remote villages in Rhodope, which could make good use of a district heating plant using energy crops from their farmland.

Concerning the energy crop, the author has chosen cardoon that presented good economic viability in land now used for soft wheat and barley.

The economic viability of either stage (the feedstock production and the conversion process) is calculated separately at the bottom of the second sheet (Sheet B), based on the lines of RECAP, by using investment indicators such as net present value (NPV) and the internal rate of return (IRR).

In detail the BIOSEM technique is based upon five linked spreadsheets, sheets A- E.

Sheet A is designed to be the 'scene setter' and contains all the information upon which all the other sheets are based. It is divided into individual sections correlating to different stages of feedstock production and conversion plant construction and operation.

The sections included are:

Tables	
1	Summary Information
2	Financial Information
3	Feedstock Production Data: Crop Establishment
4	Feedstock Production Data: Crop Management
5	Feedstock Production Data: Crop Harvesting/ Biomass Gathering
6	Feedstock Production Data: Crop/ Biomass Storage
7	Transport of the Feedstock to the Conversion Plant
8	Grubbing-up of the Biomass Crop
9	Feedstock Conversion: Capital Costs of the Bioenergy Plant
10	Feedstock Conversion: Operating and Maintenance Costs of the Bioenergy Plant
11	Labour Costs
12	Farm Machinery Costs
13	Economic Data
14	Financial Information Regarding the Agricultural Activity Displaced
15	Processing of the Agricultural Activity Displaced
16	Value of Agricultural Processing Displaced

Sheet B calculates the financial viability of crop production and the bioenergy plant over a 15-year period. No provision is made for altering the length of projects because any changes so far into the future will have marginal impact since all future costs are discounted to facilitate current day comparisons. The sheet provides both annual and cumulative cash flows and investment indicators i.e. net present values (NPVs) and internal rates of return (IRRs), which can confirm the viability of the project, thus allowing subsequent employment and income analysis to take place.

Sheet C calculates all the pecuniary linkages from the regional economy. The calculations contained within this sheet are critically reliant upon the information given in sheet A and highlights the importance of stating the equipment and labour sourcing in Sheet A. A lack of data in Sheet A can lead to errors or un-calculated cells in this sheet.

Sheet D details the displacement effect of transferring one type of crop production to bioenergy production and the impact on the primary processing of the agricultural activity displaced. All the variables used to calculate the value of the displaced activity have come from sheet A. Sheet D reads data from sheet A and calculates the discount net margin, the interest charge and the net margin after interest for the displaced agricultural activity. Sheet D has been set-up as a separate worksheet to ring-fence the displaced activity. In some instances the sheet may be redundant because the bioenergy feedstock is a by-product of another economic activity. For instance forest residues and straw are both by-products from other activities, therefore feedstock production does not displace any other productive economic activity.

Sheet E calculates the final direct, indirect and induced multipliers along with income and employment gains. The basic components of the gross effect are:

The direct effect: the direct spending of the plant and the feedstock production process.

The direct displacement: the reduced demand for competing activities. This effect results from the reduction in goods and services for competing activities. The net direct impact is the difference between direct gains and losses.

The indirect effect: it results from the purchase of local goods and services by suppliers to the bioenergy plant.

The indirect displacement: the effect resulting from the displacement of spending on supplies for the displaced activities.

Net induced impact: the consumption multiplier, i.e. the re-iterative spending of additional income on goods and services in the local community through the spending of increased salaries and profit (this can be negative if the displaced activity is more profitable and generates a greater level of employment and income generation)

The total net impact: this is the sum of all the above functions.

8.4 SOCIO-ECONOMIC EVALUATION

The district heating plant fuelled with cardoon appeared to be a robust project in financial terms under the current subsidisation framework for 'renewable energy investments in Greece. However, in economic terms, with no subsidy, the plants' NPV presents negative value (- 97,561 Euro) while the respective IRR falls from 19% to 7%.

It is evident that in this framework the investment is not attractive under economic terms, therefore the resources could be allocated elsewhere, creating profit.

Table 8.4.1. Total Net impact of the bioenergy plant with and without subsidies

	Unit	Value (incl. Subsidies)	Value (without Subsidies)
Net Additional Labour Income	Euro	18,947	18,825
Net Additional Profit	Euro	264,189	259,359
Net Additional Direct Jobs	Jobs	3.4	3.4
Net Additional Indirect Jobs	Jobs	0.3	0.3
Net Additional Induced Jobs	Jobs	18.9	18.5
Total Net Additional Jobs	Jobs	22.6	22.2

The socio-economic evaluation with BIOSEM indicates that the implementation of a 1MWth district heating plant in Rhodope results to 3.4 net additional jobs and approximately (depending on subsidies and crop selling price fluctuations) 18,948 Euros in terms of additional labour income.

Table 8.4.2. Socio-economic impact in terms of income, profit and jobs for different crop selling prices and heat price 0.041 Euro/KWh.

Crop selling price (Euro/odt)	Net Additional labour Income (Euro)	Net Additional Profit (Euro)	Net Additional Direct Jobs	Net Additional Indirect Jobs	Net Additional Induced Jobs	Total Net Additional Jobs
39.9	18,948	172,183	3.4	0.3	12.5	16.2
45.6	18,948	202,852	3.4	0.3	14.6	18.3
51.3	18,948	233,250	3.4	0.3	16.7	20.4
57	18,946	264,189	3.4	0.3	18.9	22.6
62.7	18,947	294,858	3.4	0.3	21.0	24.7
68.4	18,947	325,527	3.4	0.3	23.2	26.9
74.1	18,947	356,196	3.4	0.3	25.3	29.0

In the above table we can see that depending on the crop selling price the total net additional jobs range from 16.2 to 29 for each 1MWth district heating plant implemented.
However, it should be mentioned that this is due to the increase in the net additional induced jobs. Both the direct and the indirect jobs do not present any sensitivity in the change of crop selling prices and present values of 3.4 jobs and 0.3 jobs, respectively. Using current prices (Commercial and Industrial Service of Rhodope, 2001), in monetary terms this means 30,000 Euro and 2,600 Euro, respectively.
Similar observations can be made concerning net additional labour income, which is estimated by the BIOSEM technique at 18,948 Euros.
As expected, in terms of net additional profit there is a linear increase ranging from 172,183 Euros (crop selling price 39.9 Euro/odt) to 356,196 Euros (crop selling price 74.1 Euro/odt).
In the table below we estimated sensitivity of the above socio-economic factors to the changes of heat selling price.

Table 8.4.3. Socio-economic impact in terms of income, profit and jobs for different heat selling prices and crop price 57 Euro/odt.

Heat selling price (Euro/kWh)	Net Additional labour Income (Euro)	Net Additional Profit (Euro)	Net Additional Direct Jobs	Net Additional Indirect Jobs	Net Additional Induced Jobs	Total Net Additional Jobs
0.031	18,952	228,564	3.4	0.3	17	20.7
0.036	18,950	246,377	3.4	0.3	17.9	21.6
0.041	18,947	264,189	3.4	0.3	18.9	22.6

Net additional labour incomes as well as direct and indirect jobs do not present any sensitivity in the fluctuation of heat selling prices.
On the other hand, net additional induced jobs range from 17 to 18.9 resulting to a respective range in the total net additional jobs from 20.7 to 22.6.

8.5 CONCLUSIONS

In this chapter the type and the size of the bioenergy scheme were selected. The site, as previously mentioned was Rhodope, northern Greece, mainly due to the following reasons:

- It has well-established agricultural system and the respective farming incomes are very low and based mainly on subsidies.
- Relative experience in Greece and other Mediterranean countries shows that soil climatic conditions are favourable for the introduction of the selected energy crops, cardoon and giant reed.
- Heat demand is relatively high compared to other regions of the country since it is situated to the north (six to seven months annually).
- There are a number of remote villages where district heating plants could be successfully established.

Following the assessment for the raw material, which was conducted in the previous chapter, here the technology was defined and the district heating plant was evaluated under economic and socio-economic terms.

Under the current subsidisation framework for 'renewable energy investments' in Greece, the district heating plant fuelled with cardoon appeared to be a robust project in financial terms (although it appears to present sensitivity, if oil prices fall drastically).

However, the investment is not attractive under economic terms, therefore the resources could be allocated elsewhere, creating profit.

In terms of additional jobs created, the potential impact is very low and could be significant only at 'village level' combined with other advantages of bioenergy such as alternative land uses and sustainable energy production.

In addition, it should be clarified that at the moment, there is no market for biomass, so a 'key player' is missing who would have to be the instigator of the energy scheme and to create a market by being a reliable buyer of bioenergy crops.

Based on proven examples of other EU Member States like Austria (Rakos, 1995) it can be assumed that in the beginning the initiator are more likely to be either local cooperatives or local authorities. Both have good knowledge of the local infrastructure and can develop schemes by using local resources and links whenever necessary. Finally, since at such cases as the one examined, the heat will be consumed by a limited number of people their perception would be more positive if that would be a local 'community scheme (Richards, 2000).

As previously mentioned in several points of this study, renewables including biomass, are strongly promoted for environmental and social reasons despite the fact that in economic terms they are not directly competitive to those of fossil fuel technologies. At this point it should be stressed that prices of fossil fuels are kept deliberately low for political and economic stability reasons, creating big "distortion effects" when compared with the respective renewable ones.

In addition, to that, we should mention that for the respective (fossil fuel) conversion technologies no external costs, namely health and environmental pollution effects, are taken into account when doing an investment appraisal.

Both the abovementioned facts put bioenergy in a difficult state concerning economic viability.

Prior to concluding, the author conducted a thorough analysis for the adoption of bioenergy as an innovation at local level.

CHAPTER 9.ADOPTION OF INNOVATIONS

The analysis in the earlier chapters shows that bioenergy schemes could be economically viable under reasonable technical and price assumptions. However, where an innovation is being considered, there are always uncertainties and the adopters are often understandably reluctant to adopt innovations because of lack of familiarity with them and the possible risks of failure. In addition, there could also be concerns about replacing annual arable crops with perennial crops requiring heavy initial investment. Even if the energy crops are being considered for set aside land, farmers may be reluctant to commit heavy initial investment, which would be required. Therefore, it is necessary to make an assessment of the attitudes of farmers and the community towards bioenergy crops and local energy schemes as innovations and the likelihood of their adopting such innovations.

9.1. AN INNOVATION CALLED 'BIOENERGY'

Biomass energy being an alternative form of power production is an innovative practice, which involves a 'diffusion' process through certain channels over time among the members of a social system (Rogers, 1995).

Bioenergy itself, especially the use of wood fuel, is not a 'new' idea. However, technological improvements along with continuously rising concern about environmental problems caused by the extensive use of fossil fuels as well as oil- price increases, favour the development of new 'diffusion- adoption' channels.

Two important research questions arise with respect to the adoption of technology:

- how the earlier adopters differ from later ones and
- how the perceived attributes of bioenergy, such as its relative advantages, affect its rate of adoption, whether rapidly or slowly.

Biomass has been widely used as a fuel for heat in the past and today is contributing approximately 38% in the primary energy production of developing countries (OECD/ IEA, 1985- 1988). The main reasons for this high adoption rate are listed below:

- cheap and easy to collect source of energy for rural areas in the developing countries of Africa, Asia and South America, and
- lack of , or high cost of alternative sources of energy.

However, it should be stressed out that the traditional use of biomass energy has its own environmental problems – inefficient energy production and depletion of a valuable resource.

Nowadays, the new potential adopters of biomass energy face other significant challenges, which might lead them to the development of a favourable attitude towards it. The main ones deal with: i) environmental problems (greenhouse effect), ii) increasing fossil energy prices and iii) scarcity of fossil fuel supply.

However, we should clearly note that their favourable or unfavourable attitude will rely on factors such as:

- relative advantages of bioenergy schemes, in economic terms, convenience and satisfaction compared to the existing power supply
- compatibility of the biofuel with the existing infrastructure or amount of additional investment required to buy new or modify the machinery is relatively low
- trialability, which is the degree to which bioenergy has been or is being experimented elsewhere or on demonstrative projects
- complexity of the bioenergy scheme.

The overall objective of this chapter is to explore the reactions of different key groups in the population to the prospect of wider use of energy crops as fuel to small scale bioenergy schemes.

The outline of the diffusion of bioenergy is presented in the following paragraphs in terms of key groups involved as well as 'gatekeepers' of information during the planning and implementation of a bioenergy scheme.

9.2 WHAT DOES EACH DO OR WILL DO?

The development of local bioenergy schemes includes an innovation- diffusion process through which the relevant parties (individuals or other decision making units such as local authorities) pass from 1) technological knowledge of the whole scheme in agricultural and energy conversion terms, to 2) evaluating the economic and socio-economic viability of the raw material (if energy crops are involved) and the scheme as a whole, to 3) reviewing and using the current policy and financial instruments, to 4) form a decision to adopt or reject, and to 5) implementing the 'new' idea.

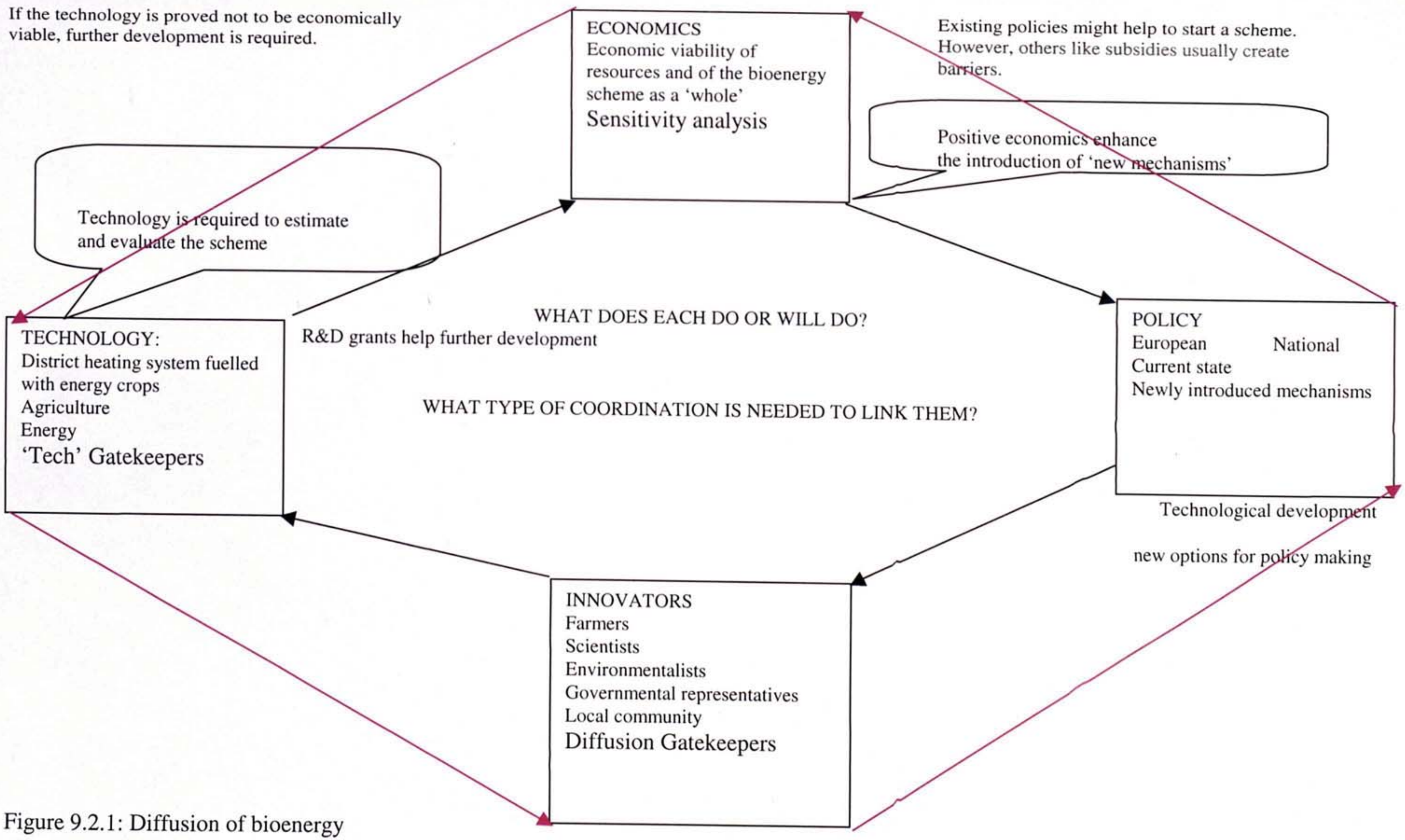

Figure 9.2.1: Diffusion of bioenergy

This process consists of a series of actions and choices over time through which individuals or organisations (research institutes dealing with technological aspects) evaluate the new idea and decide whether or not to incorporate the innovation into ongoing practice.

The main aspects of each stage, as outlined in figure 9.2.1, are described below.

Technology: Bioenergy schemes involve a number of professions, namely agricultural, forest, mechanical and chemical engineers. Each of them is a 'gatekeeper' for certain technological aspects of the bioenergy chain.

Agricultural and forest engineers are involved in the:

- Assessment of raw material, if this involves residual biomass types.
- Establishment and maintenance of energy plantations in terms of yield maximisation and adaptation under different cultural practices.
- Pre-treatment of the feedstock involving harvesting, sizing, baling and storing techniques.

Mechanical and chemical engineers are involved in the:

- Design and construction of the power plant.
- Design of control measures (filters, etc) for reduced emissions.
- Monitoring of functional parameters when the plant is in operation (e.g. temperature, air flow, etc.)

Knowledge of the above-described aspects as well as consensus development is essential to estimate and evaluate the potential bioenergy scheme.

Prior to designing the bioenergy scheme, the scientists should be brought together in an effort to evaluate the most important technological parameters and estimate the effects of their implementation as a production- conversion chain.

At this point it should be mentioned that technological development is still ongoing in all the phases of biomass energy so the provision of R&D grants helps to further develop and optimise both the feedstock quality and the conversion efficiencies of the technologies.

In the district-heating scheme, which is evaluated in this thesis, all the above parameters were taken into account and analysed in the respective chapters. Although the project is a 'feasible innovation' under technological terms for the region under study, it was decided that one of the crucial steps to pass from the knowledge to decision stage was to evaluate the economics along with the possible distortions that the existing financial mechanisms (capital grants for the power plant and set aside grants for the crop) might cause.

Economics: Although bioenergy is promoted for obvious environmental and social reasons, its economic viability is not well proven when compared to existing fossil fuel technologies.

In order to have a 'full' picture of the economics of a bioenergy scheme such as the district heating examined here, first the economics of the raw material were carefully assessed.

In general, if residues are involved then in most cases (AIR Programme, 1993b) a contractual price is set that normally reflects the opportunity cost of the residue type.

If energy crops are involved, as is the case in this thesis, then the economic analyses take into account the production costs of the respective crop in relation to the farming income that the farmer gets from current conventional cropping.

Usually, the analysis allows for grants to be incorporated (AIR Programme 1993b, FAIR Programme 1996a) but the farm income should be first evaluated without any of them (Soldatos, 1996).

After defining the economics of the raw material, an economic appraisal of the whole scheme was conducted in order to define under which terms and whether the investment is viable.

All data used in this thesis derived either from experimental/ demonstrative scale for the plantations or from estimations based on technology supplier companies but no data exist for commercial applications at the moment. Since validation of the results is practically impossible at the moment, sensitivity analysis was used as a method to explore the effects of variation in input parameters on the outcomes.

Policy: In order to conduct the financial evaluation of the bioenergy scheme, all related financial mechanisms in the form of subsidies and grants were taken into account. Since renewables and bioenergy are currently promoted through EU directives and Policy Papers and the Member States form their policy based on them, it was considered necessary for the thesis to examine the existing policy and financial incentives both at EU and at national Member States. In this way, the context under which a potential bioenergy scheme would operate and the financial mechanisms affecting its viability and/ or the possibility of implementing more similar schemes at regional or national level can be assessed.

Additionally, when the grants and subsidies are known in monetary terms, it is relatively easy to define the economic viability of the scheme or its components (raw material and power plant) by excluding them from the appraisal. The results without the policy "influence" could help forming suggestions for the long-term viability of bioenergy schemes and to define the key aspects of future policy targets in comparison to the current state.

Innovators: Following the technological and economic evaluation of the examined (in each case) bioenergy scheme, perceptions and key characteristics of the groups involved in bioenergy were examined for each of the involved parties.

Gatekeepers at this process are considered the scientists who control the flow of messages through certain communication channels. During the thesis, and based on the results of networking (Altener Programme 1996, Altener Programme 1997, Altener 4.1030/Z/98 –593. 1999 – 2000) a number of questions were answered concerning the attitudes of each group.

Five groups were thought to be the key ones to cover in this study: farmers, scientists, local planners, environmental groups, and government representatives.

Parts of the results were accomplished in the framework of the EU funded Altener programme biomass networks, AFB and BIOGUIDE (Altener Programme 1996, 1997, AFB network, 2000, Altener 4.1030/Z/98-593). These networks were formed to encourage dialogue between farmers, potential end users of heat and/or power, environmental groups, the government and the local community and to create a consensus view on the environmental status of biomass and its potential contribution to environmental objectives in global, national and local terms (Foster, 1995).

Based on the results of the formation and the operation of the aforementioned team, as well as on questionnaires used in the area under study (Rhodope) this chapter analyses the situation from the point of view of each member group.

