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Preliminary Remarks on Socio-Economic Impacts of Biofuel Production and Use in Europe

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Abstract: - Biofuels represent an attractive substitute for classical, fossil fuels with some important advantages such as renewable sources and environmental friendliness. However, the physicochemical characteristics of biofuels are different from fossil fuels, therefore new technologies have to be developed. One of the most prospective fields for the use of biofuels is Combined Heat and Power (CHP) production, where new industrial gas turbines provide the needed new technologies. To justify the development of these new technologies and to assess the effects of use of different liquid and gaseous biofuels in CHP production, we have performed a preliminary socio-economic analysis. In this analysis we included liquid biofuels available in EU (rape-seed oil, biodiesel, flash pyrolysis oil) and processes such as gasification from wood, waste methanization and slow pyrolysis for gaseous biofuels. The analysis covers the whole production chain starting from crop production, oil extraction, and biodiesel production to CHP production using various liquid and gaseous biofuels. The most important, preliminary qualitative and quantitative results of the performed socio-economic analysis have been presented.

Key-Words: - Socio-economic analysis, Biofuels, CHP production, Rape-seed oil, Biodiesel, Flash pyrolysis oil, Gasification from wood, Waste methanization, Slow pyrolysis

1 Introduction

In the last few years much attention in the EU has been paid to define the policy of sustainable development as a consequence of the awareness of exhaustiveness of traditional fossil fuels and the influence on serious climate changes triggered by their uncontrolled exploitation and usage in the last century. The AFTUR (Alternative Fuels for Industrial Gas Turbines) project offers an attractive alternative for fossil fuels in the process of Combined Heat and Power (CHP) generation using different kinds of biofuels (liquid and gaseous).

In this paper many socio-economic impacts of the AFTUR project have been examined using the preliminary input data. These preliminary input data are based either on projected CHP plants using novel biofuel technologies, or on real CHP plants using classical, fossil fuels.

The economic impacts are divided on local, regional and national implications of implementing particular investment decisions. Local economic impacts are expressed using the financial indicators (e.g. net present value, internal rate of return, payback period, etc.) of cash-flow analysis for given liquid biofuel production or CHP power plant. Regional and national economic impacts are divided on: macroeconomic effects (regional growth, export potential, import dependence, security of supply, risk diversification), supply side effects (enhanced competitiveness, labor mobility, improved infrastructure, increased productivity), demand side effects (income and wealth creation, employment, support of related industries).

Social impacts include: impacts on health, impacts on education, quality of life, avoided rural depopulation and rural diversification.

Various socio-economic studies that discuss the impacts of Renewable Energy Technologies (RET) stress different aspects of the complex problem of socio-economic analysis [1]. The methodologies used for the preparation of the socio-economic analysis can be divided into two broad categories: qualitative and quantitative. The qualitative methodologies give the description of the main impacts of the technology on the economy and society at different levels (national, regional, local) and can provide subjective socio-economic criteria. On the other hand the quantitative methodologies offer quantified measures for the economic and social impacts. Some of the most popular quantitative methodologies are:

- General Equilibrium Model [2] also known as input-output (I/O) model relies on use of I/O tables, which give the details of all relevant inter-industry flows. This model can be used to assess impacts on employment, income, economic gain, or even emissions of greenhouse gasses. The main drawback of the model is that it requires a large amount of input data, which may not be readily available
- Cash-Flow Analysis [3] is a standard methodology used for the preparation of feasibility studies, which proved very useful in the assessment of microeconomic impacts. In the appraisal of investment opportunities the methodology uses various static (financial and efficiency) and dynamic indicators (net present value, internal rate of return, payback period, …).
- Externality Analysis [4] is used to assess different socio-economic and environmental impacts on parties which are not directly involved in the production-consumption chain. Externality Analysis is not a single technique, but rather a collection of techniques, which, for instance, may include financial or life-cycle analysis of technologies that are integrated to provide the needed assessment.
- Keynesian Economic Model [5] is based on income-expenditure model where it is supposed that total income of a community (local, regional, national) is dependent on how much this community is spending locally. This model can be used to assess direct, indirect, displacement and induced effects on employment and income.

There are also many software tools based on these quantitative methodologies for the preparation of socio-economic studies such as:

- SAFIRE [6],
- ABM [7],
- ELVIRE [8],
- BIOSEM [9],
- INSPIRE [10] and
- EXTERNE [11].

