BIO-ENERGY CHAINS FROM PERENNIAL CROPS IN SOUTH EUROPE.

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ABSTRACT: As set out in the White Paper, the goal is to significantly increase the use of biomass, adding a further 90 Mtoe by the year 2010. Of these 45 Mtoe are expected to derive from energy crops. The overall objective of this project is to "*evaluate, in terms of technical, socio-economic and environmental feasibility, the whole bioenergy chain from biomass production to thermochemical conversion for a number of perennial energy crops carefully selected to ensure, by successive harvesting, a year-round availability of raw material*". The output of this project is to identify the best options of bioenergy resources and technologies in southern Europe, in monetary, social and environmental terms.
Keywords: biomass production, biomass conversion, LCA

1. INTRODUCTION

The introduction of energy crops in EU bioenergy schemes under existing financial and legislative frameworks is still rather uncertain and in many cases uneconomic. Among the most promising identified options so far are perennial crops. Particular disadvantage is the lack of all year round availability of the raw material with consequent large storage costs.

In addition, little attention has been paid so far to measuring and evaluating the performance of energy crops in an integrated bioenergy chain. Use of multicrop agricultural systems offers the potential for year round operation without the need to store large quantities of materials and feeding systems developed for energy crops and related materials would be capable of handling a wide range of materials with comparable handling characteristics. Laboratory tests on the different stages of handling, pre-treating and processing these less commonly processed materials is the essential first step in the evaluation and development of integrated systems, particularly to compare performance on these material with performance criteria derived from more orthodox biomass forms such as wood.

In December 2001, a European Network started, entitled "Bio-energy chains from perennial crops in South Europe", aiming to generate information on the whole bioenergy chain from biomass production to thermochemical conversion of four selected perennial crops, in an attempt to define these chains that will lead to technically, economically, socially and environmentally improved systems of energy production from crop-derived biomass.

Table 1: The consortium and their involvement

The consortium		Involvement
CRES	Greece	Biomass production
UPM	Spain	"
UNIBO	Italy	"
INRA	France	"
ASTON	UK	Pyrolysis tests
VT-TUG	Austria	Combustion tests
BTG	Netherlands	Gasification tests
AUA	Greece	Financial/economic assessment
IFEU	Germany	Environmental assessment
IUS	Germany	"

The ultimate objective of the project is to evaluate, in terms of technical, socio-economic and environmental feasibility, the whole bioenergy chain from biomass production to thermochemical conversion for a number of perennial energy crops carefully selected to ensure a year-round availability of raw material.

2. APPROACH

2.1 Project structure

To achieve the goals of this project, the following work packages have been scheduled.

WP1 will address the whole biomass production chain of four selected perennial crops under South European conditions. The selected biomass crops (cardoon, giant reed, miscanthus and switchgrass) will be cultivated in large fields in representative agricultural regions in Greece, Spain, France and Italy and successively harvested. Field measurements will be used for the technical, economic and environmental analyses in the following work packages.

WP2 will address the thermochemical conversion processes, covering fuel characterization and multifueled tests of combustion, pyrolysis and gasification of the raw material produced in WP1. From the previous workpackages, a report on the technical evaluation of the overall integrated bio-energy chain performance from biomass in the field to a derived heat and/or power product will be produced.

A financial/ economic assessment of the data collected from the previous work packages will be accomplished in ***WP3***.

The overall performance from biomass in the field to a delivered energy product as heat and or power will be measured by reference to the component parts in the chain starting in the field and progressing through each stage of handling and processing. An overall performance model will be derived to provide consistent comparison between different bio-energy chains. This will be complemented in ***WP4*** with an environmental assessment, which will be conducted in all stages of all bioenergy chains. A list of the best options, of a combination of biofuels and technology, in terms of economic and environmental benefits, for each country will be produced.

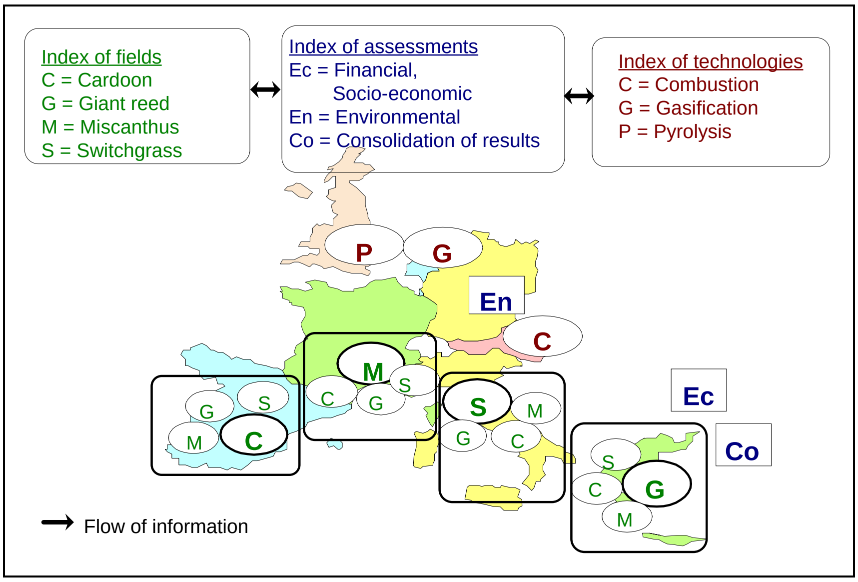

Figure 1: Index of field trials, technologies tested and assessments.