9.3 GROUP PERCEPTIONS ON ENERGY CROPS

Farmers

Farmers in Greece, clearly face an increasingly difficult and uncertain situation (European Union. 1995, Panoutsou, 1998c). Unstable incomes, reduced subsidies, small size of farming land, decreasing employment opportunities, lack of alternative solutions for cropping and a constantly changing, complex policy situation leads them to confusion and adverse conflicts with the government. Under this complex framework, the option of cultivating crops dedicated to energy purposes seem to them a promising alternative land use.

However, as mentioned in this thesis, agriculture in the country is highly subsidised and farmers rely on that fact to form decisions for crop choices.

Cotton and cereals are currently accounting for the highest percentage of cultivated land both at national and local level (Rhodope). Although the respective annual incomes before subsidies are negative for both crops, farmers take into account the income they gain when subsidies are included.

Based on that along with the fact that at the moment there is not a market for energy crops, both the farmers that participated in the national network for biomass (Altener Programme 1996, Altener Programme 1997, Altener 4.1030/Z/98 –593. 1999 – 2000) and the ones who were interviewed individually expressed interest on the energy crops but were reluctant to devote all or part of their productive land. The main reasons are the following:

- Lack of market infrastructure does not form a secure context on which farmers can rely for their income, especially when their farms are relatively small and no other sources of income are available for them.
- Farmers are sceptical especially for perennial energy crops, such as cardoon and giant reed, which are examined in this thesis, since they would have to devote their land for a very long period. This along with the fact that the agricultural policy situation is constantly changing and farmers' choices to maximise their income are rather limited (especially in the region under study) reduce the attractiveness of energy crops as alternative land use.

However, and in the context of maximising their profits, some farmers were keen to use set aside land (the one they have or more, if policy allows it) to cultivate energy crops. That of course would also require long-term contracts with the end users.

Scientists

Scientists involved in the biomass to energy schemes are greatly concerned about the technicalities and the economic viability of such energy systems. They focus on the following aspects:

- the future of biomass (residues and energy crops) as a fuel and its market price
- the governmental support which they believe will be necessary to encourage both production and conversion to energy to take-off.

Considering current policies, several views were expressed. Some were in favour of subsidies in all parts of the bioenergy chains (crop production, capital grants, etc.). Others believed that the best way to increase competitiveness of biomass to energy schemes is through environmental taxes on fossil fuels.

Some stressed out that prospects for biomass might be better if people could see its role in an appropriate agricultural, environmental and energy policy, which will emphasise the advantages for the agricultural development, the energy conservation and the preservation of the environment with the use of renewable energy sources.

Concerning state-of-the-art technologies, advanced combustion systems and co-generation schemes seemed to be the most economically viable solutions for energy production at the moment.

Environmentalists

Environmentalists are eager to use agricultural biomass as a way to produce renewable energy, but are sceptical on the possible environmental impacts of both using residues and producing energy crops in large scale. Some of the critical factors under consideration are:

- soil erosion
- nutrient balance
- bio-diversity and landscape level effects
- emissions and air quality

All these concerns can be turned to advantages if benefits that biomass can provide are communicated and well justified. Energy crops provide variety, good habitats for wildlife, controlled integration into the landscape, and they are a non-polluting source of renewable energy.

Biomass has certain positive effects on the environment, but it is not an automatic, specific application. Rules, in the sense of good practice guidelines, have to be respected (Gosse, 1994).

Governmental representatives

The most important decision making group, *governmental representatives*, when they learn more about the purpose of biomass and more specifically energy crops they almost become genuinely interested and cautiously optimistic about their widespread use as a fuel. However they raise a great number of questions, which can be categorised as follows:

- Environmental impacts:
  of exploiting residues for energy purposes,
  of the energy crops themselves, and
  of their use as a fuel.
- Economic viability of energy crop fuel in the market (compared to the alternative market demands).
- Agriculture's role within an appropriate energy policy.
- Local versus national interests.

Questions in all these areas need answering in order to minimise misconceptions and possibly hostile reactions.

It is clear that there is a number of benefits from growing energy crops which are likely to increase public support for it, provided they are communicated successfully:

- Energy crops are a source of renewable energy.
- Grown sustainably, there is no net CO_2 output.
- Switching to biomass fuel helps restrain global warming.
- Energy crops provide new local opportunities and jobs - for farmers, local users of heat and power, and for locally owned and run power stations.
- Energy crops provide new habitats where wildlife can flourish.

Local community

People representing the *local community*, were more concerned on local country issues than any global ones. Nevertheless, there is widespread concern about some global environmental problems, even if some people do not fully understand them. Some of the more serious ones are believed to be climate change, underground water pollution and overuse of chemical inputs in agriculture. Most of the members of the National Team already knew that possible solutions to climate change are energy use conservation, switch to more friendly sources of energy like the renewables and cutting the use of dangerous chemical substances. Once they see how energy crops and more broadly biomass fuel can help in reducing the adverse effects of the aforementioned problems they find it more acceptable as an energy source.

However, people were sceptical on the environmental impact of the energy crops themselves, the scale of the project and its overall effect on the look of the countryside. An average of 5 to 10 hectares, carefully integrated into the landscape and adding to its variety, seem likely to be acceptable. Plantations, which dominate the landscape and reduce scenic variety, will not be welcomed. Many people feel that energy crops could spread out of control unless strict guidelines or planning restrictions are enforced.

Local community needs reassurance on the scale of energy plantations. They need to understand that the planted area will be large enough to form a new, secure local or national industry, but adequately regulated to minimize the visual impact on the countryside. They also need reassurance on the limited environmental impacts of energy crops.

9.4 QUESTIONNAIRE SURVEY

Objective and approach

The main objective of the questionnaire survey was to validate key findings of the network operation and to investigate in depth various issues arising from this. The most important ones are summarised below:

- finance and profitability considerations;
- reasons for adopting energy crops;
- the need for alternative land uses;
- markets;

Method

The sample of this survey consisted of 50 farmers and 15 end users located in the industrial area of Komotini (the capital town of Rhodope).

The farmers were stratified by age and farm size. There were two levels of farm size stratification: "large" meaning greater than 100 ha and small being less than 50 ha. Three levels of ages were employed for the stratification: younger than 30, aged from 30 to 45 years old and older than 50 years old.

The end users were selected among the total number of industries in the area, so that their business was either relevant to biomass, e.g. cotton ginning industries, or had high energy demand during the process, e.g. food processing industries with high needs of hot water.

Designing the questionnaires

Farmers: It can be seen from the questionnaire provided in the end of this chapter that it is in three parts. In Part A there are questions of fact designed to collect information on farm and farmer characteristics thus allowing the farmers and their businesses to be categorised (e.g. by age, education, farm income, farm type, labour force, etc.). In the second part there are questions designed to find out the farmers' attitude towards energy crop introduction in the current agricultural systems. The last part of the questionnaire has questions about whether and where; the interviewed farmers might plant energy crops.

End users: In the first part of the questionnaire, general questions concerning awareness of bioenergy as well as willingness to use it in their industry are collected.

In the second part detailed information both on the energy needs of the industry as well as on the availability of residual biomass forms and interest on energy crops are presented.

9.5 FARMERS AND END USERS

Farmers

Farms: The 50 respondents who answered the appropriate question farmed a total area of 3,000 ha. They were chosen randomly from villages near valleys. The average farming size is 60 ha, which is rather big for the area (average farm size is 5 ha) but it derives from big variation in the faming size. The largest farm of those who replied was 300 ha and the smallest was 0.5 ha, a wide range.

For 1999, final results of the National Statistical Service and the Ministry of Agriculture showed that the total area of agricultural land in Rhodope was 86,000 ha. Thus the area farmed by the survey respondents is representative of some 3.5 % of the total area of the region.

The most frequent enterprise on the survey respondents' farms was wheat cultivation. The least common enterprises were vineyards and livestock farmers (cattle and pigs). The most important information collected in the questionnaire are summarised below.

Table 9.5.1. Information collected during farmers' interviewing.

Type of information
Category of land to be planted
Effect of farm type
Effect of farm size
Age category of the respondents
Education level

Farmers: The mean age of survey respondents was 56 years old with a range from 30 to 75 years. No equivalent official figures are available for comparison. The respondents' age was fairly evenly distributed about the mean with 46 % being under 50 and the rest being over 50 years old. We should mention that only 10% were under 40, so it is clear that they were distinctly middle-aged, or older, a fact which could cause implications in the diffusion and adoption of innovations.

In general the respondents' education had been up to primary school only; their mean age of finishing education was nearly 12, which reflects the fact that most of them are not highly educated. Approximately 13% of them had received some form of agricultural training or education and 90% of them belonged to local farmers' cooperatives.

The 'mean' respondent had been farming for about 30 years 'on his or her own account' and almost half of them have identified a successor who would take over the farm business.

Most respondents did not have a source of income apart from that coming from their farm business, for only 15% indicated that they had an income from non- farm business sources. Of this latter group, the most common sources involved part-time work in local restaurants.

During the last year their income was highly based on the available grants for cereals and set aside land.

Level of interest shown in energy coppice

It can be seen from the questionnaire (see Annex in the end of this chapter) that farmers were provided with some information about energy crops concerning:

- adaptability and yields based on R&D programmes,
- profitability,
- subsidies: it was mentioned to them that under the current set aside regulation a 50% establishment grant is eligible for perennial crops.
- cost of setting up (estimations based on models)

which they were asked to read and then questions about willingness to adopt were posed.

The three broad questions that were posed were:

- Whether respondents might consider planting an area or areas of energy crops on their farms in the next five years.
- If the respondents were interested in planting energy coppice in the next five years, what areas they might plant on what types of land on their farms.
- If they felt they would or would not consider planting energy crops within the next five years, which of several reasons (and they could specify more than one and add additional ones) would be the most critical.

Of the 50 respondents who stated their planting intentions, 38 said they might consider planting energy crops. This is an appreciable level of interest. Before examining the factors which determined their decision, one should give a broad picture of the context under which farmers have to form their choices. It is clear that under the current agricultural policy farmers' net income relies heavily on the subsidised crops. This along with the fact that they own small pieces of land and agriculture is their main occupation limits their willingness to undertake risky 'innovations' such as energy crops when these are not supported and do not have a guaranteed market.

The above numbers become useful when they are combined with the areas and the type of land they might consider to plant energy crops. Such details are provided in Table 9.5.2, which shows the total area specified by respondents classified by the category of land they indicated they would plant on. Table 9.5.2 the areas respondents specified they might consider planting to energy coppice by category of land.

Table 9.5.2 The areas, respondents specified they might consider planting to energy coppice by category of land.

Category of land to be planted	Total area specified by respondents (ha)
Set aside land	500
Non irrigated land growing cereals	350
Irrigated land growing cereals	100
Other sites[1]	70
Total	1020

Obviously, a statistic of great interest to local authorities and policy makers will be that approximately 1,000 ha (1.2% of the regional agricultural land) - but this is a very high proportion of the land (33%) cultivated by the farmers interviewed) could be available for energy cropping. The result is significant but special note should be made to the fact that a very large proportion of the land is set aside.

The table below also shows the most 'likely' categories of land that the respondents said they might consider planting on are, in order of total area specified, as follows:

i) Set aside land 500 ha
ii) Non irrigated land growing cereals 350 ha
iii) Irrigated land growing cereals 100 ha

The above categories of specified land to be planted make up 93% of the total area specified as being considered for planting.

Characteristics of potential adopters (ETSU, 1993a)

The aim of this section is twofold. First, to identify factors, which will aid policy-makers in future, if they wish to encourage energy crops, to more easily target their promotional efforts. Second, the analysis in itself might as well, through identifying differences in potential adopters compared with non- adopters, establish what it is about energy crops that make it potentially attractive as an alternative land use for farmers in Rhodope.

Effect of farm type and size

Table 9.5.3 A comparison of the proportions of respondents who indicated they might consider planting energy coppice with the proportions of those who wouldn't by type of farm business.

Farm type category	Wouldn't plant energy crops	Might plant energy crops
Cotton	3	8
Cereals	9	30
Totals/overall proportions	12	38

In Table 9.5.3 the division between potential adopters and those showing no interest is presented on the basis of farm type.

It can be seen that cotton farmers were less likely to indicate that they might plant energy coppice when compared with those with cereals. This difference confirms what, a priori, might have been expected, for cotton farmers, with a guaranteed income have less chance to turn to an unknown crop at the moment.

Interest in energy crops in relation to size of total area farmed by the respondents is shown in Table 9.5.4.

It is clear that there is a size threshold affecting interest in planting energy crops, for respondents in the size categories of over 100 ha total area farmed were more likely to indicate that they were interested in it than those with smaller farmed areas.

This difference was significant and can probably be explained by suggesting that the respondents with larger farms may have thought that they had enough land to be able to afford to risk trying this 'new' enterprise. Those who farmed smaller areas probably felt that they could not risk their income for novelties.

[1] Other miscellaneous sites specified by respondents e.g. corners of their farms, stream bans, farm land close to roads, etc.

Table 9.5.4 A comparison of the proportions of respondents who indicated they might consider planting energy coppice with the proportions of those wouldn't by size of total area farmed.

Size of total are farmed	Wouldn't plant energy crops	Might plant energy crops
Under 50	4	5
50-100	5	7
101-150	2	11
150 and over	1	15
Totals/overall proportions	12	38

End-users

The fifteen end-users that answered the questionnaire were the main industries existing in the area of Rhodope, producing by-products or having high heat demand during their processing. In detail, the industries and their answers are categorised in Table 9.5.5.

Table 9.5.5 Type of industries responding to the questionnaire and their perception on energy crops.

Industry type	Number	Interest	Already using biomass	Perception on energy crops
Cotton ginning	5	High	Residues for heat	Good
Dairy products	3	Low	No	Never heard of them
Frozen food	4	Medium	No	Good but not interested
Sawmills	3	High	Residues for heat	Good

Out of fifteen industries, only the cotton ginning factories and the sawmills were familiar with biomass energy use. As expected they were covering part or in total their heat demand from their residues, cotton ginning residues or wood processing ones. In detail their arguments are presented below.

i) Cotton ginning factories cannot use oil as a fuel during the ginning process because it seriously affects the quality of the produced cotton (black and oily). This in addition to the fact that the residues are a problem for the surrounding areas as they are dump and lots of insects are gathered in these piles, made the factory owners to buy biomass boilers. They cover part of their needs with biomass and their secondary fuel is gas.

ii) The sawmills exploit their residues for energy purposes mainly because these are a problem to get rid of. They also cover part of their needs and their secondary fuel is heating oil.

iii) The frozen food industries have high heat requirements and consume large amounts of heating oil per week. Their perception on biomass was very good however, since they are small enterprises they are not willing to buy new boilers and turn to biomass unless there is a subsidy for the capital cost.

iv) The dairy product industries produce a sufficient number of effluents and their option for exploiting them is anaerobic digestion. Similarly to the previous industries the investment costs were considered high due to the small-scale of the enterprises and subsidies were considered essential.

Most of the respondents were familiar with the term 'energy crops' except people in the dairy industry.

Cotton ginning and wood processing industries considered the introduction of these crops to the agricultural system as positive. They were keen on using them as supplementary fuel and their main worry was if they could use this '*multi-fuel*' option in their burning appliances. Energy crops together with the residues could cover totally their heat demands. Combined heat and power was not considered as an option since these industries are seasonal (four to five months annual operation) and cannot cover the anticipated high capital costs for such a system.

A potential problem which was identified through interviewing end users is that there is no evidence of them being willing to create a market for energy crops by setting up new schemes. This should be pointed out as an important weakness and support mechanisms should be oriented towards this direction especially at regional planning.

9.6 CONCLUSIONS

In general industries involving new crops should be compatible with the community into which they are introduced (Keeney, 1994). Bioenergy schemes fuelled with energy crops in Rhodope and their potential spread in throughout the country would involve a number of issues concerning:

- Community relationships.
- Local employment and the rural economy, as well as
- Self- sufficiency.

In detail, both the results of the network formation concerning all the key groups involved as well as the questionnaires of the most relevant parties (farmers, end-users) lead to the following conclusions:

Community relationships: A reliable source of energy (heat and/or power) requires long term guaranteed contracts with fuel suppliers. This was also stressed by the farmers interviewed during this study.

Therefore in the development of a local bioenergy scheme it would be advisable to encourage local farmers' cooperatives or other local businesses to participate as contract coordinators. Cooperatives could indeed act as independent power producers, producing the feedstock and burning it locally to produce heat and/or electricity. Such a role for cooperatives would be consistent with their existing roles with respect to conventional crops. Local farmers' cooperatives which are governed by central farmers' cooperatives at the regional level, deal with all the sales, distribution, formation of market prices and so on for agricultural products. In many cases they also own the more expensive machinery for farmers to hire. Farmers would also be more willing to join bioenergy schemes if they have the leadership and guidance of their cooperatives. Thus, in the case of energy crops, farmers' cooperatives could act as initiators of the innovation adoption by farmers and also facilitate adoption by providing guidance and advice and hiring out the main pieces of machinery required by farmers.

Another advantage to a community- based grower system supplying a local biomass energy plant could be the potential to recycle plant wastes. Combustion of energy crops for energy generation would remove organic matter from the field, but some of the mineral fertility could be returned in the form of ash applied back on the producer's land.

Local employment and the rural economy: A regional energy plant supplied by locally produced biomass crops would provide incomes for individuals in a community and money, which would be spent in the community as well. Several studies suggest that communities in which biomass projects are developed will experience employment increases (Brower, 1993, Woolsey, 1993). Development of community-based industries often results in strengthening of community support services, providing additional jobs in the local government and service sectors.

Self-sufficiency: Some energy crops have alternative uses or co-products associated with them, which would provide the farmer with greater cropping and marketing flexibility. Farmers and other landowners who can be flexible in response to the economic environment have operations, which are more sound and less dependent on outside help.

Strengthening the income of farmers through long-term contracts and reduced dependence on federal subsidies can help stabilize rural economies. The local business cycles and tax support associated with the development of a biomass energy industry would enable rural communities to be more self-sufficient and less dependent on outside assistance. On a broader scale, the use of biomass for energy generation could reduce our dependence on fossil fuels and make our energy production systems more efficient and cost-effective.

In addition, energy crops offer an environmental and economic compromise between high input, intensively managed conventional crops (high economic return but negative impacts on local ecology) and natural, unmanaged systems (little, if any, economic reward and little impact on the local ecology). This is a statement that Hughes and Ranney (Hughes, 1993) also support. It can therefore be assumed that for many hectares of marginal farmland, energy crops could provide a desirable ecological compromise and an economic opportunity.

The development of a biomass energy industry will require creation of a sound infrastructure ***(Please explain what you mean by infrastructure here. Do you mean physical infrastructure e.g. transport or institutional infrastructure – to be linked with the rest of the para).*** In Greece and especially in Rhodope, there are still many technological and economic obstacles to be overcome and a number of social and environmental issues, which should be addressed to ensure that a strong infrastructure is built. New relationships among unlikely partners must be formed. These relationships could be encouraged through governmental actions at national and local levels.

Current subsidy programmes for the energy industry and for agriculture should be evaluated and perhaps integrated for this uniquely sustainable energy opportunity. An obvious possibility would be the Set aside regulation, which pays farmers to keep their land without cultivations or introduce perennial energy crops (EC Regulation 1251/1999). Perennial crops could as well be introduced in such land receiving grants equal to 50% of their establishment costs. At the moment there are no such schemes operating in Greece, but set aside grants are given annually. Some of these funds could as well be used to bridge the gap between cost to farmer and the amount end users are willing to pay.

Biomass energy production has the potential to benefit not only the power industry and the agricultural community, but the public and environment as well. At this juncture there is an opportunity to plan and develop a new industry, which is ecologically and economically sustainable.

CHAPTER 10. CONCUSIONS- STRATEGIC ANALYSIS

This thesis focused on the financial and socio-economic evaluation of energy crops as raw material for bioenergy schemes at a local level. The case examined was Greece, a southern Mediterranean country.

Due to the multifaceted nature of the subject and in order to cover all the aspects involved the study comprised of technical, economic and socio-economic studies.

A literature review was undertaken at the beginning of the study to identify the key features affecting bioenergy deployment in terms of policies, technical, environmental, economic and social aspects. In addition, the current status of bioenergy in Greece was presented in order to define the region and the local scheme, which would be further evaluated in the framework of the thesis.

Based on current bioenergy schemes in the country, on foreseen trends and on the information presented in the literature survey for EU, the following fields were defined as the most promising for bioenergy penetration in the Greek energy market for the near future (five to ten years) (European Commission 20001, Panoutsou, 2000 c).

- Small to medium scale heat generation for the industrial and the domestic sector.
- Medium scale CHP for industries, which can exploit the excess heat (processing needs/ heat requirements) or are located close to other industries willing to buy the produced heat.
- District heating in remote agricultural communities.

Of course such estimates would only be realistic if they are integrated approaches combining environmental and social aspects of rural development with the economics of a new investment.

Although these trends have been identified a long time ago and much effort continues to be expended from experts within the country and from all over Europe, bioenergy deployment rates still remain stubbornly low in the country, around 3% of the Greek total primary energy supply (CRES, 2000c). This is the case for the last ten years. Such a position raises severe doubts as to whether the favourable conditions in terms of biomass resources and the market potential would lead to increased bioenergy deployment in the near future.

An approach which has not yet received the co-ordinated attention that it deserves but which may well be able to help gear up biomass deployment rates significantly is the more obvious linkage of residues exploitation to mainstream (dedicated crops) biomass developments. This approach uses the driver of immediate need to cope with a problem (residues disposal mostly) and scales up appropriately to draw in a dedicated biomass resource. The result would be significantly larger projects or hybrid ones, which at one and the same time deliver more RES whilst also taking developers, financiers (key stakeholders) forward into more mainstream biomass ventures able to deliver greater and earlier replication.