Wherever it was possible we used a quantitative approach: for microeconomic analysis we used Cash-Flow Analysis, while for demand-side effects we used BIOSEM technique based on Keynesian Income Multiplier approach. In the absence of quantitative values we used qualitative values to describe macroeconomic, supply-side and various social impacts.

One of the main results of socio-economic analysis in AFTUR project should be the selection of biofuels. In AFTUR project the following liquid biofuels have been considered:

- vegetable oils (rape-seed, sunflower),
- esters (Rape-seed Methyl Ester – RME, Sunflower Methyl Ester - SME) and
- flash pyrolysis oils,

as well as gaseous biofuels produced in the following processes:

- gasification from wood,
- waste methanization and
- slow pyrolysis.

2 Economic Impacts

There are many different economic impacts, and they will be described by various effects such as:

- Microeconomic effects
- Macroeconomic effects
- Supply side effects
- Demand side effects

2.1 Microeconomic effects

To assess the microeconomic effects of different biofuels various feasibility studies have been prepared for the production of different liquid biofuels (vegetable oils, RME and flash pyrolysis oils), CHP plants that use these liquid biofuels as well as for CHP plants using gasification from wood and slow pyrolysis processes, and gas from waste methanization.

In the preparation of input data for feasibility studies, we used the projected prices for a CHP plant with the overall power of 18,6 MW, which has the heat to power ratio of 1,5 and 90% of heat and power efficiency.

The construction phase takes 2 years and operating life is 30 years for all plants. For the financing of investment costs a 20 years long-term loan is used with constant principal, 4 years grace period and 5,5% interest.

The price of electricity is 13 c/kWh, while the price of thermal power is 2 c/kWh. The prices have been determined so that the rape-seed oil CHP plant is financially acceptable.

The price of rape-seed oil is 523 €/tonne, the price of biodiesel is 485 €/tonne, while the price of flash pyrolysis oil is 161 €/tonne.

The most important dynamic indicators of liquid biofuel production efficiency at 12% discount rate are presented in Table 1.

Table 1. Dynamic indicators of CHP plants using liquid biofuels

Indicator	Rape-seed oil	RME	Flash pyrolysis oil
NPV (€)	734.663	3.872.718	9.346,802
IRR (%)	13,59	20,26	31,47
Payback (years)	8	6	4
Relative NPV	0,12	0,64	1,54

However, even the flash pyrolysis oil CHP plant is not efficient for the market prices of electricity (6 c/kWh) and thermal power (1 c/kWh), which means that the CHP plants using liquid biofuels still cannot compete with classical power plants using fossil fuels (e.g. coal), unless substantial subsidies for electricity and thermal power are provided, or environmental taxes are introduced for greenhouse gases and other air pollutants emissions.

The feasibility studies for the combined heat and power generation using the slow pyrolysis (EDDITh) process, direct gasification and waste methanization are using the projected data for the plant with the same characteristics as for liquid biofuels – the overall size of 18,6 MW, heat to power ratio of 1,5 and overall efficiency of 90%.

The duration of construction phase is 2 years, while operating life of the plant is 30 years. The investment costs for all CHP plants are financed using a 20 years long-term loan, with constant principal, 2 years grace period and 5,5 % interest.

The price of electricity for all CHP plants using gaseous biofuels is 6 c/kWh, which is quite acceptable for most EU countries, thermal energy (1 c/kWh) and wood (10 €/tonne).

The dynamic indicators of gaseous biofuel production efficiency at 12% discount rate are presented in Table 2.

Table 2. Dynamic indicators of CHP plants using gaseous biofuels

Indicator	Slow pyrolysis	Gasification	Waste methanization
NPV (€)	7.421.627	18.354.047	9.472,450
IRR (%)	21,87	24,63	27,54
Payback (years)	5	5	5
Relative NPV	0,68	0,90	1,09

All three CHP plants are financially efficient even using the market prices for electricity and thermal power. If environmental taxes are applied, then these plants will be even more efficient, because the prices for electricity and thermal power can be increased. From the financial point of view, CHP plants using gaseous biofuels show much better performance than CHP plants using liquid biofuels.

2.2 Macroeconomic effects

If the CHP production based on various biofuels is extensively used, then this will have significant impacts on the long-run security of supply, because the risk involved with the fluctuations of prices on the crude oil market will be avoided.

The EU is a net importer of fuel, both gas and oil. The use of natural gas for power generation is projected to double in the next 20 years, contributing to an increase in dependence on imported energy of up to 70%. This will be a drain on the overall EU budget. Natural gas has become the fossil fuel of choice in areas where it is available and market estimates indicate a market for 575GW_e over the next 15 years.