2.2 Biomass production

Since the south European countries present similar climatic conditions and in order to avoid quadruplicating the work and the associated costs, each partner will be responsible for the establishment and cultivation of one main perennial crop, for which he has adequate previous experience and the necessary conventional equipment for mechanised cultivation. These crops will be established in large fields of 10 ha.

Three smaller fields of about 0.25 ha each will additionally be established in each country, with the rest three crops, in order to fulfil the requirements of site-specific financial, economic and environmental analyses of WPs 3&4 for all the crops in each country.

The perennial crops and the partners responsible for each one are:

- *Arundo donax* (giant reed) - CRES (Greece)
- *Cynara cardunculus* (cardoon) – UPM (Spain)
- *Miscanthusxgiganteus* (miscanthus) – INRA (France)
- *Panicum virgatum* (switchgrass) – UNIBO (Italy)

The establishment of the crops will be carried out mechanically. Irrigation and fertilisation will be applied soon after establishment, according to the crop-specific requirements and the local soil-climatic conditions, in order to ensure successful establishment of plants. Weed control is expected to be negligible from the second and in the subsequent years.

A key point for the feasibility of the utilization of energy crops is the harvesting and pre-treatment of the feedstock. The selected perennial crops exhibit the critical advantage to be harvested successively, covering a period of 9 months (figure 2). This offers the potential for a year round availability without the need to store large quantities of material.

- ▶ Cardoon will be harvested twice from July to September by means of a swath-mower.
- ▶ Switchgrass will be harvested twice from October to December, using also a swath-mower
- ▶ Miscanthus will be harvested twice from November to January, with a maize silage harvester
- ▶ Finally, giant reed will be harvested twice from January to early spring, by means of a maize silage harvester

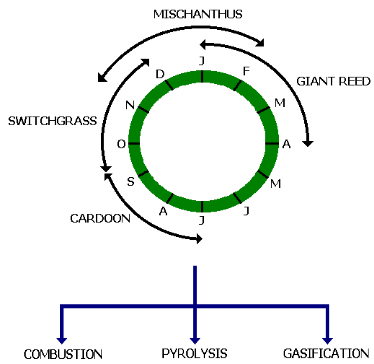

Figure 2: Schematic view of the succesive harvests of the crops and the thermochemical tests to be performed.

Samples from each crop will be sent to ASTON, VT-TUG and BTG for feedstock characterisation and the performance of combustion, pyrolysis and gasification tests.

2.3 Thermochemical conversion

<u>Fuels characterization</u>

Elemental and proximate analyses, as well as calorific value determinations for all crops in the large fields in the four countries will be carried out by CRES, VT-TUG and BTG.

<u>Combustion tests</u>

The lab-scale furnace of VT-TUG is specially designed for test runs to investigate the decomposition behaviour of different fuels. Based on the results of the lab-scale test runs risks concerning the combustion of the crops mentioned such as the formation of ecological relevant gaseous emissions (NO_x, SO_x, HCl) as well as the ash behaviour with respect to deposit formation and corrosion issues will be identified. Further test runs in a pilot-scale combustion plant will be performed and data like mass energy balances, gaseous and particulate emissions, deposit formation and risks for corrosion will be collected. Based on these data guidelines for furnace manufacturers concerning furnace conception, process control systems and the need for flue gas cleaning devices will be worked out.

Pyrolysis tests

ASTON will carry out the multifueled tests of fast pyrolysis. Samples will be pyrolysed under a range of conditions, such as: water content 5%, temperatures from 450^{o}C to 550^{o}C in 25^{o}C steps, to derive the temperature for maximizing liquid yield and the temperature for optimizing liquid quality. For each experimental run, mass balance, energy balance, liquid product yield, viscosity, water content, stability, heating value, density will be determined.

Gasification tests

BTG will conduct experimental gasification tests for each crop in a fluidized bed gasifier. Measurements will include the gas composition of main constituents (up to C3), tar and dust content in the product gas, amount of ash production, carbon content in the ashes and gasifier efficiency. Tests will be conducted at varying conditions, i.e. at different load levels and different fuel moisture content. In this way, the suitability of the crop for gasification at varying conditions can be determined.
The results from all the tests will be evaluated and used to derive overall integrated bio-energy chain performance from biomass in the field to a delivered heat and/or power product. Performance will be measured by overall efficiency, capital cost and product cost.

2.4 Economic/financial assessment

Economic analysis of cropping systems

Base for comparison will be conventional crops, of similar cultural practices as each perennial crop cultivated in agricultural areas of southern EU regions. A detailed cost analysis will be conducted to evaluate the possibility of introducing the perennial crops as alternative land use in the existing fields. The cost analysis will be based on the sequence of cropping practices for each crop (establishment, maintenance and harvesting) clarifying also costs according to production factor category (land labour, machinery, variable expenses and energy). Current subsidies will be taken into account in the determination of the net farming income. Cost of working capital and overheads will be added to the agricultural costs.