Bearing these in mind, the main goal of this thesis is to examine the evidence supporting a strong role for dedicated energy crops in local bioenergy developments in Greece, a sector that is forecasted to be increasingly important in the short to medium term.

10.1 FINANCIAL APPRAISAL OF CARDOON AND GIANT REED COMPARED TO CONVENTIONAL CROPS

The study focused on two perennial crops- cardoon and giant reed. Both crops have been evaluated in experimental plantations for several years. Experience to date in Greece (and other Mediterranean countries) indicates that these crops can be used in dedicated feedstock supply systems addressing technical, economic and environmental issues of concern to farmers, landowners and the rural community.

In the work undertaken in this study, it was taken into account that energy crops introduction into regional agricultural systems strongly depends on their competitiveness with existing conventional crops in the area. It is obvious that farmers are going to grow energy crops only if they earn an equal or a higher net income with that of the displaced conventional ones. However, even if the incomes are satisfactory there are other factors, which should be taken into account to ensure the success of "energy cropping" in a rural area.

The thesis thoroughly analysed the introduction of energy crops in the agricultural system of Rhodope, Northern Greece, as alternative land use, through financial appraisal of the main conventional crops (soft, durum wheat, barley, and cotton) compared to cardoon and giant reed. In addition, the author presented the expected technical and non-technical barriers affecting their implementation along with the most feasible ways to overcome them.

Table 10.1.1: Net profit and profit after subsidies (Euro/ha/year)

Crops		Yields	Selling price (Euro/odt)	Gross income	Total production costs	Net Profit	Subsidy	Profit after Subsidies
Durum wheat	Irrigated	5	162	810	1003	- 193	480	287
Durum wheat	Non-irrigated	2.5	162	405	634	- 229	480	251
Soft wheat	Irrigated	5	162	810	1003	- 193	145	- 48
Soft wheat	Non-irrigated	2.5	162	405	634	- 229	145	- 84
Barley	Non-irrigated	2.5	162	405	634	-229	145	-84
Cardoon low price	Non-irrigated	20	57	1140	804	336	57[1]	393
Cardoon high price	Non-irrigated	20	80	1600	804	796	57	853
Giant reed low price	Irrigated	20	57	1140	1240	- 100	166[12]	66
Giant reed high price	Irrigated	20	80	1600	1240	360	166	426

The breakeven for the two selected energy crops was defined, based on the output of this comparative analysis along with a sensitivity analysis for the risk of the potential implementation. In relation to the existing crops, cardoon and giant reed could be cultivated

[1] Annual equivalent of 50% of the establishment costs according to EC Regulation 1251/1999 for set aside.

mainly in marginal land or they could replace cereals. In the latter case, table 10.1.1 presents the net profit and profit after subsidies both for cereals and the selected energy crops.

In all cases the table clearly indicates that net profit from cardoon is higher than net profit from soft wheat (both irrigated and non-irrigated).

Therefore, it seems reasonable to assume that substitution of the conventional crop may take place if the selling price of cardoon can be ensured under a contract basis. It is also clear that giant reed becomes economic only if the high price is achieved.

The economic appraisal of cardoon and giant reed further assisted to determine an accepted selling price for the produced feedstock in order to be competitive with other fuels used in the region for small/ medium heat and in other regions for power generation (heavy fuel oil, gasoline, lignite, natural gas, fire wood, straw and solar panels).

It is evident from the table below that energy crops' price could be competitive if it ranged between 3 Euro/GJ (heavy fuel oil) to 4.2 Euro/GJ (straw).

Table 10.1.2: Market prices of common and potential fuels for the heat market (Euro/GJ)

Fuels	Market price including taxes for fossil fuels	Price (Euro/GJ)
Lignite	0.012 – 0.015 Euro/KWh	3.419 – 4.273
Heavy fuel oil	0.123 Euro/lt	3.160
Gasoline	0.646 Euro/lt	19.84
Natural Gas	15 Euro/ KWh	4.273
Fire wood	108 Euro/odt	5.6
Straw (for animal feeding)	80 Euro/ odt	4.2
Energy crops	***57 – 80***	***3 – 4.2***

However, given the present situation in the agricultural system, which is distorted by subsidies, these crops do not present attractive alternatives for farmers without any financial incentive.

In the aforementioned analyses the author tried to estimate farmers perceptions for energy crops, under monetary terms trying to maximise their profits, and made comparisons with the income they gain from conventional crops. As mentioned '..they are going to grow energy crops only if they earn an equal or a higher net income than that of the replaced conventional ones.'

However, an important obstacle, which further complicates the policy analysis is that, every farmer in the region knows the exact amount of subsidies he will get for each hectare of his land. Psychologically, if you tell farmers that they are going to get half subsidy of cereals, 'suspicious minds' would object to the idea even if the farming income is the same with previous crops. In addition, if all their money comes out from subsidies then they would have to claim for the highly subsidised crops. This aspect has lead the author to further design detailed questionnaires for farmers in the region and conducted a survey through interviewing fifty of them.

Following the abovementioned results, the author performed an economic and socio-economic evaluation of *a district heating system fuelled with energy crops* in the selected region. For this, the principles of the BIOSEM technique were followed and the author adapted the methodology to the specific local conditions.

10.2 ECONOMIC AND SOCIO-ECONOMIC EVALUATION

Small-scale bioenergy schemes were identified as very promising in the Greek energy market, especially in the remote parts of the country.

Energy crop fuelled district heating plants for villages in northern Greek regions are expected to increase the share of renewables in the primary energy supply thus providing alternative sources of income to the local agriculture.

In the framework of this thesis, the selected bioenergy scheme was evaluated in terms of economic and socio-economic viability, using the principles of the BIOSEM technique.

The BIOSEM technique was developed through a two-year project, which started in January 1997 under the FAIR Programme of DG IV under the European Commission's Fourth Framework Programme. The objective was to construct a quantitative economic model to capture the income and employment effects arising from the deployment of bioenergy plants in rural communities.

The author was the scientific manager and contributed to the development of the technique as well as the Greek case study for the project.

The methodological approach of BIOSEM (FAIR Programme. 1996a) starts with the investment appraisal, evaluating the economic viability of the bioenergy scheme and then proceeds to the evaluation of the wider socio-economic benefits (income and jobs).

The investment appraisal was necessary to ensure that the resources used on the construction and operation of the plant, were allocated correctly. Viability was only possible with financial support and this was taken into account. If the plant is not viable over an acceptable period of investment time, then it is extremely unlikely that the plant would be built. To test the viability of the plant, the RECAP model was used.

RECAP, developed as part of the UK government's New and Renewable Energy Programme (Renewable Energy Crop Analysis Programme, 1997) analyses all the costs associated with the production and conversion of energy crops to heat and/ or power. With given feedstock and power/ heat selling prices, RECAP calculates both the Internal Rate of Return (IRR) and Net Present Value (NPV) for both the producer and the farmer, and the Net Margin (NM) for the farmer. The IRR and NPV give an indication of the economic viability of the investment in the bioenergy plant and in the production of the biomass feedstock. In addition, the level of net margin generated by the biomass crops can be compared with the net margin generated by existing land uses. This gives the farmer a quick assessment of whether biomass crop production can be a realistic alternative income source.

RECAP also allows a number of grants to be modelled. These include crop production grants and capital grants for the plant construction or price support for electricity sold to the grid.

In the following table we present the base case scenario examined for the selected bioenergy scheme.

Except this, several other scenarios were analysed in the respective chapters in order to define the sensitivity of the scheme both in terms of crop selling prices and heat selling price.

The viability of the district heating plant is strongly influenced by two major factors, the fuel (energy crop) price and the heat-selling price. In the framework of BIOSEM technique the author evaluated the economic viability of the bioenergy scheme, using the criteria of Net Present Value (NPV) and Internal Rate of Return (IRR).

Table 10.2.1. Base case scenario for the evaluation of a district-heating scheme fuelled with cardoon, in Rhodope, Northern Greece.

Variable	Value (incl. Subsidies)	Value (without Subsidies)
Cardoon price[2]	57	57
Energy crop subsidies[3]	57	0
Farmers Net Margin/ Opportunity Cost[4]	145	145
Farmers Interest Rate[5]	10	10
Interest Rate for Conversion Plant[6]	10	10
Capital Costs[7]	575,000	575,000
Operating Costs[8]	100,572	100,572
Nominal Plant Output	1	1
Conversion Efficiency to Heat	80	80
Plant Operating Life	20	20
Labour hours required per year	700	700
Annual Plant Operating hours	4,000	4,000
Conversion Plant Subsidy[9]	280,000	0
Construction Time	1	1
Plant Biomass Fuel Consumption	0.32	0.32
Heat Price[10]	0.041	0.041
OUTPUTS		
Total Cost	***2,625,240***	***2,625,240***
Average per year Total Cost	***132,043***	***132,043***
Revenue	***3,560,000***	***3,280,000***
Average per year Revenue	***171,250***	***153,750***
Farmers Net Margin	***242***	***242***
Average Annual Profit (before Interest)	***40,923***	***40,923***
Average Annual Profit (after Interest)	***3,365***	***3,365***
Farmers NPV	***7,099***	***6,837***
Farmers IRR	***10***	***10***
Bioenergy Plant NPV	***156,984***	***- 97,561***
Bioenergy Plant IRR	***19***	***7***

More specifically:

Attractiveness of bioenergy crops for farmers: Although farmers in the area are looking for alternative land uses, their decisions will be based on the net potential annual income which

[2] The price used for cardoon is estimated at Chapter seven based on comparative prices for other fuels (utilised for heat generation) in Rhodope.
[3] Annual equivalent of 50% of the establishment costs according to EC Regulation 1251/1999 for set aside.
[4] Average farm income from cereals non irrigated (see table 7.2.1).
[5] Common interest for agricultural investment projects (Agricultural Bank of Greece, 2000).
[6] Common interest for renewable energy investment projects (OPE, 1997).
[7] Maximum allowed capital cost as set in the submission form for subsidisation or renewable energy projects (OPE, 1997).
[8] Operation costs as set in the submission form for subsidisation or renewable energy projects (OPE, 1997).
[9] 45% subsidy as set for biomass district heating in as set in the submission form for subsidisation or renewable energy projects (OPE, 1997).
[10] Heat price is calculated as 70% of the heat price when the district heating plant uses heating oil. This is the case in a commercial district heating plant in the area of Kozani, northwest Greece. The oil prices used were of March 2001. It is clear, however, that this price as well as the viability of the plant is strongly influenced from any fluctuations in oil prices. Sensitivity analysis is presented afterwards.

should be equal or a little higher than the current one in order to decide changing to energy cropping. In addition, the energy crop price will be based on the prices of other fuels used for heat purposes in the region (Table 7.3.4). Based on the boundaries we use as base case for cardoon a price of 57 Euro/odt.

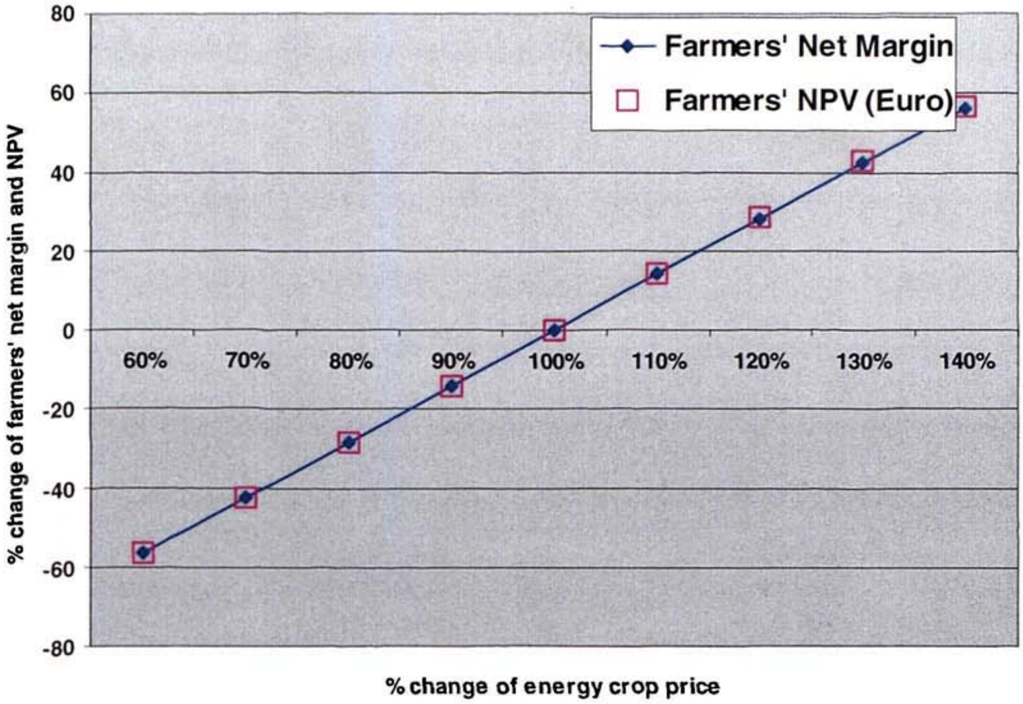

Figure 10.1.1. Percentage change of the farmers' Net Margin and NPV with the change (%) of the base price (57 Euro/odt).

Both farmers' net margin and NPV are linearly affected by changes in the energy crop's selling price. Farmers will appreciate the higher price of course.

It is worthwhile to mention that farmers' net margin for the above-examined cases ranges from 105 to 378 Euro/ha/year.

Values above 150 euro/ha/year can be considered acceptable ones compared to incomes obtained in Rhodope by non- irrigated soft wheat and barley (Table 7.3.4).

The latter are negative, so it is likely that farmers will agree to change their activity to energy cropping starting with a price of with a price 45.6 Euro/odt.

Table 10.2.2. Changes in farmers' Net Margin and farmers' NPV with the change (%) of the base price (57 Euro/odt.

Price (Euro/odt)	% change from the base case scenario	Farmers' Net Margin (Euro)	Farmers' NPV (Euro)
28.5	- 50	71	2,062
34.2	- 40	105	3,069
39.9	-30	139	4,077
45.6	- 20	173	5,084
51.3	-10	207	6,091
57	0	242	7,099
62.7	10	276	8,106
68.4	20	310	9,113
74.1	30	344	10,121
79.8	40	378	11,128

Since the subsidy included in the financial calculations, is considerably low (57 Euro/ha/year) no changes are observed in the economic calculations where it is excluded (Table 10.1.1).

Production of energy

Financial calculations: In real terms, the most likely energy crop price will be that one for which the district heating plant will be economically viable.

For this reason we present below, a comparative sensitivity analysis for the Internal Rate of Return (IRR) and the NPV of the conversion plant making the following assumptions:

- the energy crop's price, using 57 Euro/odt as base case scenario, and
- the heat-selling price.

In order to estimate the latter we use as indicator the production costs of 1 kWh_{th} at a district heating plant fuelled with oil. The heat price from biomass is set as 70% of the aforementioned price, as is the case in the district heating plant of Kozani, northwest Greece, currently under operation.

Since oil prices present significant fluctuations during the year, we use as base case oil prices of March 2001 (0.47 Euro/lt) and we run a sensitivity analysis for the medium and the lower case (0.41 and 0.35 Euro/lt) of the same year.

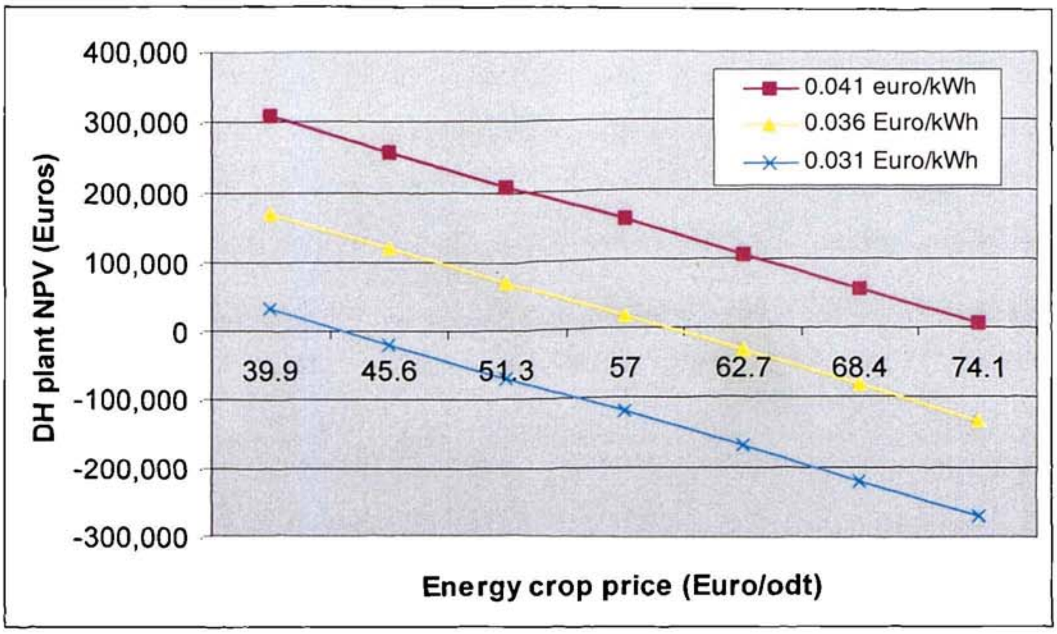

Figure 10.2.2. Net Present Value (NPV) of the district heating plant at different energy crop and heat selling prices.

The NPV of the conversion plant is positive and in some cases presents high values when the heat price is 0.041 Euro/kWh, a price based on the higher oil price (0.47 Euro/lt).
Even with the medium heat-selling price, an energy crop price below 57 Euros/odt presents positive values for the district heating plant.
Values change dramatically when the heat price falls to 0.031 Euro/kWh and then the plant is not economically viable for the energy crop prices, which also offer an acceptable farmers' net margin.
However, the latter case of heat price derives from an oil price of 0.35 Euro/lt, which is considered very low under current market prices.
Therefore, we can assume that the plant will be able to sell at higher prices, ensuring both its viability and adequate income for the local farming community.

Economic calculations: Current policy (OPE, 1997) supports renewable energy investments with a 45% subsidy on capital cost. This, as seen in Table 8.1.1, is critical for the examined district heating plant.
With no subsidy, NPV presents negative value (- 97,561 Euro) while the plant's IRR falls from 19% to 7%.

It is evident that in this framework the investment is not attractive under economic terms; therefore the resources could be allocated elsewhere, creating profit.

The district heating plant fuelled with cardoon appeared to be a robust project in financial terms under the current subsidisation framework for 'renewable energy investments in Greece. However, in economic terms, with no subsidy, the plants' NPV presents negative value (- 97,561 Euro) while the respective IRR falls from 19% to 7%.
It is evident that in this framework the investment is not attractive under economic terms, therefore the resources could be allocated elsewhere, creating profit.

Table 10.2.3 Total Net impact of the bioenergy plant with and without subsidies

	Unit	Value (incl. Subsidies)	Value (without Subsidies)
Net Additional Labour Income	Euro	18,947	18,825
Net Additional Profit	Euro	264,189	259,359
Net Additional Direct Jobs	Jobs	3.4	3.4
Net Additional Indirect Jobs	Jobs	0.3	0.3
Net Additional Induced Jobs	Jobs	18.9	18.5
Total Net Additional Jobs	Jobs	22.6	22.2

The socio-economic evaluation with BIOSEM indicates that the implementation of a 1MWth district heating plant in Rhodope results to 3.4 net additional jobs and approximately (depending on subsidies and crop selling price fluctuations) 18,948 Euros in terms of additional labour income.
In the table below we can see that depending on the crop selling price the total net additional jobs range from 16.2 to 29 for each 1MWth district heating plant implemented.
However, it should be mentioned that this is due to the increase in the net additional induced jobs. Both the direct and the indirect jobs do not present any sensitivity in the change of crop selling prices and present values of 3.4 jobs and 0.3 jobs, respectively. Using current prices (Commercial and Industrial Service of Rhodope, 2001), in monetary terms this means 30,000 Euro and 2,600 Euro, respectively.

Table 10.2.4. Socio-economic impact in terms of income, profit and jobs for different crop selling prices and heat price 0.041 Euro/KWh.

Crop selling price (Euro/odt)	Net Additional labour Income (Euro)	Net Additional Profit (Euro)	Net Additional Direct Jobs	Net Additional Indirect Jobs	Net Additional Induced Jobs	Total Net Additional Jobs
39.9	18,948	172,183	3.4	0.3	12.5	16.2
45.6	18,948	202,852	3.4	0.3	14.6	18.3
51.3	18,948	233,250	3.4	0.3	16.7	20.4
57	18,946	264,189	3.4	0.3	18.9	22.6
62.7	18,947	294,858	3.4	0.3	21.0	24.7
68.4	18,947	325,527	3.4	0.3	23.2	26.9
74.1	18,947	356,196	3.4	0.3	25.3	29.0

Similar observations can be made concerning net additional labour income, which is estimated by the BIOSEM technique at 18,948 Euros.

As expected, in terms of net additional profit there is a linear increase ranging from 172,183 Euros (crop selling price 39.9 Euro/odt) to 356,196 Euros (crop selling price 74.1 Euro/odt).

In the table below we estimated sensitivity of the above socio-economic factors to the changes of heat selling price.

Table 10.2.5. Socio-economic impact in terms of income, profit and jobs for different heat selling prices and crop price 57 Euro/odt.