In the meantime, a source of power exists. It is based on the energy contained in the biofuels, and also in some process gases (e.g. refineries). This energy is either released to atmosphere, thus participating in the greenhouse gases emissions, or it is converted to power, by using various means of transformation, but not by using Low Emissions (NO_x and CO) gas turbine technologies.

The substitution of fossil fuels with biofuels is very attractive, because it reduces the import dependence of the EU and its vulnerability to the changes of fossil fuels prices on world markets. For this reason, the new technologies used in the CHP production based on biofuels could enhance the export potential of the EU countries.

The Industrial Gas Turbine market is substantial and expanding but very competitive. This development would provide an important element in maintaining the capability to compete and possibly enhance market growth for the main partners. Especially by considering the fact that the European Manufacturers of Industrial Gas Turbines will be able to supply the market with products and technologies that are the best solutions for those who wish to have a responsible behavior towards their emissions.

European gas turbine manufacturers have a 40% of the world market, which is forecast to be worth 18 billion Euros per annum for the next 15 years. This is indicative of their future ability to exploit the technologies developed in shared cost RTD programs.

There is an expanding market, with a need for new designs and in many cases the opportunity to use a variety of fuels, to minimize waste, and also use renewable fuels.

2.3 Supply side effects

Supply side effects are generally hard to quantify, but have significant long-run regional impacts. These effects are related with the increased competitiveness of the region, and improvements in regional productivity. As a consequence, a region becomes more attractive for inward investment and draws inward migration, which by itself, generates the investment in resources and the complementary economic activity.

The AFTUR project is contributing to the more effective use of energy through Combined Heat and Power systems (CHP). In this regard, the use of the very appropriate characteristics of Industrial Gas Turbines and the availability of alternative fuels will encourage the use of distributed power and in particular the expansion of electrical generation by major consumers (cement manufacturers, or others).

2.4 Demand side effects

The demand side effects represent the focal point of the majority of socio-economic studies, because they are easy to define, and are most important to regional developers and decision makers. The most important demand side impacts are on employment and regional income. They can be divided into:

- direct effects,
- indirect effects,
- induced effects
- and displacement effects.

These effects can be used to represent some economic and social criteria from the socio-economic study:

- Economic gain (net additional profit)
- Income (net additional labor income)
- Economic activity (proportional to net additional income/profit)
- Related industry support (proportional to operating/annualized capital costs excluding labor costs)
- Employment generated (total net additional jobs)
- Avoided rural depopulation (proportional to net additional direct jobs)

The demand side effects will be described using an example of 18,6 MW CHP plant, with the overall heat and power efficiency of 90% and heat to power ratio of 1,5 (6,7 MW_e, 10 MW_{th}).

Table 3 gives the summary of demand side effects for CHP plants using different liquid biofuels. As may be expected, from the national point of view, the most efficient is combined heat and power production using biodiesel (RME). It shows the best performance according to socio/economic criteria (income, economic activity, related industry support, employment generated, avoided rural depopulation), except for economic gain where CHP plant using flash pyrolysis oil is better. The CHP production using flash pyrolysis oil shows better performance than rape-seed oil CHP production concerning economic gain and economic activity, while rape-seed oil CHP production is better than flash pyrolysis oil CHP production in case of income, support of related industry, employment generated and avoided rural depopulation.

Table 3. Total demand side effects for CHP plants using liquid biofuels

Demand side effect	Rape-seed oil	Biodiesel (RME)	Flash pyrolysis oil
Operating/annualized capital costs (excl. labor, €)	7.563.795	7.833.603	1.421.078
Net additional labor income (€)	4.571.735	4.853.322	1.240.608
Net additional profit (€)	-3.105.760	-2.258.254	780.407
Net additional income/profit (€)	1.465.975	2.595.068	2.021.015
Net additional direct jobs	110,5	117,8	30,3
Net additional indirect jobs	64,8	66,9	13,6
Net additional induced jobs	58,6	103,8	80,8
Total net additional jobs	233,9	288,5	124,7

These results are not surprising, having in mind that CHP plant that uses biodiesel requires an extensive agricultural production, but also the extraction of rape-seed oil and biodiesel production. Negative economic gain in case of rape-seed oil and biodiesel CHP plants are compensated by large net additional labor income from labor intensive agricultural production. The CHP production using liquid biofuels is still not profitable, and substantial subsidies should be provided or environmental taxes must be introduced to enhance its profitability. Even when subsidies are applied, from the national point of view, CHP production using liquid biofuels is very attractive.