Economics of transport, supply and energy generation

The process performance measures derived in WP2, will be used to estimate overall process capital costs and product costs. A consistent basis will be used to ensure comparability and enable economic and technical comparisons to be made. A methodology for providing an overall assessment of the alternative processes will be devised that properly considers technical performance, economic performance, technical and financial risk, environmental factors and development requirements in order to derive recommendations for implementation.
Full consideration of capital costs of construction of power station, likely conversion efficiencies, feedstock purchase price and quality (which will depend on quality), and running costs will be made. Spreadsheets will be developed to derive generation cost figures (∈/kWh) which are capable of generating system sensitivity analysis.

Analysis of all direct and indirect energy costs (and carbon costs) associated with growing the crops and generating the electricity.

The work will initially formulate a 'base-case scenario' for the husbandry of each crop, by providing detailed information on crop inputs. For each operation in the production chain a detailed analysis of the associated direct and indirect energy inputs (MJ) and resultant CO_2 will be derived from the literature. The base-case scenario will then be modified to consider the sensitivity of the system to, for example, yield, quality and conversion efficiency variations.
The overall performance from biomass in the field to a delivered energy product as heat and or power will be measured by reference to the component parts in the chain starting in the field and progressing through each stage of handling and processing. Sensitivity analyses will be included to identify important cost components.

Financial analysis of all combinations of crops in each site.

The examination of the cost of storage and degradation of the most economic biomass type, against the economy of harvesting throughout the year will be estimated by a model with the simultaneous evaluation of more than one biomass crops in one energy chain/system. The benefit of better use of capital equipment (spread in more months) will be taken into consideration. Optimisation techniques will be used to identify the most advantageous scenarios and economic advantages will be compared with increased risk and environmental consequences.

2.5 Environmental assessment

Assessment of environmental impacts using EIA and LCA

Two assessment tools will be used, environmental impact assessment (EIA) and life cycle assessment (LCA):

- Using EIA, the local environmental impacts due to the production of the energy crops will be evaluated, with focus on parameters like erosion, implications on water resources and supply, biodiversity, etc. The influence of the crops itself and the choice of the farming location will also be investigated. Results will be country/crop/field conditions specific. Overall interactions and similarities or equalities will be pointed out.
- Using LCA, according to the ISO 14040-43 standards, the environmental implications of the biofuels under concern will be assessed compared to their fossil counterparts. The complete life cycles of all fuels will be taken into account. The whole production chain of each crop will be included as well as agricultural reference systems, use of byproducts and ashes, the different thermo-chemical

conversion technologies under concern etc. Life cycle inventory parameters like primary energy demand, CO_2 or NO_X will be used to describe resource demand, greenhouse effect, acidification, eutrophication, ozone depletion and human toxicity. For this, international standards will be used.

Modeling of dependencies and sensitivities

The basic scenarios of the previous task, for each comparison of a biofuel versus his fossil counterpart, will be transferred to so called "reference scenarios", which will incorporate correlations using functional dependencies (for instance saving of CO_2 along the whole life cycles depending on the yield of the crop). One or more reference scenarios for each biofuel describing all environmental implications will be produced. The scenarios include multi-functional dependencies as from yields, farming methods, fossil fuels to be substituted, country specific conditions etc.

Identification of the best options

Using a multi-functional assessment tool the best options for the production and use of a set of different biofuels in the future will be conducted. Four steps are necessary:

- All the reference scenarios will be combined.
- The combinations will be optimized in terms of their environmental implications. Options with a high potential to save fossil energy carriers (EU White Paper) and greenhouse warming potential (Kyoto protocol) will be preferred.
- For all options scenario calculations will be done to investigate the overall potential on the environmental implications. Basic data for these calculations will be assessed by the respective partner.

The reference scenarios and the results of the potential analyses will be compared with the results of the economic analysis. Modifications will be made to finally ensure realistic options with an optimal combination of economic and environmental implications.

3 PROJECT RESULTS

Project results will concern:

- Use as biomass feedstock four selected perennial crops, having low input requirements, as shown in previous RTD projects, and are well adapted in the Mediterranean Basin.
- Successive harvest of the selected crops in order to ensure a year-round availability of raw material with minimum storage requirements.
- Test the energy-crop derived biomass through thermochemical conversion processes
- Implementation relative financial/economic and environmental analyses
- Definition of the optimum combination of low technical risk, low specific capital cost, high efficiency and minimum environmental impact.
- The dissemination of the results will be performed through publications in scientific and trade journals, presentations in international conferences, a dedicated web page, working contacts with decision-making groups, local authorities, local agricultural and energy organisations, and farmers' visits in the experimental fields.
- Eventually, a handbook on the specific features of the selected bioenergy chains will be prepared in the end of the project.

As this project has not started yet, there are not results available to present.

4. ACKNOWLEDGEMENTS

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