Heat selling price (Euro/kWh)	Net Additional labour Income (Euro)	Net Additional Profit (Euro)	Net Additional Direct Jobs	Net Additional Indirect Jobs	Net Additional Induced Jobs	Total Net Additional Jobs
0.031	18,952	228,564	3.4	0.3	17	20.7
0.036	18,950	246,377	3.4	0.3	17.9	21.6
0.041	18,947	264,189	3.4	0.3	18.9	22.6

Net additional labour incomes as well as direct and indirect jobs do not present any sensitivity in the fluctuation of heat selling prices.

On the other hand, net additional induced jobs range from 17 to 18.9 resulting to a respective range in the total net additional jobs from 20.7 to 22.6.

10.3 STRATEGIC ANALYSIS

The strategic analysis was based on the information compiled during the study. The results are shown below.

10.3.1 Internal diagnostics

WEAKNESSES

- *Experience with the selected energy crops is scarce, or in any case non-commercial*

A large number of crops have been investigated for their potential as energy crops in Greece. Only a few, including the two selected ones- cardoon and giant reed- have been grown on larger areas with the support of the Greek Development funds for sustainable agriculture (CRES, 2001).

The situation is similar also at EU level where a few examples exist of energy crops that have reached beyond the stage of R&D and have become commercialised. Venendaal *et al.* (1998) state that these few examples exist due to the political and financial support given by some countries such as France and oilseed crops for biodiesel, UK and Short Rotation Coppice for heat and willow plantations for heat and electricity generation in Sweden (Christersson, 1994).

It is also worthwhile to mention that in Sweden (Rosenqvist, 2000) willow plantations increased from almost nil to 17,000 hectares between 1991 and 1996 (Larsson, 1996) when favourable mechanisms were introduced in the form of subsidies for i) set aside land and ii) willow growing along with heavy taxes on fossil fuels. However, from 1997, the increase has ceased as subsidies for willow plantations were reduced and grain prices have become more volatile.

It is evident from the above that energy crops are still not cultivated unless political support is given in the form of R&D grants, agricultural subsidies and/ or taxation.

- *Management practices for energy crops are less developed than for traditional crops in the area, and therefore they require continuous follow-up.*

The first demonstration plantations in Greece and in Rhodope have shown the following: good advice to farmers is necessary; good and cheap establishment is essential for the long-term production capacity and for the economics; crop water requirement is high and often water availability is the limiting factor for production (this is not the case for cardoon which is anon-irrigated plantation); heterogeneity of fields has a strong influence on yield; fertilisation below recommended levels results in decreased yields.

- *Storage of energy crops needs careful planning.*

Storage of perennial energy crops raw material is necessary to ensure year round delivery because harvesting and end-use periods do not usually coincide.

Crop storage could be done either on the plantation itself or elsewhere on the farm or at an intermediate location or the power generating plant. Special consideration should be given to storage facilities (indoors or outdoors), which are related to the quantity and the particular type of stored material required as well as the access required by commercial vehicles.

Depending on the harvesting method used, the material can be stored in the form of chips, bales, bundles or pellets. Bundles can be stored in simple outdoor facilities uncovered or covered (with plastic). Plastic rainproof cover is recommended to prevent fluctuations in moisture content. Chipped and compacted material as well as bales can be stored effectively under cover, though open-air storage is also possible. Rarely is it stored in advanced storage establishments, such as storage in several types of silos.

Storage conditions and especially moisture content of the harvested material during storage determine its quality. If stored material has high moisture content, it may self heat rapidly and decompose. This leads to loss of dry matter, loss of energy value, danger to human health posed by spores of micro-organisms and danger of fire. Therefore, it is aimed to either reduce storage time or to optimise storage methods in order to minimize the aforementioned problems.

- *Fuel availability*

In a local district- heating plant or small scale power station one single crop does not have to be relied upon since several different biomass and fossil fuels can be used together.

Scandinavian countries and Austria are successful in developing the energy crop industry, partly because they have a long history using biomass from forest and agricultural residues and peat in small power stations, district heating and CHP plants. Novel crops can be slotted into this system (Luger, 1996).

STRENGTHS

- *Benefits might arise from the establishment of energy crops in a local agricultural system.*

The establishment of biomass energy crops local agricultural systems such as that of Rhodope presents advantages in the following aspects:

- The crops can be introduced as supplementary activity for the agricultural system and fit properly in with the conventional crops.

- They could stabilise farm incomes and provide alternative land uses, only if equal treatment was applied in terms of subsidies. This implies that either all subsidies should be removed (which at the moment seems impractical) or a sufficient amount of them should be redirected towards the development of energy farming.
- They will provide local energy production, as well as decrease imports of fossil fuels.

- *Labour force requirements are similar and complementary in terms of timing to traditional ones.*

The proposed energy cropping system in this study, with farmers growing both cardoon and giant reed, would complement other crops very well in terms of timing and harvesting. Giant reed would be harvested in the period January to March, when no other crops are harvested. Cardoon would be harvested in the period July to September, following the harvest of durum, soft wheat and barley in June. Corn harvest in August would be done within the same period as cardoon while cotton harvest in September and October would overlap in time with cardoon harvest.

- *Soil erosion is substantially less when perennial energy crops replace agricultural crops and soil physical properties as well as leaching are in some cases improved (Panoutsou, 1997b).*

Greece is considered one of the most erosion-affected regions of European Union. Cultivation of these perennial energy crops in hilly areas may significantly reduce the erosion risks.
For example, cardoon has a very positive effect on soil erosion from autumn until late spring when most of the precipitation occurs. During this period a very huge canopy develops which offers almost absolute protection from soil erosion.

In conclusion it could be stated that all the perennial crops under consideration for energy purposes in Greece have a positive effect on soil erosion due to their huge canopy compared to many other conventional agricultural crops (such as cereals and cotton) grown in the same areas.

Soil Physical Properties: Perennial energy crops for two basic reasons positively affect soil structure:

1. The huge canopies of energy crops interrupt rainfalls and the water leaches downward to the soil slowly so that the soil structure remains unaffected.
2. One of the main causes for soil structure disintegration is tractors and other machinery movement especially when the soil is wet. Compared to almost all conventional crops energy crops require less tillage and machinery movement.

Concerning *leaching*, we must emphasize that the perennial crops under study and the short rotation coppice plants are planted in dense populations and therefore a thicker root system is encountered through the various soil layers. It is clearly understood that even if nitrate leaching occurs in such plantations there are increased chances for nitrates to be trapped during their downward movement by the richer root systems of these crops compared to the poorer root system of many other agricultural crops.

- *Energy crops can help by minimising problems of security of supply and non uniform-bulky material of low quality, which normally hinder biomass development.*

Dedicated energy feedstocks in the form of energy crops represent the most promising solution in the first two barriers for further bioenergy development. Like the other biomass resources, they can be converted into virtually any energy form. However, their main advantage is that they can be developed to optimise key characteristics for energy applications and their sustained production can better ensure long term large-scale supplies with uniform characteristics.

Energy crops also have significantly higher yields per unit of land area than natural stands. These higher yields improve their cost effectiveness over conventional crops and minimise land requirements, associated chemical use, hauling requirements and other negative environmental impacts.

- *Reliability of the technology with commercial experience (mainly in Denmark, Sweden, Austria).*

A large number of district heating plants already operate in Scandinavian countries and Austria and the respective industry serving supply ((boilers, feeders, automatic operation instruments, environmental control, etc.) and maintenance is well developed. So in our case, reliability of the technology is not going to present problems.

THREATS

- Low fertility of soils for energy crop cultivation.
- Transportation network has low quality and poor maintenance.
- Depopulation is a clear characteristic of the area, with a low specialised labour force.
- *Low commercial and industrial activity could present difficulties in the supply of components.*

This statement means that most of the supplied equipment will have to be brought from foreign countries with respective spending of money abroad and not even nationally.

• *Political variability and interest confrontation (changes in the regional Government and ecological objections).*

Since most of the successful bioenergy projects rely mainly on governmental incentives, it is clear that any political changes in terms of strategic priorities for financial support might have negative effects on further bioenergy development. In addition, special attention should be paid to 'possible' conflicts of interest in local projects that might hinder the development of a bioenergy plant.

OPPORTUNITIES

• *Most of the conventional crops result in negative farm income, prior to subsidies.*

This could be a very good opportunity to think of restructuring the subsidization policies and provide alternative land uses to farmers, locally and nationally. From the analyses conducted in this dissertation it was made clear that cereals and cotton are uneconomic for farmers and for the government thus resulting in surpluses. The development of 'energy cropping' by providing equal opportunities to the respective crops could be a possible outlet for the existing problems.

• *Favourable legislative framework for the installations of industrial and commercial firms in this part of the country.*

Current support mechanisms favour the development of 'new renewable energy projects' in Greece by providing up to 45% subsidies on capital costs. As presented in the respective investment appraisal (Chapter Eight) these funds were critical for the viability of the examined district heating plant.

• *Effects on rural employment and development in a depressed economic area.*

Regions like Rhodope with high agricultural activity and high unemployment level, could take advantages from the development of bioenergy schemes. Some of them are:

- Better use of their agricultural land by producing biomass raw material with environmentally sound and sustainable practices.
- Maintenance of employment in the agricultural sector along with the creation a few jobs at 'village level' where the power plant will be established.

Based on the above strategic analysis the following actions are considered sensible to overcome the weaknesses.

- The lack of commercial experience with the selected energy crops could be improved through a short-scale pilot programme.
- Supply and storage chains must be studied in more detail in order to optimise the costs and land use in the power plant area.
- Training programmes will be necessary for the maintenance labour force.
- Threats related to the transportation network could be avoided with a detailed analysis of alternative supply chains in order to define optimal supply routes.

In addition, there is a large list of strengths obtained through the strategic analysis that need to be confirmed through trials before the final implementation of the project. When confirmed, they must be observed as competitive advantages compared to energy alternatives. Likewise, most of the opportunities detected along the strategic analysis should be utilised.

Therefore, any effects on regional development, rural employment, energy security as well as use of set aside land need to be converted as competitive advantages through a transparent and credible information process.

A conclusion of the strategic analysis, a step head in the successful implementation of the project should confirm the declared strengths and opportunities should improve the discovered weaknesses and should avoid the announced threats.

For all these reasons, some work should to be carried out before the final implementation and more detailed and practical analysis should be developed.

10.4 BIOENERGY INNOVATION

Bioenergy and especially energy cropping are identified as innovations since they are complex processes involving groups of people with different opinions and variant adoption rates.

The author, following the lines of policy analyses and acknowledging that bioenergy deployment should be studied in the context of 'diffusion of innovations' proceeded in examining the diffusion channels as well as the different perceptions of the key groups involved, farmers and potential end users. More specifically, she undertook the steps described below.

First, through a series of meetings of the existing National Biomass Network team, she interviewed the key groups involved and monitored their perceptions. The national team was formed in the framework of the EU funded programme aiming to encourage dialogue between industry, environmental organisations, government and local communities and thereby create a consensus view on bioenergy schemes.

The groups involved in the network consisted of scientists, local planners, environmental groups, farmer co-operatives and government representatives.

Secondly through detailed questionnaire surveys of farmers and end users in the region, she analysed the features of the two main groups involved. Conclusions about the features favouring or hindering adoption of energy crops and bioenergy derived from surveying fifty farmers and fifteen end users in the region.

Results so far prove that real life introduction of bioenergy requires a complex learning process involving numerous players. Improvement often takes place but it is not always the rule. Unless significant resources can be devoted to this learning process, optimal results will not be achieved.

Concerning Greece, the country under study, results of the thesis prove that energy crops present good adaptation and high yielding potential. Especially, cardoon and giant reed which were analysed further in the study can also be economically feasible solutions compared to the conventional crops in the agricultural system of Rhodope.

Although research efforts at the moment continue aiming at increasing yields and handling the produced material there is considerable lack in efforts towards defining market demand and potential customers' requirements.

Following the research on the adoption of bioenergy as innovation and the 'in depth' analysis of the key groups involved the following points were clear:

- Research and development are good and essential to provide better options for the future but at the moment there is an urgent need to take things off the ground and begin to implement a few 'real' projects.
- In order to enhance the development of bioenergy schemes at local and regional level special attention should be given to the market demand for biomass and its energy efficient use in both the domestic and the services sector (space heating, district heating, power generation, etc.).
- Actions should be taken to involve the local actors (planners, authorities, industries, etc.) in the process of understanding the benefits of bioenergy. In that way they will be able to assist in any further development and they will certainly not oppose to it out of ignorance.
- Priority should be given to develop standards for the produced biomass so that they meet the final requirements of the existing and future customers and secondly to increasing their yielding potential. Standards will also be an incentive for the Greek equipment manufactures to become more involved in bioenergy and new options will arise for their businesses.

REFERENCES

1. Abrahamson, L. P., Robison, D. J., Volk, T. A., White, E. H., Neuhauser, E.F., Benjamin, W.H., and J. M. Peterson. 1998. Sustainability and environmental issues associated with willow bioenergy development in New York (U.S.A.). In Biomass and Bioenergy, Vol. 15. No 1, pp. 17 -22. Elsevier Science Ltd. Printed in Great Britain.
2. Agricultural Bank of Greece. 2000. Statistics.
3. AIR Programme. 1992a. AIR-CT92-0041. 'Sweet sorghum': A sustainable crop for energy production in Europe: Agriculture, industrial improvement, optimization and implementation.
4. AIR Programme. 1992b. AIR-CT92-0294. 1992-1995. Miscanthus productivity network.
5. AIR Programme. 1993a. AIR-CT93-1089. 1993-1997. Cynara cardunculus network.
6. AIR Programme. 1993b. AIR-CT-931671. 1994-1996. Development of a standard methodology for integrating non-food production in rural areas with niche energy markets.
7. AIR Programme. 1994a. AIR-CT-942455. 1995-1997. Environmental aspects of biomass production and routes for European Energy Supply.
8. AFB network. 2000. www.vtt.fi./afb
9. Altener Programme 1996. AL/4.1030/94-05. Bioguide. 1996-1998. Best Practice Guidelines for the development of an economically and environmentally sustainable industry.
10. Altener Programme 1997. Altener 4.1030/D/97-029. 1998- 1999. Agriculture and Forestry Biomass Network. PhaseIV
11. Altener 4.1030/Z/98 –593. 1999 – 2000. Agriculture and Forestry Biomass Network. PhaseV
12. ARBRE project. 2001. www.arbre.co.uk.
13. Aruna P.B., Laarman J. G., Araman P., Coulter E., Cubbage F. Used\pallet as a source of pellet fuel: current industry status. Forest Product Journal. 1997; 47(9). Pp 51-56.
14. Badin, J., Kirschner, J., and R., McGuckin. 1999. Biomass Energy- A fuel switching strategy to reduce net carbon emissions and enhance asset utilization. ID #99/58. United BioEnergy Commercialisation Association. www.ubeca.org.
15. BEAVER. Models for the Economic Evaluation of Biomass Cultivation as an alternative land use in the EU. Project AIR CT93 0985
16. Bell, S., 1994. Energy forestry in the landscape. Biomass Bioenergy, 6: 53-62.

17. Beyea, J., Cook, J., Hall, D.O., Socolow, and Williams, R., 1991. Toward ecological guidelines for large-scale biomass energy development. National Audubon Society/ Princeton University Workshop, Audubon Society, New York.
18. Biomass Department, CRES. 2000. Annual activities. In Greek. Center for Renewable Energy Sources. Pikermi, Athens, Greece.
19. Bioenergia, 1993. Bioenergy 93 Conference. Technical Research Centre of Finland Combustion and Thermal Engineering Lab., Jyvaskyla, Finland.
20. BMWF, 1994. Energy from Biomass: R&D in Austria. Federal Ministry of Science and Research, Vienna.
21. Boose, A.B. and Holt, J.S., 1999. Environmental effects on asexual reproduction in *Arundo donax*. Weed Research, 39: 117-127.
22. Bowles 1981
23. Brower, M., C., Tennis, M., W., Denzler, E., W. and M., M. Kaplan. 1993. Powering the Midwest: Renewable electricity for the economy and the environment. Union of Concerned Scientists, Washington, DC.
24. Brown, A. and R. Venendaal. 1996. EECO Country Report for the Netherlands. BTG Biomass Technology Group, Enschede.
25. Brower, M. C., Tennis, M. W., Denzler, E. W. and M. M. Kaplan. 1993. Powering the Midwest: Renewable Electricity for the Economy and the Environment. Union of Concerned Scientists, Washington, DC.
26. Census 1991. National Statistical Service of Greece.
27. Center for Renewable Energy Sources. www.cres.gr
28. Chadwick, L. 1996. Farm management handbook 1996/97. Scottish Agricultural College. Edinburgh 1996. ISBN 1 85482 566 6.
29. Chartier, P. et al. (Editors), 1995. Proc. 8th European Conf. Biomass for Energy, Environment, Agriculture and Industry. Elsevier, Oxford.
30. Clarke J.F, Edmonds J. A. Modelling energy technologies in a competitive market. Energy Economics. 1993. pp. 123-129.
31. Christersson, L., Senneby- Forsse, L. 1994. The Swedish programme for intensive short-rotation forests. In Biomass and Bioenergy 6. pp. 145- 9.
32. Christou, M., D. Papavassiliou, E. Alexopoulou and Chatziathanassiou, A., 1998. Comparative Studies of Two Potential Energy Crops in Greece. In "Biomass for Energy and Industry". Proc. 10th European Conference. Ed. Chartier et. al., C.A.R.M.E.N. Press. Germany. 935-938.

33. Christou, M., Mardikis, M., and E., Alexopoulou. 2000a. Propagation material and plant density effects on the Arundo donax yields. 1st World Conference and Exhibition on Biomass for Energy and Industry, 5-9 June 2000, Sevilla, Spain.

34. Christou, M., Alexopoulou, E., and M. Mardikis. 2000b. Giant Reed (Arundo donax L.) Network Improvement. Productivity and Biomass Quality. 1st World Conference and Exhibition on Biomass for Energy and Industry, 5-9 June 2000, Sevilla, Spain.

35. Christou, M., Mardikis, M., Kyritsis, S., Cosentino, S., Jodice, R., Vecchiet, M. and G. Gosse. 2000c. Screening of Arundo donax populations in south Europe. 1st World Conference and Exhibition on Biomass for Energy and Industry, 5-9 June 2000, Sevilla, Spain.

36. Commercial and Industrial Service of Rhodope. 2001. www.rodopicci.gr/prefecture/economy.

37. Cook, J.H., Beyea, J. and Keeler, K. H. 1991. Potential impacts of biomass production in the US on biological diversity. Ann. Rev. Energy Environ., 16: 401-431.

38. CRES, 2000a. www.cres.gr

39. CRES, 2000b. Renewable energy statistics. National Report for EUROSTAT.

40. Curt, M. D., Aguado, P. L., Fernandez, J. 1998. Adaptation of *Cynara cardunculus* photosynthesis to winter Mediterranean temperatures. Proc. 10th European Conference and Technology Exhibition "Biomass for Energy and Industry. Ed. C.A.R.M.E.N. Germany. 846- 848 pp.

41. Dalianis, C., Sooter, Ch. and Christou, M., 1994a. Growth and Biomass Productivity of *Arundo donax* and *Miscanthus sinensis "giganteus"*. In 'Biomass for Energy, Environment, Agriculture and Industry'. Proc. 8th EU Biomass Conference. Ed. Chartier, et.al., Pergamon Press, Oxford, UK. 575-582 pp.

42. Dalianis, C. D., Christou, M., Sooter, Ch., Kyritsis, S., Zafiris, C., and Samiotakis, G., 1994b. Adaptation and biomass productivity of *Cynara cardunculus* in abandoned, marginal fields. In "Biomass for Energy and Industry". Proc. 7th EU Biomass Conference. Ed. Hall et. al., Ponte Press, Bochum Germany. 1235-1240 pp.

43. Dalianis, C., 1995. Non-wood Energy crops for Southern EU. Seminar AFB-NETT European Agriculture and Forestry Network. Glasgow, UK. October 11.

44. Dalianis, C., Panoutsou, C. and N. Dercas. 1996a. Spanish Thistle Artichoke, *Cynara cardunculus* L., under Greek Conditions. In '*Biomass for Energy and Environment*'.

Proc. 9th European Bioenergy Conference. Ed. Chartier et. al., Pergamon Press U.K. 663-668 pp.

45. Dalianis, C. and C. Panoutsou. 1996b. Energy potential of agricultural residues in EU. Report for EC Project: APAS- RENA CT 940053: EUREC NETWORK ON BIOMASS (BIOELECTRICITY).
46. DEH. 2000. Sales of electricity. Public Power Corporation Statistical Office. Athens. Greece.
47. Dercas, N., Panoutsou, C. and N. Djouras. 1996. Environmental impacts from biomass production and exploitation. In "Biomass exlpoitation for electricity production from DEH in Greece". CRES. 285- 302 pp.
48. Development Law 2601/98.
49. EC Directive 1964/87.
50. EC Directive 1201/89.
51. EC Directive 1554/95.
52. EC Regulation 1251/1999 for set aside land.
53. El Bassam, N., 1998. Energy plant species. James & James. London.
54. Elliot, P. 1995. Energy market overview- Heat and Power. In Biomass for Energy, Environment, Agriculture and Industry, 8th E.C. Conference, 129. ed. P. Chartier, A. Beenackers and G. Grassi. Pergamon Press, Oxford.
55. EPRI, 1993. Host Utility. March 1993, HU-102164. Electric Power Research Institute, Palo Alto, CA, USA.
56. ETSU B 1322. 1993a. Farmers' current attitudes to energy forestry in Great Britain.
57. ETSU B/W5/00340/REP. 1993b. Public perceptions of short rotation coppice.
58. European Union. 1995. Regional Development Studies. Development prospects of the central Mediterranean regions (Mezzogiorno- Greece). ECSC- EAEC. Brussels, Luxemburg.
59. European Union. 1996. State of Agriculture in the European Union.
60. European Commission. 1998. Working document of non-food crops in the context of Agenda 2000.
61. European Commission. 2000a. Biomass. An Energy Resource for the European Union. Luxembourg: Office for Official Publications of the European Communities

62. European Commission. 2000b. Energy in Europe. 1999- Annual Energy Review. ISBN 92-828-7448-6. Luxembourg: Office for Official Publications of the European Communities, 2000.

63. European Union. (1996). State of Agriculture in the European Union.

64. European Union. Regional Development studies. (1995). Development prospects of the central Mediterranean regions (Mezzogiorno - Greece). ECSC - EAEC. Brussels. Luxemburg.

65. FAIR Programme. 1996a. FAIR CT96 1389. 1996- 1999. Socio-economic Multiplier Technique for Rural Diversification Through Biomass Energy Deployment.

66. FAIR Programme. 1996b. FAIR CT 96 2028: Arundo donax network

67. FAO. 2000

68. Fernandez., J. 1991. Production and utilization of *Cynara cardunculus* L. Biomass for Energy, Paper-pulp and Food Industry. In "*Biomass for Energy, Industry and Environment*". Ed. Grassi et. al., Elsevier Applied science. London. pp. 312-316.

69. Fernandez, J., Curt, M. D., Hidalgo, M. 1996. Nutrient extraction by the harvestable biomass of *Cynara cardunculus* L. Proc. 9th European Bioenergy Conference. Ed. Chartier et. al., Pergamon Press U.K. 467- 472 pp.

70. Foster, C. (1995). BIOGUIDE Project.

71. General Directorate for Agriculture in Rhodope. 2000. Personal Communication.

72. Gittinger, J. P. 1995. Economic analysis of agricultural projects. EDI Series in economic development. World Bank.

73. Gosse, G. 1994. Environmental issues and biomass. In Biomass for Energy, Environment, Agriculture and Industry. 8th EC Conference. Ed. Ph. Chartier, A.A.C.M. Beenackers, G. Grassi, pp. 52-62.

74. Graham, R. L., and Walsh, M. 1995. Evaluating the economic costs, Benefits and Tradeoffs of dedicated biomass energy systems: the importance of scale. In the Proceedings OF second Biomass Conference of the Americas: Energy, Environment, Agriculture and Industry. Pp 207- 215. Portland, Oregon; published by National Renewable Energy Laboratory, Golden, Colorado.

75. Graham, R.L., Liu, W., Downing, M, Noon, C. E., Daly, M., and A. Moore. 1997. The effect of location and facility demand on the marginal cost of delivered wood chips from energy crops: a case study of the state of Tennessee. In Biomass and Bioenergy, Vol. 13, No 3, pp. 117- 123. Elsevier Science Ltd. Printed in Great Britain.

76. Graham, R. L., Lichtenberg, E., Roningen, V.O, Shapouri, H., and Walsh, M. 1999. The economics of biomass production in the United States. Msc. Thesis. Oak Ridge National Laboratory.

77. Graham, R. L., English, B. C., and C. E. Noon. 2000. A Geographic Information System-based modelling system for evaluating the cost of delivered energy crop feedstock. In Biomass and Bioenergy, Vol. 18., pp. 309- 329. Elsevier Science Ltd. Printed in Great Britain.

78. Greek Centre for Solid Fuels Technology and Application (CSFTA)

79. Gosse, G. (1994). Environmental issues and biomass, *in* Biomass for Energy Environment Agriculture and Industry 8th E.C. Conference, editors Ph. Chartier, A. A. C. M. Beenackers, G. Grassi, Pp. 52 - 62.

80. Greenpeace. 1997. Energy subsidies in Europe. Vrije University, Amsterdam.

81. Gumz, R. G., Saupe, W. E., Klemme, R. M. and J.L. Posner. 1994. A four years gross margins comparison of three cash grain rotations. In Managing the Farm 27. pp. 1-9.

82. Gustaffson, L. (Editor) 1994. Environmental aspects of energy forestry cultivation. Biomass Bioenergy, 6 (Spec. Iss.): 1-58.

83. Hall, D.O. and de Groot, P.J., 1988. Biomass for fuel and food – a parallel necessity. In K.W. Boer (Editor), Advances in Solar Energy, Vol. 4. Plenum Press, New York, pp. 1-90.

84. Hall, D.O., Rosillo- Calle, F., Williams, R.H. and Woods, J., 1993. Biomass for Energy: Supply Prospects. Chapt. 14. In: B.J. Johansson, H. Kelly, A.K.N. Reddy and R.H. Williams (Editors), Renewables for Fuels and Electricity. Island Press, Washington, DC.

85. Hall, D.O. and House, J.I. 1994. Biomass as a modern fuel. In: C.P. Mitchell and A.V. Bridgewater (Editors), Environmental Impacts on Biomass. CPL Press, Newbury, UK, pp. 81-114.

86. Hall, D.O., Rosillo- Calle, F., and Scrase, J. I. 1996. Biomass: An environmentally acceptable and sustainable energy source for the future, Report to the Division of Sustainable Development, United Nations, New York.

87. Hall, D. O. and J. I. Scrase. 1998. Will biomass be the environmentally friendly fuel of the future? In Biomass and Bioenergy, Vol. 15. Nos 4/5, pp. 357- 367. Elsevier Science Ltd. Printed in Great Britain.

88. Hanegraaf, C. M., Biewinga, E.E, and G. van der Bijl. 1998. Assessing the ecological and economic sustainability of energy crops. In Biomass and Bioenergy Vol.15, Nos 4/5. pp. 345-355. Elsevier Science Ltd. Printed in Great Britain.

89. Hartmann, D. and M. Kaltschmitt. 1999. Electricity generation from solid biomass via co-combustion with coal. Energy and emission balances from a German case study. In Biomass and Bioenergy, Vol. 16., pp. 397- 406. Elsevier Science Ltd. Printed in Great Britain.

90. Hevin, C. 1996. EECO Country Report for France. ADEME.

91. Hillring, B. 1997. Price trends in the Swedish wood- fuel market. Biomass and Bioenergy, 12, 41-51.

92. Hohenstein, W.G. and Wright, L.L., 1994. Biomass energy production in the United States: An overview. Biomass and Bioenergy, 6 (3), 161-173.

93. Howes, R., 1992. Set- aside and energy policy: The potential of short rotation energy forestry. M. Sc. Thesis, Center for Environmental Technology, Imperial College, University of London.

94. Hughes, M. and J., W., Ranney. 1993. Environmental issues related to biomass: an overview. In Proc. of the First Biomass Conference of the Americas. National Renewable Energy Laboratory. U.S. Department of Energy, Washington, DC.

95. IEA, 1994 World Energy Outlook. International Energy Agency, OECD, Paris.

96. Jodice, R., Vecchiet, M., Schenone, G., and Parrini, F., 1994. Giant reed multiplication and cultivation experiences. The 8th Conference on Biomass, Vienna, 1994.

97. Jodice, R., Vecchiet, M., Schenone, G., and Parrini, F. 1998. Giant reed as energy crop: Initial economic evaluation of production costs in Italy

98. Jordan, V.W.L. (Editor), 1993. Agriculture- scientific basis for codes of good agricultural practice. EUR 14957, Commission of EC, Brussels.

99. Jorgensen, U. and E. F. Kristensen. 1996. EECO Country Report for Denmark. Danish Technological Institute of Agricultural Science, Department of soil, Tjele/ Horses.

100. JOULE Programme. 1992. JOUB-0036. Sweet sorghum productivity network

101. Kaltschmitt, M., Lewandowski, I., Stelzer, T., Hardtlein and A. Bohn. 1996. EECO Country Report for Germany. IER, University of Stuttgart/ Institut fur Pflazenbau und Grhnland, University of Hohenheim, Stuttgart.

102. Kaplow, D.N., 1993. Federal energy subsidies: energy, environment and fiscal impact. The Alliance to Save Energy, Washington, DC.

103. Keeney, D. R. 1994. New crops and new uses: discovering common ground. Leopold letter 6. pp 3-10.

104. Klass, D., L. 1995. Biomass in north American policies. In Energy policy. Vol. 23. No. 12, pp. 1035-1048. Elsevier Science Ltd. Printed in Great Britain.

105. Kort, J., Collins, M., and Ditsch, D., 1998. A review of soil erosion potential associated with biomass crops. Biomass and Bioenergy, 14 (4), 351-359.

106. Kypriotis E. 2000. Personal communication.

107. KYOTO PROTOCOL

108. Laboratory of Steam Boilers and Thermal Plants (NTUA)

109. Laboratory of environmental fuels and hydrocarbons (CPERI)

110. Larsson, S., Rosenqvist, H. 1996. Willow production in Sweden- politics, cropping development and economy. In: Paper presented at the European Energy Crops Conference. 30 September- 1October. Enschede, The Netherlands, Organised by BTG Biomass Technology Group B.V.

111. Liapis, A. 1993. Komotini and the surrounding area. An outline. History-Archaeology- Places of interest. Second revised edition. Cultural Association of Komotini.

112. Ledig, F.T., 1981. Silvicultural systems for the energy efficient production of fuel biomass. In: D.L. Klass (Editor), Biomass as a Non Fossil Fuel Source, Symp. 144, American Chemical Society, Washington, DC.

113. Ledin, S. and Alriksson, A., 1992. Handbook on How to Grow Short Rotation Forests. Swedish University of Agricultural Sciences, Uppsala.

114. Luger, E., Rathbauer, J., Worgetter, M. and B. Blumauer. 1996. EECO country Report for Austria. BLT Federal Institute of Agricultural Engineering. Wieselburg.

115. Makeschin, F., 1994. Soil ecological aspects of arable land afforestation with fast growing trees. In: D.O. Hall et al. (Editors), Biomass for Energy and Industry, VIII EC Biomass Conference, Pronte Press, Bochum, Germany, pp. 534-538.

116. Maniatis, K. and E. Millich. 1998. Energy from biomass and waste: the contribution of utility scale biomass gasification plants. In Biomass and Bioenergy Vol. 15, No 3, PP. 195- 200. Elsevier Science Ltd. Printed in Great Britain.

117. Mardikis, M., Namatov, I. and Panoutsou, C., 2000. Research and technological development in the field of energy crops in Greece. 1st World Conference and Exhibition on Biomass for Energy and Industry, 5-9 June 2000, Sevilla, Spain.

118. Martinez, J. M., Escalada, R., Murillo, J. M., Carasco, J. E. 1998. Feasibility study of the fluidized bed combustion of *Cynara cardunculus* biomass in BAFB pilot plant. Proc. 10th European Conference and Technology Exhibition "Biomass for Energy and Industry. Ed. C.A.R.M.E.N. Germany. 1420- 1423 pp.

119. Merret, A. J., and Allen Sykes. 1973. The Finance Analysis on Capital Projects. 2d rev. ed. London: Longman.

120. Millich, E., Maniatis, K. and A. Kotronaros. 1997. Renewable energy technologies: from demonstration to implementation. The European Congress on RES implementation. Athens- Greece 5-7 May.

121. Ministry of Agriculture in Greece. 2001. Subsidies for wheat and cotton. www.minagric.gr

122. Mitchell, C. P, Stevens, E.A and M.P. Watters. 1999. Short-rotation forestry-operations, productivity and costs based on experience gained in the UK. In Forest Ecology and Management, 121. pp. 123- 136.

123. Mitchell, C. P. 2000. Development of decision support systems for bioenergy applications. In Biomass and Bioenergy, Vol. 18., pp. 265- 278. Elsevier Science Ltd. Printed in Great Britain.

124. National Statistical Service of Greece. Statistical Yearbook. 2000.

125. National Statistical Service of Greece. Provisional National Account. 2000.

126. National Statistics on employment and unemployment, 2000.

127. Nielsen, C., 1992. Straw-fired decentralised combined heat and power plants in Denmark. In: G. Grassi, A. Collina and H. Zibetta (Editors), Biomass for Energy, Industry and Environment – 6th EC Conference. Elsevier, London, pp. 1143- 1145.

128. Netherlands Scientific Council for Government Policy, 1992. Ground for choices: Four perspectives for the rural areas in the European Community. Reports to the Government, The Hague.

129. NSSG, 1997-99: Estimates and Forecasts of the Directorate of Macroeconomic Analysis

130. OECD/ IEA, 1985 – 1988. World Energy Statistics and Balances. 1985-1988. OECD/ IEA, Paris.

131. OECD, 1994. Biofuels. OECD/ IEA, Paris.

132. OECD, 2000. Country Report- Greece.

133. Office of Technology Assessment, 1993. Potential environmental impacts of bioenergy crop production. OTA, US Congress, Washington, DC.

134. Official Gazette of the Hellenic Republic. (1994). First Issue, No 168, October 7. Act No 2244.

135. Olsson, R., Hadders, G., Landstrom, S. and J. Burvall. 1996. EECO Country Report for Sweden. Swedish University of Agricultural Sciences/ Swedish Institute of Agricultural Engineering, Umea/ Uppsala.

136. OPE. Operational Programme for Energy, (1997). Ministry of Development.

137. Paine, L. K., Peterson, T. L., Undersander, D. J., Rineer, K. C., Bartelt, G. A., Temple, S. A., Sample, D. W. and R. M. Klemme. 1996. Some ecological and socio-economic considerations for biomass energy crop production. In Biomass and Bioenergy Vol. 10. No.4. pp.231- 242.Elsevier Science Ltd. Printed in Great Britain.

138. Panoutsou, C. 1996. Energy crops in Greece. In "Biomass exploitation for electricity production from DEH in Greece". CRES. 106-119 pp.

139. Panoutsou, C. and C. Dalianis. 1997a. *Cynara cardunculus* L. under Greek climatic conditions. *Final Report for EC Project: AIR3 CT 931089.*

140. Panoutsou, C., Christou, M. and C. Dalianis. 1997b. "Perennial energy crops in Greece. The development of an economically and environmentally sustainable industry. Best Practice Guidelines." *2nd Progress Report for AL/4.1030/94-05. BIOGUIDE.*

141. Panoutsou, C. 1998a. Energy potential of agricultural residues in EU. Proc. 10th European Conference and Technology Exhibition "Biomass for Energy and Industry. Ed. C.A.R.M.E.N. Germany. 863-866 pp.

142. Panoutsou, C. and E. Kipriotis. 1998b. Economic viability of energy plantations in farming systems of Rhodope county- Thrace. Proc. 10th European Conference and Technology Exhibition "Biomass for Energy and Industry. Ed. C.A.R.M.E.N. Germany. 870-873 pp.

143. Panoutsou, C., Nicholaou, A., and S. Rozakis. 1998c. Energy production from agricultural biomass in Greece: Synergies and antitheses of actors involved in the BIOGUIDE project. Proc. 10th European Conference and Technology Exhibition "Biomass for Energy and Industry. Ed. C.A.R.M.E.N. Germany. 1173-1176 pp.

144. Panoutsou, C. 1998d. An important mechanism for the promotion of RES applications in Greece. Operational Program for Energy - Biomass. ALTENER 4.1030/D/97-029. AFB Newsletter 3.

145. Panoutsou, C. 1998e. Regional review of nomos Rhodope. Socio-economic aspects affecting the implementation of bioenergy systems in the region. *1st Progress Report for FAIR CT 96 1389: BIOSEM.*

146. Panoutsou, C., Alexopoulou, E. and A. Nikolaou. 1999. Greece: National Report on Biomass. AFB IV & BIOGUIDE III.

147. Panoutsou, C., Kipriotis, E., and Soldatos, P. 2000a. Estimation of energy crops breakeven points in northern Greece. 1st World Conference and Exhibition on Biomass for Energy and Industry, 5-9 June 2000, Sevilla, Spain.

148. Panoutsou, C. 2000b. Research and technological development in the field of bioenergy in Greece. Presented in the World Renewable Energy Conference. Brighton-UK. 1-7 July 2000.

149. Panoutsou, C. 2000c. European Research Area (ERA) on Biomass. The case of Greece. Presentation to the "ERA on Biomass" meeting. Brussells, 20, 21st November. European Commission. DG Research.

150. Pari, L. 1996. Alternative crops mechanization: first trials of *Cynara cardunculus* harvesting. Presented at AGENG' 96. Madrid. 23-26 September.

151. Pari, L. 1996. *Cynara cardunculus* harvesting mechanisation. In '*Biomass for Energy and Environment*". Proc. 9th European Bioenergy Conference. Ed. Chartier et. al., Pergamon Press U.K. 467- 472 pp.

152. Pasztor, J. and Krostoferson, L.A. (Editors), 1990. Bioenergy and the environment. Westview Press, Boulder, CO.

153. Parfomak, P. W. 1997. Falling generation costs, environmental externalities and the economics of electricity conservation. Energy Policy, 25. pp. 845- 860.

154. Patterson, W. and Grubb, M. 1996. Liberalising European Electricity: impacts on generation and the environment, Royal Institute of International Affairs Briefing Paper.34.

155. Perdue, R.E., 1958. *Arundo donax* – source of musical reeds and industrial cellulose. Economic Botany, 12, 368-404.

156. Rahmani, M., Hodges A.W., Stricker J.A. and C. Ki. 1998. Cost analysis of biomass to energy systems. A case study in central Florida. Proc. 10th European Conference and Technology Exhibition "Biomass for Energy and Industry. Ed. C.A.R.M.E.N. Germany. 1162- 1165 pp.

157. Rakos C. 1995. The diffusion of biomass district heating in Austria. Project report to the European Commission. Institute of Technology Assessment, Austrian Academy of Sciences, Vienna.

158. Raneses, A., Hanson, K., and Shapouri, H. 1998. Economic impacts from shifting cropland use from food to fuel. In Biomass and Bioenergy, Vol. 15. No 6, pp. 417- 422. Elsevier Science Ltd. Printed in Great Britain.

159. Ranney, J.W., 1992. Environmental considerations in biomass resource management for a greenhouse –constrained society. In: M.A. Kuliasha et al. (Editors), Technologies for a Greenhouse –constrained Society. Lewis, Boca Raton, FL, pp. 519-546.

160. Ranney, J.W., 1994a. Principles and issues of biomass energy crops and the environment. In: D.O.Hall, G. Grassi and H. Sheer (Editors) Biomass for Energy and Industry, VII EC Biomass Conference, Pronte Press, Bochum, Germany, pp. 60-71.

161. Ranney, J.W. and Mann, L.K., 1994b. Environmental considerations in energy crop production. Biomass and Bioenergy, 6 (3), 211-228.

162. Ravn –Jenson, L., 1992. Danish experiences from combustion of straw. In: G. Grassi, A. Collina and H. Zibetta (Editors), Biomass for Energy, Industry and Environment – 6th EC Conference. Elsevier, London.

163. Reihardt, G. A, Herbener, R. and N. Junk. 2000. Life Cycle Analysis of perennial rhizomateous grasses versus fossil fuels. 1st World Conference and Exhibition on Biomass for Energy and Industry, 5-9 June 2000, Sevilla, Spain. pp 2106- 2109. 2001 James and James (Science Publishers) Ltd.

164. Richards, K. 2000. Realising the vision of a green business community. In Renewable Energy. Renewables: The Energy for the 21st century. pp. 1280- 1287. World Energy Congress VI. 1-7 July 2000. Brrighton. UK.

165. Richards, K. 2001. Personal Communication.

166. Roberts, J and C. A . Foster. 1996. EECO Country Report for United Kingdom. AEA technology, Harwell, Oxfordshire.

167. Rogers, E. M. 1995. Praise for diffusion of innovations. 3rd Edition. THE FREE PRESS. Printed in USA.

168. Rosenqvist, H., Roos A., Ling, E. and b. Hector. 2000. Willow growers in Sweden. In Biomass and Bioenergy 18. pp. 137- 145. Elsevier Science Ltd.

169. Rosillo- Calle, F.R., Furtado, P. and Hall, D.O., 1994. Brazil charcoal. In: D.O.Hall, G. Grassi and H. Sheer (Editors) Biomass for Energy and Industry, VII EC Biomass Conference, Pronte Press, Bochum, Germany, pp. 779-785.

170. Saez, R. M., Linares, P. and J. Leal. 1998. Assessment of the externalities of biomass energy and a comparison of its full costs with coal. In Biomass and Bioenergy, Vol. 14. Nos 5/6, pp. 469- 478. Elsevier Science Ltd. Printed in Great Britain.

171. Sarigiannis, D. (1991). Social aspects of biomass use for development at the local level in the Mediterranean, *in* Biomass for Energy and Industry, 6th E.C. Conference, editors Ph. Chartier, A. A. C. M. Beenackers, G. Grassi, Pp. 75 - 79.

172. Shell/ WWF, 1993. Guidelines. In Shell/ WWF Tree Plantation Review, Shell International Petroleum Co., London.

173. Sims, R.E.H. and Riddell-Black, D., 1998. Sustainable production of short rotation forest biomass crops using aqueous waste management systems. Biomass and Bioenergy, 15 (1), 75-81.

174. Soldatos, P.G. 1996. Large-scale biomass cultivation for energy in the EU. Evaluation of long-term impact on farm income, employment and the environment. In RE development. Proc. of the EC Conference and the Contractor's meeting. Pp. 315-319.

175. Stern P.C. Blind spots in policy analysis: what economics doesn't say about energy use. Journal of Policy Analysis and Management. 1986; 5. pp 200- 227.

176. Strauss, C. H. and Wright, L. 1990. Woody biomass production costs in the United States: An economic summary of commercial populus plantation systems. In Solar Energy, Vol. 45. No 2. Pergamon Press Inc.

177. STRIDE HELLAS. 1992. STRIDE HELLAS 289. 1992-1994. An integrated and innovative R&D approach exploring the potential of biofuel production in Greece from renewable biomass resources.

178. Swedish National Board for Industrial and Technical Development, 1992. Energy in Sweden 1992. S-117 86. NUTEK, Stokcholm, Sweden.

179. Technical Research Centre of Finland, 1992. New options in bioenergy from Finland. VTT, Laboratory of Fuel and Process Technology, Espoo, Finland.

180. The Centre for Biomass Technology. 1998. Straw for energy production. Technology- Environment- Economy. Second Edition. ISBN: 87- 90074-20-3.

181. Thermie, 1994. Proc. European Workshop on Market Penetration of Biomass Technologies, Commission of the EU, DG XVII, Brussels.

182. Tucker, G.C., 1990. The genera of Arundinoideae (Graminae) in the southeastern United States. Journal of the Arnold Arboretum, 71(2), 145-177.

183. Turhollow, A.H., 1991. Economics of dedicated energy crop production. ORNL, Oak Ridge, TN.

184. Turhollow, A. 1994. The economics of energy crops production. In Biomass and Bioenergy, Vol. 6. No 3, pp. 229- 241. Elsevier Science Ltd. Printed in Great Britain.

185. Turnbull, J.H. 1996. Strategies for achieving a sustainable clean and cost effective biomass resource. In Biomass and Bioenergy, Vol. 10. No 2-3, pp. 93-100. Elsevier Science Ltd. Printed in Great Britain.

186. Unteregger, E., 1992. Country report for short rotation forestry: Austria. In: S. Ledin and A. Alriksson (Editors). Handbook on How to Grow Short Rotation Forests. Swedish University of Agricultural Sciences, Uppsala, pp. 10.1.1 –10.1.4.

187. Varela, M., Lechon, Y., and R. Saez. 1999. Environmental and socio-economic aspects in the strategic analysis of a biomass power plant integration. In Biomass and Bioenergy, Vol. 17. pp. 405- 413. Elsevier Science Ltd. Printed in Great Britain.

188. Venendaal, R., Jorgensen, U. and C. A. Foster. 1997. In Biomass and Bioenergy Vol. 13, No.3, pp. 147- 185. Elsevier Science Ltd. Printed in Great Britain.

189. Vinterback J., Roos A., Folk R., Rakos C, Grubl A. Pellet consumers in Austria, Sweden and thhe United States. In: Wickert D., editor. Proceedings of the 8th Bionnal Conference, Bioenergy '98, Expanding Bioenergy Partnerships. Madison (WI, USA): Great Lakes Regional Biomass Energy Program, 1998. p. 134- 142.

190. Walsh, M. 1994. The cost of producing dedicated energy crops: Comparisons with conventional crops. Oak Ridge National Laboratory.

191. White Paper: Energy for the future: Renewable Sources of Energy, COM (97) 599.

192. Woolsey, E., L., and G. Hallberg. 1993. Switchgrass to electricity: power generation and jobs creation. Biomass Conference of the Americas, 30 August. NREL, Golden, CO.

193. Wormald, T.J. 1992. Mixed and pure forest plantation in the tropics and subtropics. For Pap. No. 103, FAO, Rome.

APPENDIX I: Energy crops tested under Greek climatic conditions

(Source: National Report on biomass. 1999. Panoutsou *et al.*)

Annual Energy Crops

	Description of the Crop	Yields	Biofuel	Market
Sweet sorghum	Sweet sorghum is an annual crop with high photosynthetic rate among crop plants, high biomass yields potential, high percentage of easily fermentable sugars and combustible organic (fiber), tolerant to water stress and with low nitrogen requirements. Furthermore, sweet sorghum is a crop with wide adaptability to different soils and weather conditions, showing higher biomass yields especially in southern EU countries. During the last nine years several varieties and cultural practices have been already explored throughout Greece. Among all the tested varieties c.v. Keller was proved the best adapted as well as the most productive in Greece. In addition, c.v. Keller has been tested under many different cultural practices (plant densities, irrigation and fertilization rates).	In Greece, fresh biomass yields ranged from 71 t/ha to 141 t/ha and dry biomass yields from 20.3 t/ha to 49.1 t/ha, depends on the site, the variety and the cultural practices.	Ethanol	Energy (Transportation)
Brassica carinata	Brassica carinata is considered as a potential crop for biomass and industrial non-food oil production. Experiments are being conducted in Greece during the last two years on their adaptability and their yielding potential. Several *Brassica carinata* varieties were examined (BRK-85, BRK-160, BRK-146, BRK-99, BRK-131, BRK-60, BRK-13, BRK-95, BRK-155, BRK-159, BRK-81, BRK-13, BRK-24, BRK-75, BRK-77, BRK-55 and BRK-26) in two regions, Kopaida (central Greece) and Komotini (northern Greece) in order to test both the adaptability and biomass productivity to both cold and mild climatic conditions. Experimental results indicate that *Brassica carinata*, being a native crop of the Mediterranean basin, is very cold sensitive.	The most promising variety, in terms of fresh biomass and dry matter yields was BRK-24 in central Greece with 20.56 t/ha and 12.57 t/ha, respectively, during the final harvest (late June 1997). In northern Greece, the most productive variety was BRK-13, which reached at 6 t/ha and 5.3 t/ha fresh biomass and dry matter yields, respectively.	Biodiesel	Energy (Transportation)

ENERGY CROP	Description of the Crop	Yields	Biofuel	Market
Kenaf	Kenaf (*Hibiscus cannabinus* L.) is a short day, annual plant possessing high quality cellulose. The stems consist of central pith with short wood fibres and a bark with long fibres, while high quality paper can be made from long fibres. It is capable of adapting itself to a large variety of climatic and soils conditions, although since it is sensitive to frost, it is best grown to tropical and subtropical locations. A well drained, sandy loam soil, about neutral in reaction with a considerable quality of humus it appears to suit best the requirements of the plant. In Greece, several varieties have all been tested during the last five years and total fresh dry biomass yields depends on the variety, cultural practices and soil climatic conditions of the area of cultivation.	Fresh biomass yields ranged from 29.5 t/ha for the early variety PI 3234923 to 60.9 t/ha for the late variety Everglades 71. The corresponding values for the dry matter were 6.93 to 6.39 t/ha.	Solid biofuel	Energy (heat & electricity) Non - energy (pulp)
Fiber sorghum	Fiber sorghum is also a C_4 annual crop with a great potential for energy purposes and pulp production. Unlike sweet, fiber sorghum has relatively low yields in fermentable sugars and its energy potential is based mainly in the high ligno-cellulosic fiber percentage. Several hybrids are being tested in France, Italy and Greece under various cultural practices. In fiber sorghum, sugar content ranged from 9-12% of dry matter (2 t/ha) most of the stalk dry matter was represented by ligno-cellulosic fiber (20 t/ha). It must also be stated that according to experimental data, lodging which is a serious bottleneck for sweet sorghum doesn't exist for fiber.	Five fiber sorghum hybrids, H130, H58, H132, H173 and H202, have been tested. Fresh and dry matter biomass yields reached up to 110.36 t/ha and 31 t/ha for fiber sorghum (H202), respectively.	Solid biofuel	Energy (heat & electricity) Non-energy (pulp)

Perennial Energy Crops

ENERGY CROP	DESCRIPTION OF THE CROP	YIELDS	BIOFUEL	MARKET
Giant reed	Giant reed is a native of the Mediterranean countries and, therefore, naturally adapted to south EU agro-climatic conditions. Certain wild grown genotypes attain a height of 6 meters or more with peak growth rates up to 7 cm/day. Giant reed is a potentially high yielding non-food crop that could meet EU market requirements for energy, paper and other industrial uses.	In Greece, the final plant height of two years old plants was 5.80 m while fresh and dry matter biomass yields for autumn cuttings were 58.56 t/ha and 31.47 t/ha, respectively. Calorific value of 17.1 MJ/kg was determined and based on this value energy potential up to 12.9 toe/ha/year was estimated.It should be stressed out that these high yields were obtained from unimproved wild populations and conventional cultural methods. This indicates the great biomass potentiality of this energy crop for the future.	Solid biofuel	Energy (heat & electricity) Non - energy (building materials, pulp)
Cardoon	Cardoon is a perennial herbaceous species, traditionally cultivated in some places of the Mediterranean area, for human consumption of its leaf petioles and for cheese making. Like most thistle species, it is very well adapted in southern semi-arid EU conditions and as a winter crop its reaches its maximum biomass yields by exploiting the available soil moisture of the autumn and winter rainfalls. In addition, due to its winter growth and to its robust rooting system, it offers protection against soil erosion in sloping and marginal lands.	In experiments, conducted in central Greece, the final plant height reached up to 2.60 m, while dry biomass yields, depending on plant density (10,000 plants/ha to 50,000 plants/ha) ranged from 16.96 to 31.67 t/ha, respectively. Representative values for the energy potential ranged from 6.9 to 12.9 toe/ha.	Solid biofuel	Energy (heat & electricity, transportation) Non - energy (pulp)

ENERGY CROP	Description of the Crop	Yields	Biofuel	Market
Eucalypt	Eucalypts has been extensively used for energy production worldwide (Brazil, India, South Africa). In EU some 850,000 ha are covered by eucalypt plantations, consisting of two species (E. globulus and E. camandulensis) managed under short rotation time of 8-13 years, for pulp and paper production. In Greece, very short rotation times (2-3 years) and dense plantations (10,000 – 40,000 plants/ha) have been studied in various regions.	Depending on soil fertility and cultural practices (irrigation, fertilization and plant density) dry matter yields up to 35 tons/ha/year have been obtained with a respective energy potential up to a 15 toe/ha/year.	Solid biofuel	Energy (heat & electricity) Non - energy (pulp)
Switchgrass	Switchgrass (*Panicum virgatum* L.) is a perennial C4 grass native to North America. Switchgrass has been used as a forage crop for many years in the United States and Canada, and its currently being developed, by the Department of Energy (in the USA) as a perennial energy crop for ethanol production, gasification, and direct combustion for electricity. Several attributes make switchgrass a promising crop for energy production: a)there is the wide geographic adaptation, b) it produces seed which makes it relatively cheap to establish, c) it has a root system up to 3 m deep which contributes to an increase in soil carbon content, d) switchgrass is a perennial crop than can easily be incorporated into current farming systems, where it can be cut and baled with standard farming equipment. Switchgrass can tolerate a large range of soil pH values. Just like Miscanthus, switchgrass has very high potential yields with relatively low fertilizer and water requirements.	A European Network under the name "Switchgrass (*Panicum virgatum* L.) as an alternative energy crop in Europe" has been established (the participating countries are the Netherlands, Greece, Italy, UK, Germany) since February 1998. Hence there are no data available yet concerning the yields of Switchgrass under Greek conditions. In Alabama, one switchgrass cultivar yielded 26 tons of dry matter per ha per year over a 6 year period under experimental conditions.	Solid biofuel Ethanol	Energy (heat & electricity, transportation)

ENERGY CROP	Description of the Crop	Yields	Biofuel	Market
Miscanthus	Miscanthus sinensis x giganteus is a C4 species of oriental origin that has been grown in Europe for many years as ornamental. In addition, to its horticultural value, it appears to meet many of the requirements as a biomass crop plant for energy production, pulp production and for building materials. It is promoted for northern EU countries but at the moment, it appears to be an energy crop better suited for southern than northern EU conditions, the reason being that it is a cold sensitive crop. Irrigation constitutes a limiting factor in achieving high biomass yields. However, even with low irrigation levels sufficient biomass yields are being produced. Nitrogen fertilization do not affect growth and biomass productivity, though a certain superiority of the higher rates applied was occasionally observed.	In west Greece, the average height of the plantation reached up to 3 m, while dry biomass yields ranged from 26.34 to 32 t/ha/year from the second growing period onwards and the estimated energy potential was 13.8 toe/ha/year.	Solid biofuels	Energy (heat & electricity) Non - energy (pulp, building materials)
Black locust	Black locust is a widely spread species for ornamental, afforestation and reclamation purposes as well as for timber and energy production, covering all over the world 3 million hectares, being third in terms of worldwide planted area, among broadleaved species. Black locust demonstrates a rapid growth in various soil types, resprouts vigorously after cutting and has very good properties as wood fuel (good combustibility, high energy content). The species has not been used for establishing large-scale energy plantations in Europe, except in Hungary. Fields experiments for studying adaptation biomass productivity and energy potential of black locust have been established from 1990 by CRES.	Fields experiments for studying adaptation biomass productivity and energy potential of black locust have been established from 1990 by CRES. In three successive two-year rotation cycles dry matter biomass yields ranged from 45.6 to 17.1 tons.ha/year in fertile field. The energy potential was estimated at 8 toe/ha/year at the third harvest.	Solid biofuels	Energy (heat & electricity)

APPENDIX II: Biosem Model- Runs for Greece

Table 1: Summary Information

Country	Greece	
Region	Rodopi County	
Energy Crop Type(s)	Spanish Thistle Artichoke	
Area of Energy Crop Grown(ha)	23	Do not enter "0"
Other Biomass Used (eg. farm/forestry residue	n/a	
Conversion Technology	Combustion	
Size of the Bioenergy Plant(e.g. kWe, kWt, tonn	1	MW (Heat)
Market	Small Scale District Heating	
Comments	Greek Case Study	

Table 2: Financial Information

Variable	Value	Units	Comments/Source of data(In addition, comment on the source of the subsidy)
Energy crop/biomass price	57	ecu/odt	Greek data
Energy crop subsidies (A)	57	ecu/ha/y	Do not enter "0"
Energy crop subsidies (B)	1	ecu/ha/y	Do not enter "0"
Farmers Net Margin/Opportunity Cost	145	ecu/ha/y	Greek data
Farmers Interest Rate	8	%	Greek data
Conversion Plants Internal Rate of Return	10	%	Greek data
Conversion Plants Subsidy (A)	0	ecu/kWh	Greek data
Conversion Plants Subsidy (B)	0	ecu/y	Greek data
Conversion Plants Subsidy (C)	280000	ecu	Greek data
Heat price	0,041	ecu/kWh	Greek data
Electricity price	0	ecu/kWh	Greek data

Table 3: Feedstock Production Data: Crop Establishment

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour	Farmer	type	yes	100	no	0	Greek data
Average Land Rent	180,00	ecu/ha	yes	100	no	0	Greek data
Seeds/cuttings	100	%	yes	100	no	0	Greek data
Cost of seeds/cuttings	25	ecu/kg					Greek data
Planting density	2	kg/ha					Greek data
Time sub-soiling	2	hours/ha					Greek data
Time ploughing	2,5	hours/ha					Greek data
Time harrowing	1	hours/ha					Greek data
Time disking	1	hours/ha					Greek data
Time planting	2	hours/ha					Greek data
Time fencing	0	hours/100m					Greek data
Cost of fencing	0	ecu/metre	yes	50	yes	50	Greek data
Perimeter	0	m					Greek data
Cost of spray	15	ecu/kg	no	0	yes	50	Greek data
Application	2	kg/ha					Greek data
Time spraying	1	hours/ha					Greek data
Fertiliser type	inorganic	type	no	0	yes	70	Greek data
Cost of fertiliser	0,3	ecu/kg					Greek data
Application	50	kg/ha					Greek data
Time fertilising	0,5	hours/ha					Greek data
Time cutting-back	0	hours/ha					Greek data
Time replanting	0	hours/ha					Greek data

Table 4: Feedstock Production Data: Crop Management

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour	Regular	type	yes	100	no	0	Greek data
Cost of spray	0	ecu/kg					No spraying is required after the establishment year. The crop develops a huge can
Application	0	kg/ha					
Time spraying	0	hours/ha					
Fertiliser type	Inorganic	type	no	0	yes	70	Greek data
Cost of fertiliser	0,3	ecu/kg					Greek data
Application	50	kg/ha					Greek data
Time fertilising	0,5	hours/ha					Greek data
Irrigation capital costs	0	ecu/ha					Greek data
Water abstraction charges	0	ecu/ha					Greek data
Time irrigating	0	hours/ha					Greek data

Table 5: Feedstock Production Data: Crop Harvesting/Biomass Gathering

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour	regular	type	yes	100	yes	0	Greek data
Harvester	forage	type	yes	50	yes	50	Greek data use Greek cost data in table 12
Time to harvest	0,13	hours/t					Greek data
Time to harvest	4	hours/ha					Greek data
Time to chip	0	hours/t					Greek data
Time to chip	0	hours/ha					Greek data
Harvesting interval	1	years					must enter "1" for perennial crop
Time to gather residues	0	hours/t					Greek data
Time to gather residues	0	hours/ha					Greek data
Ultimate Yield (crop)	20	odt/ha/yr					Greek data
First harvest yield (% of ultimate)	100	%					must use "100" for perennial crop
Second harvest yield (% of ultimate)	100	%					must use "100" for perennial crop
Yield (residues)	0	odt/ha					Greek data
Harvesting/storage losses	10	%					Greek data

Table 6: Feedstock Production Data: Crop/Biomass Storage

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour	Regular	type	yes	100	no	0	Greek data
Time caretaking storage	0	h/y	yes	100	no	0	Greek data
Storage method	field	type	yes	100	no	0	Greek data
Cost of storage construction	0	ecu/ha					Greek data
Life of storage building	100	years					Greek data
Storage capacity required	24,55	t/ha					

Table 7: Transport of Feedstock to the Conversion plant

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour	driver	type	yes	100	no	0	Greek data
Transporter	curtain	type	no	0	yes	50	Greek data
odt carried by the transporter	30	odt					Greek data
Average total journey time	2,5	hours					Greek data

Table 8: Grubbing-up of the Biomass Crop

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour	Regular	type	yes	100	no	0	Greek data
Cost of spray	0	ecu/kg	no	0	yes	60	Greek data
Application	0	kg/ha					perennial - no grubbing up
Time spraying	0	hours/ha					perennial - no grubbing up
Time Ploughing	0	hours/ha	no	0	yes	70	perennial - no grubbing up
Time disking	0	hours/ha					perennial - no grubbing up
Life of plantation	0	years					perennial - no grubbing up

Table 9: Feedstock Conversion: Capital Costs of the Bioenergy Plant

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour (A)	Labourer	type	yes	75	yes	25	Greek data
Labour (B)	Engineer	type	yes	25	yes	75	Greek data
Labourer time to build plant	*4062,5*	*h/y*					*Calculated data - do not enter*
Engineer time to build plant	750	h/y					Calculated data - do not enter
Plant Capacity	1	MW					Greek data
Plant Capacity	0,32	tonnes/h					derived from Greek data
Land cost	15.000	ecu	yes	100	*no*	0	Greek data
Plant and Equipment cost	450.000	ecu	no	0	yes	25	Greek data
Building cost	50.000	ecu	yes	50	yes	50	Greek data
Planning costs	45.000	ecu	yes	20	yes	80	Greek data
Financial Service Costs	5.000	ecu	yes	40	yes	60	Greek data
Environmental Audit Costs	7.000	ecu	yes	15	yes	85	Greek data
Legal Costs	3.000	ecu	yes	35	yes	65	Greek data
Other project start-up costs	0	ecu					Greek data
Construction time	1	years					Greek data

Table 10: Feedstock Conversion: Operating and Maintenance Costs of the Bioenergy Plant

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour	Operator	type	yes	100	yes	0	Greek data
Labour	Engineer	type	no	0	yes	100	Greek data
Plant Operating life	15	years					
Labour hours required per year	700	hours					Assumed Data to make Enter 0.5 x true labour hours
Operating hours of plant	4.000	hours					Greek data
Conversion efficiency to heat and power	80	%					Greek data
Conversion efficiency to power	0	%					
Maintenance and consumables	1	ecu/tonne	yes	30	yes	70	assumption based on new data in b168 above
Feedstock costs	57	ecu/tonne	yes	100	0	0	Greek data
Disposal costs	0,4	ecu/tonne	yes	100	yes	0	derived from Greek data
Annual maintenance	0	ecu	yes	30	yes	70	included above
Insurance	8.000	ecu/year	yes	0	yes	100	Greek data
Overheads	1.500	ecu/year	yes	100	yes	0	Greek data
Heat generated	1	MW					
Electricity generated	0	MW					

Table 11: Labour Costs

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Regular farm labour	5	ecu/hour	yes	100	no	0	Greek data
Contract/casual farm labour	6	ecu/hour	yes	100	no	0	Greek data
Farmer/spouse labour	5	ecu/hour	yes	100	no	0	Greek data
Transport driver	8	ecu/hour	yes	100	no	0	Greek data
Construction plant engineer	10	ecu/hour	no	0	yes	100	Greek data
Construction plant labour	8	ecu/hour	yes	50	yes	50	Greek data
Bioenergy plant operator	10	ecu/hour	yes	25	yes	75	Greek data
Bioenergy plant engineer	18,96	ecu/hour	no	0	yes	100	Greek data
Average labour/turnover ratio	20.000	ecu/job					Greek data
Civils labour/turnover ratio	25.000	ecu/job					Greek data
Equipment labour/turnover ratio	30.000	ecu/job					Greek data
Services labour/trunover ratio	20.000	ecu/job					Greek data
Average gross wages	6.000	ecu/annum					Greek data
Agriculture sector gross wages	2.500	ecu/annum					Greek data
Energy sector gross wages	8.800	ecu/annum					Greek data
Rate of unemployment pay	1700	ecu/annum					Greek data

Table 12: Farm Machinery Costs

Variable	Capital Cost (ecu)	Life (h)	Usage (h/y)	Maint'an (ecu/h)	Fuel Consump (l/h)	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data		Mach Cost (ecu/h)
Tractor	30.000	10.000	1500	3,5	8	no	0	yes	100	Greek data		11,49
Trailer	6.888	4.610	922	1,57	0	no	0	yes	100	Greek data		3,44
Plough	5.000	1.200	100	4,5	9	no	0	yes	100	Greek data		15,63
Sub-soiler	6.500	1.000	100	3,8	10	no	0	yes	100	Greek data		18,49
Disc	4.500	1.200	100	3,6	7	no	0	yes	100	Greek data		13,07
Harrow	4.500	1.200	100	3,6	7	no	0	yes	100	Greek data		13,07
Planter	4.000	2.600	240	1,6	1	no	0	yes	100	Greek data		4,46
Fertiliser distributor	4.000	900	100	2,6	2	no	0	yes	100	Greek data		10,00
Sprayer	3.000	900	100	1,7	1	no	0	yes	100	Greek data		7,00
Irrigator	9.000	900	100	3,4	0,5	no	0	yes	100	Greek data		18,06
Forage Harvester	10.000	5.600	1124	*4*	51	no	0	yes	100	Greek data	*assumption*	31,73
Sugar cane harvester	275.500	5.040	720	55,48	42,5	no	0	no	0	UK data	not used	150,22
Whole shoot harvester	50.750	2.240	320	10,7	9	no	0	yes	100	UK data	not used	45,66
Chipper	174.000	7.008	2336	34,64	30,6	no	0	no	0	UK data	not used	78,84
Transporter	32.866	16.380	2340	6,09	21,9	no	0	no	100	UK data	not used	19,74

Agricultural Fuel Price (ecu/l)	0,5	Greek data
Commercial Fuel Price (ecu/l)	0,5	Greek data

Table 13: Economic Data

Variable	Value	Units	
Share of grants retained in region	60	%	Greek data
Share of net additional profit spent in region	25	%	Assumptions
Share of net additional labour incomes spent in	25	%	Assumptions
Traditional energy market share displaced by bi	5	%	Greek data
Tax deductions	20	%	Greek data
Profit tax rate	25	%	Greek data

Table 14: Financial Information Regarding Agricultural Activity Displaced

Variable	Value	Units	
Enterprise output	1	ecu/ha	Do not enter "0"
Variable costs	1	ecu/ha	Do not enter "0"
Fixed costs	1	ecu/ha	Do not enter "0"
Net Margin per ha (before interest)	1	ecu/ha	Do not enter "0"
Depreciation on fixed capital and equipment	1	ecu/ha	Do not enter "0"
Value of services	1	ecu/ha	*Greek Data*
Value of equipment	1	ecu/ha	*Greek Data*
Value of civils	1	ecu/ha	*Greek Data*
Value of labour	1	ecu/ha	*Greek Data*
Amount of serviced sources from region	85	%	*Greek Data*
Amount of equipment sourced from region	100	%	*Greek Data*
Amount of civils sourced from region	100	%	*Greek Data*
Amount of labour sourced from region	100	%	*Greek Data*

Table 15: Processing of the Agricultural Activity Displaced

Questions	Yes/No	%
Is the above displaced agricultural production sold locally for primary processing?	Yes	
If yes, what % does this represent to the local primary processing company?		30
What % of the local processing company's income is spent locally?		25

Table 16: Value of Agricultural Processing Displaced

Variable	Value	Units	
Value of services	***1***	***ecu/ha***	Do not enter "0"
Value of equipment	***1***	***ecu/ha***	Do not enter "0"
Value of civils	***1***	***ecu/ha***	Do not enter "0"
Value of labour	***1***	***ecu/ha***	Do not enter "0"
Amount of services sourced from region	65	%	Greek data
Amount of equipment sourced from region	40	%	Greek data
Amount of civils sourced from region	85	%	Greek data
Amount of labour sourced from region	100	%	Greek data

Crop Production

All costs are in euro per hectare

Years			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Establishment - Capital Investment in Agriculture Sector																							
Soil bed preparation			109 86	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Planting			116 89	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Fencing			0,00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Spraying			53 49	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Cut-back			0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Re-planting			0 00	0 00	0 00	0,00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Fertilising			28 24	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0,00	0 00
Management - Operation and Maintenance in the Agriculture Sector																							
Management			28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24
Harvesting			226 65	226,85	226 65	226 65	226 65	226 65	226 65	226 65	226 65	226 65	226 65	226 65	226 65	226 65	226 65	226 65	226 65	226 65	226,85	226 65	226 65
Storage			0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Transport			46,23	46 23	46 23	46 23	46 23	46 23	46,23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46,23	46 23	46 23
Grubbing-up			0,00	0 00	0 00	0,00	0 00	0,00	0,00	0,00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0,00	0 00	0,00	0,00	0,00
	Average per year	Total																					
Total Costs	318	6632	609,61	301 12	301 12	301 12	301 12	301 12	301 12	301 12	301 12	301 12	301 12	301 12	301 12	301 12	301 12	301 12	301 12	301 12	301,12	301,12	301 12
Revenue	1040	21832	1084 00	1083 00	1083 00	1083,00	1083 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00
of which Grant			58,00	57 00	57 00	57 00	57,00	0 00	0,00	0,00	0 00	0,00	0 00	0,00	0,00	0 00	0 00	0 00	0 00	0,00	0,00	0,00	0 00
Avg Ann Profit		15200																					
After interest		15175																					
Annual cash flow			474,39	781,88	781 88	781 88	838 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724,88	724 88	724 88
Cumulative cash flow			474,39	1256,27	2038 14	2820 02	3658 90	4383 77	5108,65	5833 52	6558 40	7283 28	8008 15	8733,03	9457 90	10182,78	10907 65	11632 53	12357 41	13082,28	13807,16	14532,03	15256,91

Total	Annualised 1	Ann Paym 0,08	Interest cost
109 86	109 86	118 65	8,79
116 89	116 89	126 24	9 35
0 00	0 00	0,00	0 00
53 49	53 49	57,77	4 28
0 00	0 00	0,00	0 00
0 00	0 00	0 00	0 00
28 24	28 24	30,50	2,26
308,48	308,48	333 16	24,68

Crop Conversion

All costs are in total ecu

Years			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Construction - Capital Investment in Energy Sector																							
Land			15 000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plant, equipment, buildings			500 000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Services			60 000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Management - Operation and Maintenance in the Energy Sector																							
Operation			0	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272
Maintenance			0	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280
Feedstock			0	72 960	72.960	72.960	72 960	72 960	72 960	72 960	72 960	72.960	72 960	72 960	72 960	72 960	72 960	72.960	72.960	72.960	72.960	72.960	72 960
Decommissioning			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Average per year	Total																					
Total Costs	132043	2625240	575 000	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512
Revenue	171250	3560000	280 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000
Avg Ann Profit		40923																					
After interest		3365																					
Annual cash flow			-295 000	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488
Cumulative cash flow			-295 000	-233 512	-172 024	-110 536	-49 048	12 440	73 928	135 416	196 904	258 392	319 880	381 368	442 856	504 344	565 832	627 320	688 808	750 296	811 784	873 272	934 760

Total	Annualised 16	Ann Paym 0,1	Interest cost
15000	938	1917	980
500000	31250	63908	32658
60000	3750	7669	3919
575000	35938	73495	37557

OUTPUTS

Farmers net margin	(ecu/ha)	242
Farmers NPV	(ecu/ha)	7 099
Farmers IRR	%	10%
Bioenergy plant NPV	(ecu)	156 984
Bioenergy plant IRR	(%)	19%

NOTES

This is a perennial crop so there is establishment only in the first year

For perennial crops and residues crop production and conversion years do not match

Farm Area 23 Ha — Adjust Fact 0,60

(ecu)	Total Labour	Labour Imported	% Labour Imported	Total Civils	Civils Imported	% Civils Imported	Total Equipment	Equip Imported	% Equip Imported	Total Services	Services Imported	% Services Imported
Energy Crop												
Project Life	1											
Capital	1.150	0	0	0	0	0	7 101	5.836	82	23	14	60
Annualised	1.150	0	0	0	0	0	7 101	5.836	82	23	14	60
O&M	1.208	0	0	0	0	0	5 453	5.453	100	1.311	787	60
Bioenergy Plant												
Project Life	16											
Capital	40.000	13.750	34	65.000	25.000	38	450 000	450.000	100	60 000	46.900	78
Annualised	2.500	859	34	4.063	1.563	38	28 125	28.125	100	3.750	2.931	78
O&M	20.272	13.272	65	0	0	0	75 740	72.576	96	8.000	8.000	100
Ag Displacement												
Project Life	1	NO INVESTMENT CAPITAL IS ASSUMED FOR THE DISPLACED AGRICULTURAL ACTIVITY.										
Capital	0	0	0	0	0	0	0	0	0	0	0	0
Annualised	0	0	0	0	0	0	23	0	0	0	0	0
O&M	23	0	0	23	0	0	23	0	0	23	3,45	15

Labour/T'O		25000	30000	20000		
(ecu)	Total Purchases	Civils Retained	Equip Retained	Services Retained	Purchased from Region	
Energy Crop						
Capital	7124	0	1265	9	1274	18%
Annualised	7124	0	1265	9	1274	18%
O&M	6764	0	0	524	524	8%
Bioenergy Plant						
Capital	575000	40000	0	13100	53100	9%
Annualised	35938	2500	0	819	3319	9%
O&M	83740	0	3164	0	3164	4%
Ag Displacement						
Annualised	23	0	23	0	23	100%
O&M	69	23	23	20	66	95%

LABOUR / TURNOVER RATIOS and WAGE RATES

Average Labour / Turnover Ratio	20.000 ecu/job
Civils	25.000 ecu/job
Equipment	30.000 ecu/job
Services	20.000 ecu/job
Agriculture Gross Wages	2.500 ecu
Energy Gross Wages	8.800 ecu
Average Gross Wages	6.000 ecu

	Weighted Ratio - ecu/job
Energy Crop	
Capital	29928
Annualised	29928
Operating	20000
Bioenergy Plant	
Capital	23766
Annualised	23766
Operating	30000
Displaced Agriculture	
Capital	30000
Operating	25263

Displacement Cost Calculation D

Introductory Notes
Suckler Cow Production - Severely Disadvantaged LFA
FBS 1995/6 Farm Management Survey Gross Margins, pages, 4, 27
Assume class for gross margin for severely disadvantaged LFA is "good"
Nix 27th ed. 1997, pgs 61,138 (Upland Autumn Calving - High & Livestock Rearing Upland)

Financial Information Regarding Agricultural Activity Displaced

Years	1	
Interest Rate	8%	
Enterprise output	1	ecu/ha
Variable costs	1	ecu/ha
Fixed costs	1	ecu/ha
Net Margin per ha (before interest)	-1	ecu/ha
Depreciation on fixed capital and equipment	1	ecu/ha
Discounted net margin per ha	1,08	ecu/ha
Interest charge	0,08	ecu/ha
Net margin per ha (after interest)	-1,08	ecu/ha

Agricultural Production

Variable	Value	Units
Value of services	1	ecu/ha
Value of equipment	1	ecu/ha
Value of civils	1	ecu/ha
Value of labour	1	ecu/ha
Amount of services sourced from region	85	%
Amount of equipment sourced from region	100	%
Amount of civils sourced from region	100	%
Amount of labour sourced from region	100	%

Follow-on Questions Regarding Processing

Questions	Yes/No	%
Is the above displaced agricultural production sold locally for primary processin	Yes	
If yes, what % does this represent to the local primary processing company?		30
What % of the local processing company's income is spent locally?		25

Value of Agricultural Processing Displaced

Variable	Value	Units
Value of services	1	ecu/ha
Value of equipment	1	ecu/ha
Value of civils	1	ecu/ha
Value of labour	1	ecu/ha
Amount of serviced sources from region	65	%
Amount of equipment sourced from region	40	%
Amount of civils sourced from region	85	%
Amount of labour sourced from region	100	%

			GROSS IMPACT		DISPLACEMENT				NET IMPACT	
FEEDSTOCK PRODUCTION (All financial data in ECU)					**AGRICULTURE** (All financial data in ECU)					
Area	23	Ha								
Life of Project	1	Yrs								
Direct										
		Wage Rates								
Labour Relating to Capital Investment	1.150	2.500	0,5	Jobs			0,0	Jobs	0,5	Jobs
						Wage rate				
Labour Relating to Operation & Maintenance	1.208	2.500	0,5	Jobs	23	2.500	0,01	Jobs	0,5	Jobs
Profit (Less interest)	349.030				-25				349.055	Net Profit
Indirect										
Total Annualised Purchases of Capital Goods	7.124				23					
Capital Goods Purchased in the Region	1.274				23					
Multiplier	1,00				-0,54					
Indirect Capital Expenditure Retained	1.276	29.928	0,0	Jobs	-12	30.000	0,0	Jobs	0,0	Jobs
Total Annual Sales (inc grants)	502.136				23					
Total Annual Purchases of Operating Goods in the Region	524	0%			66	285%				
Multiplier	1,00				-0,54					
Indirect Operating Expenditure Retained	525	20.000	0,0	Jobs	-35	25.263	0,0	Jobs	0,0	Jobs
Induced										
Net Direct Additional Farm Labour Incomes (before deductions)	2.335									
Tax Deductions	20%									
Net Direct Additional Farm Labour Income (after deductions)	1.868									
Net Direct Additional Profit (before Tax)	349.055									
Profit Tax Rate	25%									
Net Direct Additional Profit (after Tax)	261.791									
Share of Net Additional Profit Spent in Region	25%	(assume same as capital)								
Average Gross Regional Incomes	6.000									
Net Indirect Additional Labour Incomes (before deductions)	424									
Deductions	20%									
Net Indirect Additional Labour Income (after deductions)	339									
Net Additional Labour Incomes from Feedstock Production	2.207									
Share of Net Additional Labour Incomes Spent in Region	25%									

CONVERSION PROCESS (Excl Feedstock)

ENERGY MARKET

(All Financial data in ECU)				E	Reg Share of Nat Energy Prod			
Life of Project	16	Yrs			5,0%			
Direct								
		Wage Rates						
Labour Relating to Capital Investment	2.500	8.800	0,3	Jobs	125		0,3	Jobs
Labour Relating to Operation & Maintenance	20.272	8.800	2,3	Jobs	1.014		2,2	Jobs
Profit (Less interest)	3.365				168		3.197	Net Profit
Indirect								
Total Annualised Purchases of Capital Goods	35.938							
Capital Goods Purchased in the Region	3.319							
Multiplier	1,01							
Indirect Capital Expenditure Retained	3.367	23.766	0,1	Jobs			0,1	Jobs
Total Annual Sales	222.500							
Total Annual Purchases of Operating Goods in the Region	3.164	1,4%						
Multiplier	1,01							
Indirect Operating Expenditure Retained	3.210	30.000	0,1	Jobs			0,1	Jobs
Induced								
Net Direct Additional Energy Labour Incomes (before deduction	21.633							
Tax Deductions	20%							
Net Direct Additional Energy Labour Income (after deductions)	17.307							
Net Direct Additional Profit (before Tax)	3.197							
Profit Tax Rate	25%							
Net Direct Additional Profit (after Tax)	2.398							
Share of Net Additional Profit Spent in Region	9%	(assume same as capital)						
Average Gross Regional Incomes	6.000							
Net Indirect Additional Labour Incomes (before deductions)	1.417							
Tax Deductions	20%							
Net Indirect Additional Labour Income (after deductions)	1.134							
Net Additional Labour Incomes from Conversion Process	18.441							
Share of Net Additional Labour Incomes Spent in Region	25%							

Total Induced

Net Additional Labour Income (after deductions)	18.947	ecu
Net Additional Profit (after Tax)	264.189	ecu
Net Additional Incomes/Profit	283.137	ecu
Share of Net Additional Incomes/Profit Spent in the Region	25%	
Multiplier	1,33	
Total Additional Retained Expenditure from Additional Income/	377.599	ecu
Average Labour/Turnover Ratio	20.000	ecu
Induced Jobs	18,9	jobs

Notes

The conversion plant was unprofitable as presented because of its high capital cost and low running hours.
Running hours have been increase to 4000, it is unlikely that a plant would be built for 1700hrs.
Regional import % has also been reduced as using 100% is unrealistic and gives very high mutipliers!
The jobs are probably still overestimated to some degree.

TOTAL NET IMPACT

Net Additional Labour Income	18.947	ecu
Net Additional Profit	264.189	ecu
Net Additional Direct Jobs	3,4	jobs
Net Additional Indirect Jobs	0,3	jobs
Net Additional Induced Jobs	18,9	jobs
Total Net Additional Jobs	22,6	jobs

Table 1: Summary Information

Country	Greece
Region	Rodopi County
Energy Crop Type(s)	Spanish Thistle Artichoke
Area of Energy Crop Grown(ha)	23 Do not enter "0"
Other Biomass Used (eg. farm/forestry residue	n/a
Conversion Technology	Combustion
Size of the Bioenergy Plant(e.g. kWe, kWt, tonn	1 MW (Heat)
Market	Small Scale District Heating
Comments	Greek Case Study

Table 2: Financial Information

Variable	Value	Units	Comments/Source of data(In addition, comment on the source of the subsidy)
Energy crop/biomass price	57	ecu/odt	Greek data
Energy crop subsidies (A)	1	ecu/ha/y	Do not enter "0"
Energy crop subsidies (B)	1	ecu/ha/y	Do not enter "0"
Farmers Net Margin/Opportunity Cost	145	ecu/ha/y	Greek data
Farmers Interest Rate	8	%	Greek data
Conversion Plants Internal Rate of Return	10	%	Greek data
Conversion Plants Subsidy (A)	0	ecu/kWh	Greek data
Conversion Plants Subsidy (B)	0	ecu/y	Greek data
Conversion Plants Subsidy (C)	0	ecu	Greek data
Heat price	0,041	ecu/kWh	Greek data
Electricity price	0	ecu/kWh	Greek data

Table 3: Feedstock Production Data: Crop Establishment

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour	Farmer	type	yes	100	no	0	Greek data
Average Land Rent	180,00	ecu/ha	yes	100	no	0	Greek data
Seeds/cuttings	100	%	yes	100	no	0	Greek data
Cost of seeds/cuttings	25	ecu/kg					Greek data
Planting density	2	kg/ha					Greek data
Time sub-soiling	2	hours/ha					Greek data
Time ploughing	2,5	hours/ha					Greek data
Time harrowing	1	hours/ha					Greek data
Time disking	1	hours/ha					Greek data
Time planting	2	hours/ha					Greek data
Time fencing	0	hours/100m					Greek data
Cost of fencing	0	ecu/metre	yes	50	yes	50	Greek data
Perimeter	0	m					Greek data
Cost of spray	15	ecu/kg	no	0	yes	50	Greek data
Application	2	kg/ha					Greek data
Time spraying	1	hours/ha					Greek data
Fertiliser type	inorganic	type	no	0	yes	70	Greek data
Cost of fertiliser	0,3	ecu/kg					Greek data
Application	50	kg/ha					Greek data
Time fertilising	0,5	hours/ha					Greek data
Time cutting-back	0	hours/ha					Greek data
Time replanting	0	hours/ha					Greek data

Table 4: Feedstock Production Data: Crop Management

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour	Regular	type	yes	100	no	0	Greek data
Cost of spray	0	ecu/kg					No spraying is required after the establishment year. The crop develops a huge can
Application	0	kg/ha					
Time spraying	0	hours/ha					
Fertiliser type	Inorganic	type	no	0	yes	70	Greek data
Cost of fertiliser	0,3	ecu/kg					Greek data
Application	50	kg/ha					Greek data
Time fertilising	0,5	hours/ha					Greek data
Irrigation capital costs	0	ecu/ha					Greek data
Water abstraction charges	0	ecu/ha					Greek data
Time irrigating	0	hours/ha					Greek data

Table 5: Feedstock Production Data: Crop Harvesting/Biomass Gathering

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour	regular	type	yes	100	yes	0	Greek data
Harvester	forage	type	yes	50	yes	50	Greek data use Greek cost data in table 12
Time to harvest	0,13	hours/t					Greek data
Time to harvest	4	hours/ha					Greek data
Time to chip	0	hours/t					Greek data
Time to chip	0	hours/ha					Greek data
Harvesting interval	1	years					must enter "1" for perennial crop
Time to gather residues	0	hours/t					Greek data
Time to gather residues	0	hours/ha					Greek data
Ultimate Yield (crop)	20	odt/ha/yr					Greek data
First harvest yield (% of ultimate)	100	%					must use "100" for perennial crop
Second harvest yield (% of ultimate)	100	%					must use "100" for perennial crop
Yield (residues)	0	odt/ha					Greek data
Harvesting/storage losses	10	%					Greek data

Table 6: Feedstock Production Data: Crop/Biomass Storage

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour	Regular	type	yes	100	no	0	Greek data
Time caretaking storage	0	h/y	yes	100	no	0	Greek data
Storage method	field	type	yes	100	no	0	Greek data
Cost of storage construction	0	ecu/ha					Greek data
Life of storage building	100	years					Greek data
Storage capacity required	24,55	t/ha					

Table 7: Transport of Feedstock to the Conversion plant

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour	driver	type	yes	100	no	0	Greek data
Transporter	curtain	type	no	0	yes	50	Greek data
odt carried by the transporter	30	odt					Greek data
Average total journey time	2,5	hours					Greek data

Table 8: Grubbing-up of the Biomass Crop

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour	Regular	type	yes	100	no	0	Greek data
Cost of spray	0	ecu/kg	no	0	yes	60	Greek data
Application	0	kg/ha					perennial - no grubbing up
Time spraying	0	hours/ha					perennial - no grubbing up
Time Ploughing	0	hours/ha	no	0	yes	70	perennial - no grubbing up
Time disking	0	hours/ha					perennial - no grubbing up
Life of plantation	0	years					perennial - no grubbing up

Table 9: Feedstock Conversion: Capital Costs of the Bioenergy Plant

Variable	Value	Units	Lab, mats, mach from *region?*	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour (A)	Labourer	type	yes	75	yes	25	Greek data
Labour (B)	Engineer	type	yes	25	yes	75	Greek data
Labourer time to build plant	4062,5	h/y					*Calculated data - do not enter*
Engineer time to build plant	750	h/y					Calculated data - do not enter
Plant Capacity	1	MW					Greek data
Plant Capacity	0,32	tonnes/h					derived from Greek data
Land cost	15.000	ecu	yes	100	no	0	Greek data
Plant and Equipment cost	450.000	ecu	no	0	yes	25	Greek data
Building cost	50.000	ecu	yes	50	yes	50	Greek data
Planning costs	45.000	ecu	yes	20	yes	80	Greek data
Financial Service Costs	5.000	ecu	yes	40	yes	60	Greek data
Environmental Audit Costs	7.000	ecu	yes	15	yes	85	Greek data
Legal Costs	3.000	ecu	yes	35	yes	65	Greek data
Other project start-up costs	0	ecu					Greek data
Construction time	1	years					Greek data

Table 10: Feedstock Conversion: Operating and Maintenance Costs of the Bioenergy Plant

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Labour	Operator	type	yes	100	yes	0	Greek data
Labour	Engineer	type	no	0	yes	100	Greek data
Plant Operating life	15	years					
Labour hours required per year	700	hours					Assumed Data to make Enter 0.5 x true labour hours
Operating hours of plant	4.000	hours					Greek data
Conversion efficiency to heat and power	80	%					Greek data
Conversion efficiency to power	0	%					
Maintenance and consumables	1	ecu/tonne	yes	30	yes	70	assumption based on new data in b168 above
Feedstock costs	57	ecu/tonne	yes	100	0	0	Greek data
Disposal costs	0,4	ecu/tonne	yes	100	yes	0	derived from Greek data
Annual maintenance	0	ecu	yes	30	yes	70	included above
Insurance	8.000	ecu/year	yes	0	yes	100	Greek data
Overheads	1.500	ecu/year	yes	100	yes	0	Greek data
Heat generated	1	MW					
Electricity generated	0	MW					

Table 11: Labour Costs

Variable	Value	Units	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data
Regular farm labour	5	ecu/hour	yes	100	no	0	Greek data
Contract/casual farm labour	6	ecu/hour	yes	100	no	0	Greek data
Farmer/spouse labour	5	ecu/hour	yes	100	no	0	Greek data
Transport driver	8	ecu/hour	yes	100	no	0	Greek data
Construction plant engineer	10	ecu/hour	no	0	yes	100	Greek data
Construction plant labour	8	ecu/hour	yes	50	yes	50	Greek data
Bioenergy plant operator	10	ecu/hour	yes	25	yes	75	Greek data
Bioenergy *plant engineer*	18,96	ecu/hour	no	0	yes	100	Greek data
Average labour/turnover ratio	20.000	ecu/job					Greek data
Civils labour/turnover ratio	25.000	ecu/job					Greek data
Equipment labour/turnover ratio	30.000	ecu/job					Greek data
Services labour/trunover ratio	20.000	ecu/job					Greek data
Average gross wages	6.000	ecu/annum					Greek data
Agriculture sector gross wages	2.500	ecu/annum					Greek data
Energy sector gross wages	8.800	ecu/annum					Greek data
Rate of unemployment pay	1700	ecu/annum					Greek data

Table 12: Farm Machinery Costs

Variable	Capital Cost (ecu)	Life (h)	Usage (h/y)	Maint'an (ecu/h)	Fuel Consump (l/h)	Lab, mats, mach from region?	If yes what %?	If no, were from country?	If yes, what %?	Comments or Source of data		Mach Cost (ecu/h)
Tractor	30.000	10.000	1500	3,5	8	no	0	yes	100	Greek data		11,49
Trailer	6.888	4.610	922	1,57	0	no	0	yes	100	Greek data		3,44
Plough	5.000	1.200	100	4,5	9	no	0	yes	100	Greek data		15,63
Sub-soiler	6.500	1.000	100	3,8	10	no	0	yes	100	Greek data		18,49
Disc	4.500	1.200	100	3,6	7	no	0	yes	100	Greek data		13,07
Harrow	4.500	1.200	100	3,6	7	no	0	yes	100	Greek data		13,07
Planter	4.000	2.600	240	1,6	1	no	0	yes	100	Greek data		4,46
Fertiliser distributor	4.000	900	100	2,6	2	no	0	yes	100	Greek data		10,00
Sprayer	3.000	900	100	1,7	1	no	0	yes	100	Greek data		7,00
Irrigator	9.000	900	100	3,4	0,5	no	0	yes	100	Greek data		18,06
Forage Harvester	10.000	5.600	1124	*4*	51	no	0	yes	100	Greek data	*assumption*	31,73
Sugar cane harvester	275.500	5.040	720	55,48	42,5	no	0	no	0	UK data	not used	150,22
Whole shoot harvester	50.750	2.240	320	10,7	9	no	0	yes	100	UK data	not used	45,66
Chipper	174.000	7.008	2336	34,64	30,6	no	0	no	0	UK data	not used	78,84
Transporter	32.866	16.380	2340	6,09	21,9	no	0	no	100	UK data	not used	19,74

Agricultural Fuel Price (ecu/l)	0,5	Greek data
Commercial Fuel Price (ecu/l)	0,5	Greek data

Table 13: Economic Data

Variable	Value	Units	
Share of grants retained in region	60	%	Greek data
Share of net additional profit spent in region	25	%	Assumptions
Share of net additional labour incomes spent in	25	%	Assumptions
Traditional energy market share displaced by bi	5	%	Greek data
Tax deductions	20	%	Greek data
Profit tax rate	25	%	Greek data

Table 14: Financial Information Regarding Agricultural Activity Displaced

Variable	Value	Units	
Enterprise output	1	ecu/ha	Do not enter "0"
Variable costs	1	ecu/ha	Do not enter "0"
Fixed costs	1	ecu/ha	Do not enter "0"
Net Margin per ha (before interest)	1	ecu/ha	Do not enter "0"
Depreciation on fixed capital and equipment	1	ecu/ha	Do not enter "0"
Value of services	1	ecu/ha	*Greek Data*
Value of equipment	1	ecu/ha	*Greek Data*
Value of civils	1	ecu/ha	*Greek Data*
Value of labour	1	ecu/ha	*Greek Data*
Amount of serviced sources from region	85	%	*Greek Data*
Amount of equipment sourced from region	100	%	*Greek Data*
Amount of civils sourced from region	100	%	*Greek Data*
Amount of labour sourced from region	100	%	*Greek Data*

Table 15: Processing of the Agricultural Activity Displaced

Questions	Yes/No	%
Is the above displaced agricultural production sold locally for primary processing?	Yes	
If yes, what % does this represent to the local primary processing company?		30
What % of the local processing company's income is spent locally?		25

Table 16: Value of Agricultural Processing Displaced

Variable	Value	Units	
Value of services	***1***	***ecu/ha***	Do not enter "0"
Value of equipment	***1***	***ecu/ha***	Do not enter "0"
Value of civils	***1***	***ecu/ha***	Do not enter "0"
Value of labour	***1***	***ecu/ha***	Do not enter "0"
Amount of services sourced from region	65	%	Greek data
Amount of equipment sourced from region	40	%	Greek data
Amount of civils sourced from region	85	%	Greek data
Amount of labour sourced from region	100	%	Greek data

Financial Assessment

Crop Production
Al costs are n euro per hectare

Years			0	1	2	3	4	5	6	7	8	9	1	11	12	13	14	15	16	17	18	19	20
Estab ishment - Capita nvestment n Agriculture Sector																							
So bed preparation			109 86	0 00	0 00	0 00	0	0 00	0 00										0	0 00	0	0 00	0 00
P ant ng			116 89	0 00	0 00	0 00		0 00					0							0	00	0 00	0 00
Fencing			0 00	0 00	0 00	0 00	0	0 00	0					0						0 0	0	0 00	0 00
Spray ng			53 49	0 00	0 00	0 00	0 0	0 00	0				00						0	0	0	0 00	0 00
Cut-back			0 00	0 00	0 00	00		0 00											0		0	0	
Re-p ant ng			0 00	0 00	0 00	0 00	0	0 00	0											00		0 00	00
Fert ising			28 24	0 00	0 00	0 00	0 00	0 00	0	0	0 00			0	0	00	00		0 00	0 00	0 00	0 00	0 00
Management - Operation and Ma ntenance in the Agriculture Sector																							
Management			28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24	28 24
Harvesting			226 65	226 65	226 65	226 65	226 65	226 65	226 65	226 65	22 65	226 65	226 5	226 65	226 65	226 65	226 65	226 65	226 65	226 65	226 65	226 65	226 "5
Storage			0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0		00		0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Transport			46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23	46 23
Grubbing-up			0 00	0 00	0 00	0,00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
	Average per year	Total																					
Total Costs	316	6632	609 61	301 12	301 12	301 12	301 12	301 12	301 12	301 12	301 12	301 12	3 1 12	3 1 12	301 12	301 12	3 1 12	301 12	301 12	301 12	301 12	301 12	301 12
Revenue	1026	21552	1028 00	1027 00	1027 00	1027 00	1027 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00	1026 00
of which Grant			2 00	1 00	1 00	1 00	1 00	0 00	0 00	0 00	0 00	0	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
Avg Ann Profit		14920																					
After interest		14895																					
Annual cash flow			418 39	725 88	725 88	725 88	726 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88	724 88
Cumulative cash flow			418 39	1144 27	1870 14	2596 02	3322 90	4047 77	4772 65	5497 52	6222 40	6947 28	7672 15	8397 03	9121 90	9846 78	10571 65	11296 53	12021 41	12746 28	13471 16	14196 03	14920 91

Tota	Annua sed	Ann Paym	nterest cost
	1	0 08	
109 86	109 86	118 65	8 79
116 89	116 89	126 24	9 35
0 00	0 00	0 00	0 00
53 49	53 49	57 77	4 28
0 00	0 00	0 00	0 00
0 00	0 00	0 00	0 00
28 24	28 24	30 50	2 26
308 48	308 48	333 16	24 68

Crop Conversion
All costs are in total ecu

Years			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Construction - Capital Investment in Energy Sector																							
Land			15 000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plant, equipment bu ldings			500 000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Services			60 000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Management - Operation and Maintenance in the Energy Sector																							
Operation			0	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272	20 272
Maintenance			0	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280	9 280
Feedstock			0	72 960	72 960	72 960	72 960	72 960	72 960	72 960	72 960	72 960	72 960	72 960	72 960	72 960	72 960	72 960	72 960	72 960	72 960	72 960	72 960
Decommission ng			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Average per year	Total																					
Total Costs	132043	2825240	575 000	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512	102 512
Revenue	153750	3280000	0	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000	164 000
Avg Ann Profit		40923																					
After interest		3365																					
Annual cash flow			-575 000	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488	61 488
Cumulative cash flow			-575 000	-513 512	-452 024	-390 536	329 048	-267 560	-206 072	-144 584	-83 096	-21 608	39 880	101 368	162 856	224 344	285 832	347 320	408 808	470 296	531 784	593 272	654 760

Total	Annualsed	Ann Paym	Interest cost
	16	0 1	
15000	938	1917	980
500000	31250	63908	32658
60000	3750	7669	3919
575000	35938	73495	37557

OUTPUTS

Farmers net margin	(ecu/ha)	242
Farmers NPV	(ecu/ha)	6 837
Farmers IRR	%	10%
Bioenergy plant NPV	(ecu)	-97 561
Bioenergy plant IRR	(%)	7%

NOTES
This is a perennial crop so there is establishment only in the first year
For perennial crops and residues crop production and conversion years do not match

Farm Area	23 Ha									Adjust Fact	0,60	
(ecu)	Total Labour	Labour Imported	% Labour Imported	Total Civils	Civils Imported	% Civils Imported	Total Equipment	Equip Imported	% Equip Imported	Total Services	Services Imported	Services Imported
Energy Crop												
Project Life	1											
Capital	1 150	0	0	0	0	0	7 101	5 836	82	23	14	60
Annualised	1 150	0	0	0	0	0	7 101	5 836	82	23	14	60
O&M	1.208	0	0	0	0	0	5 453	5 453	100	23	14	60
Bioenergy Plant												
Project Life	16											
Capital	40 000	13.750	34	65 000	25 000	38	450 000	450 000	100	60.000	46 900	78
Annualised	2.500	859	34	4.063	1.563	38	28 125	28 125	100	3.750	2 931	78
O&M	20.272	13.272	65	0	0	0	75 740	72 576	96	8 000	8.000	100
Ag Displacement												
Project Life	1	NO INVESTMENT CAPITAL IS ASSUMED FOR THE DISPLACED AGRICULTURAL ACTIVITY.										
Capital	0	0	0	0	0	0	0	0	0	0	0	0
Annualised	0	0	0	0	0	0	23	0	0	0	0	0
O&M	23	0	0	23	0	0	23	0	0	23	3,45	15

	Labour/T'O	25000	30000	20000		
(ecu)	Total Purchases	Civils Retained	Equip Retained	Services Retained	Purchased from Region	
Energy Crop						
Project Life						
Capital	7124	0	1265	9	1274	18%
Annualised	7124	0	1265	9	1274	18%
O&M	5476	0	0	9	9	0%
Bioenergy Plant						
Project Life						
Capital	575000	40000	0	13100	53100	9%
Annualised	35938	2500	0	819	3319	9%
O&M	83740	0	3164	0	3164	4%
Ag Displacement						
Project Life						
Capital						
Annualised	23	0	23	0	23	100%
O&M	69	23	23	20	66	95%

LABOUR / TURNOVER RATIOS and WAGE RATES

Average Labour / Turnover Ratio	20.000 ecu/job
Civils	25.000 ecu/job
Equipment	30.000 ecu/job
Services	20.000 ecu/job
Agriculture Gross Wages	2.500 ecu
Energy Gross Wages	8.800 ecu
Average Gross Wages	6.000 ecu

	Weighted Ratio - ecu/job
Energy Crop	
Capital	29928
Annualised	29928
Operating	20000
Bioenergy Plant	
Capital	23766
Annualised	23766
Operating	30000
Displaced Agriculture	
Capital	30000
Operating	25263

Displacement Cost Calculation D

Introductory Notes
Suckler Cow Production - Severely Disadvantaged LFA
FBS 1995/6 Farm Management Survey Gross Margins, pages, 4, 27
Assume class for gross margin for severely disadvantaged LFA is "good"
Nix 27th ed. 1997, pgs 61,138 (Upland Autumn Calving - High & Livestock Rearing Upland)

Financial Information Regarding Agricultural Activity Displaced

Years	1	
Interest Rate	8%	
Enterprise output	1	ecu/ha
Variable costs	1	ecu/ha
Fixed costs	1	ecu/ha
Net Margin per ha (before interest)	-1	ecu/ha
Depreciation on fixed capital and equipment	1	ecu/ha
Discounted net margin per ha	1,08	ecu/ha
Interest charge	0,08	ecu/ha
Net margin per ha (after interest)	-1,08	ecu/ha

Agricultural Production

Variable	Value	Units
Value of services	1	ecu/ha
Value of equipment	1	ecu/ha
Value of civils	1	ecu/ha
Value of labour	1	ecu/ha
Amount of services sourced from region	85	%
Amount of equipment sourced from region	100	%
Amount of civils sourced from region	100	%
Amount of labour sourced from region	100	%

Follow-on Questions Regarding Processing

Questions	Yes/No	%
Is the above displaced agricultural production sold locally for primary processin	Yes	
If yes, what % does this represent to the local primary processing company?		30
What % of the local processing company's income is spent locally?		25

Value of Agricultural Processing Displaced

Variable	Value	Units
Value of services	1	ecu/ha
Value of equipment	1	ecu/ha
Value of civils	1	ecu/ha
Value of labour	1	ecu/ha
Amount of serviced sources from region	65	%
Amount of equipment sourced from region	40	%
Amount of civils sourced from region	85	%
Amount of labour sourced from region	100	%

E

			GROSS IMPACT			DISPLACEMENT			NET IMPACT	
FEEDSTOCK PRODUCTION (All financial data in ECU)					**AGRICULTURE** (All financial data in ECU)					
Area	23	Ha								
Life of Project	1	Yrs								
Direct		Wage Rates								
Labour Relating to Capital Investment	1.150	2.500	0,5	Jobs			0,0	Jobs	0,5	Jobs
						Wage rate				
Labour Relating to Operation & Maintenance	1.208	2.500	0,5	Jobs	23	2.500	0,01	Jobs	0,5	Jobs
Profit (Less interest)	342.590				-25				342.615	Net Profit
Indirect										
Total Annualised Purchases of Capital Goods	7.124				23					
Capital Goods Purchased in the Region	1.274				23					
Multiplier	1,00				-0,54					
Indirect Capital Expenditure Retained	1.274	29.928	0,0	Jobs	-12	30.000	0,0	Jobs	0,0	Jobs
Total Annual Sales (inc grants)	495.696				23					
Total Annual Purchases of Operating Goods in the Region	9	0%			66	285%				
Multiplier	1,00				-0,54					
Indirect Operating Expenditure Retained	9	20.000	0,0	Jobs	-35	25.263	0,0	Jobs	0,0	Jobs
Induced										
Net Direct Additional Farm Labour Incomes (before deductions)	2.335									
Tax Deductions	20%									
Net Direct Additional Farm Labour Income (after deductions)	1.868									
Net Direct Additional Profit (before Tax)	342.615									
Profit Tax Rate	25%									
Net Direct Additional Profit (after Tax)	256.961									
Share of Net Additional Profit Spent in Region	25%	(assume same as capital)								
Average Gross Regional Incomes	6.000									
Net Indirect Additional Labour Incomes (before deductions)	269									
Deductions	20%									
Net Indirect Additional Labour Income (after deductions)	215									
Net Additional Labour Incomes from Feedstock Production	2.083									
Share of Net Additional Labour Incomes Spent in Region	25%									

CONVERSION PROCESS (Excl Feedstock)

ENERGY MARKET

(All Financial data in ECU)				E	Reg Share of Nat Energy Prod		
Life of Project	16	Yrs			5,0%		
Direct							
		Wage Rates					
Labour Relating to Capital Investment	2.500	8.800	0,3	Jobs	125	0,3	Jobs
Labour Relating to Operation & Maintenance	20.272	8.800	2,3	Jobs	1.014	2,2	Jobs
Profit (Less interest)	3.365				168	3.197	Net Profit
Indirect							
Total Annualised Purchases of Capital Goods	35.938						
Capital Goods Purchased in the Region	3.319						
Multiplier	1,02						
Indirect Capital Expenditure Retained	3.371	23.766	0,1	Jobs		0,1	Jobs
Total Annual Sales	205.000						
Total Annual Purchases of Operating Goods in the Region	3.164	1,5%					
Multiplier	1,02						
Indirect Operating Expenditure Retained	3.214	30.000	0,1	Jobs		0,1	Jobs
Induced							
Net Direct Additional Energy Labour Incomes (before deduction	21.633						
Tax Deductions	20%						
Net Direct Additional Energy Labour Income (after deductions)	17.307						
Net Direct Additional Profit (before Tax)	3.197						
Profit Tax Rate	25%						
Net Direct Additional Profit (after Tax)	2.398						
Share of Net Additional Profit Spent in Region	9%	(assume same as capital)					
Average Gross Regional Incomes	6.000						
Net Indirect Additional Labour Incomes (before deductions)	1.419						
Tax Deductions	20%						
Net Indirect Additional Labour Income (after deductions)	1.135						
Net Additional Labour Incomes from Conversion Process	18.442						
Share of Net Additional Labour Incomes Spent in Region	25%						

Total Induced

Net Additional Labour Income (after deductions)	18.825	ecu
Net Additional Profit (after Tax)	259.359	ecu
Net Additional Incomes/Profit	278.184	ecu
Share of Net Additional Incomes/Profit Spent in the Region	25%	
Multiplier	1,33	
Total Additional Retained Expenditure from Additional Income/	370.996	ecu
Average Labour/Turnover Ratio	20.000	ecu
Induced Jobs	18,5	jobs

Notes

The conversion plant was unprofitable as presented because of its high capital cost and low running hours.
Running hours have been increase to 4000, it is unlikely that a plant would be built for 1700hrs.
Regional import % has also been reduced as using 100% is unrealistic and gives very high mutipliers!
The jobs are probably still overestimated to some degree.

TOTAL NET IMPACT

Net Additional Labour Income	18.825	ecu
Net Additional Profit	259.359	ecu
Net Additional Direct Jobs	3,4	jobs
Net Additional Indirect Jobs	0,3	jobs
Net Additional Induced Jobs	18,5	jobs
Total Net Additional Jobs	22,2	jobs