Table 4 gives a summary of total demand side effects for CHP plants using gaseous biofuels. It is obvious that waste methanization CHP plant is superior in all parameters to other two options, which is caused by the fact that instead of heaving biofuel costs, in case of waste methanization, we have income for gate fee. The gasification from wood process is slightly better than slow pyrolysis process concerning income, related industry support and avoided rural depopulation, while slow pyrolysis process is better in economic gain, economic activity and employment generated.

Table 4. Total demand side effects for CHP plants using gaseous biofuels

Demand side effect	Gasification from wood	Waste methanization	Slow pyrolysis
Operating/annu-alized cap. costs (excl. labor, €)	556.002	1.258.063	495.569
Net additional labor income (€)	422.910	1.184.062	376.267
Net additional profit (€)	2.317.729	4.790.105	2.452.278
Net additional income/profit (€)	2.740.639	5.974.167	2.828.545
Net additional direct jobs	9,5	30,0	8,4
Net additional indirect jobs	4,6	10,5	4,1
Net additional induced jobs	109,6	239,0	113,1
Total net additional jobs	123,7	279,5	125,6

Comparing socio-economic parameters of CHP production using liquid and gaseous biofuels, it can be generally said that CHP production using liquid biofuels is superior to CHP production using gaseous fuels concerning related industry support, income, avoided rural depopulation, and slightly better in employment generated, while CHP production using liquid biofuels is much better in relation to economic gain and economic activity. On one hand, CHP production using gaseous biofuels is very profitable without any subsidies or environmental taxes causing high economic activity, while on the other hand, it doesn't have strong influence on agricultural sector, related industry and employment as CHP production using liquid biofuels has.

3 Social Impacts

There are various social impacts of a new biofuel power plant. The first one is on employment in rural areas. New jobs will be created in the feedstock production (e.g. sunflower, rapeseed), transportation and operation of the biofuel power plant. Some short-term jobs will be created during the construction of the power plant, and also new jobs will be induced in the supporting industry.

Scientific design methodologies are needed to deal with a changing and expanding market of industrial gas turbines, and new materials are becoming available which will best be exploited by improved design methods. Failure to improve markedly will result in possibly drastic losses in the 50,000 high quality jobs in the major gas turbine manufacturing companies and consequently in a similar number of jobs in the supply chains. Many of these suppliers are Small and Medium Enterprises (SMEs). There are also many jobs in marketing, sales, installation and servicing throughout the world.

The majority of the jobs in the industry is high skilled and high added value, and will continue to depend entirely on the ability of the sector to introduce new techniques and products to remain competitive in the world market.

Employment within the gas turbine manufacturing industry is increasing concentrating in the development and application of sophisticated design and manufacturing capabilities requiring a well-educated and trained resource pool. The competition for staff of this type and calibre is intense and indeed there is a negative exchange of the appropriate staff to the competing companies in the United States of America

The creation of new jobs, together with the increase of regional income has the effect on the increase of the welfare of the society, quality of life and stopping the outward migration flows from the rural areas.

The rural areas are mainly agricultural. The construction of a new biofuel power plant will contribute to the rural diversification and decrease the dependence (and risk) of agricultural production.

Distributed power could enable a reduction in long range electrical distribution with its inherent energy waste due to distribution losses, and the potential for a reduction in unsightly pylons. There is also the unresolved concern about the health hazards of electro-magnetic radiation from power cables and their interference with some forms of telecommunications.

Comparing to other technologies, the negative public health impacts of biofuel technology are larger than for natural gas, nuclear or wind technologies, but lower than for coal and oil technologies [12].

The power plant security issues have become very important after September 11th, when the public became aware of the possibility of terrorist attacks on nuclear power plants. However, not only nuclear power plants came in danger, but also hydropower plant dams (whose destruction would result in disastrous floods), and large thermal power plants (whose disabling could cause the collapse of the national power systems and long power shortages).

From the security point of view, biofuel power plants do not represent interesting targets for the terrorist attacks, because they don't contain toxic or radioactive material, hence even if they are destroyed, they will not pollute the environment.

Unlike other technologies whose power supply is limited by draughts (hydropower, nuclear power), miners' strikes (coal), wars, embargos (crude oil), the power supply of a biofuel power plant is reliable and not so limited by the external conditions.

4 Conclusions

This paper presents the preliminary results of socio-economic analysis of Combined Heat and Power (CHP) production using liquid and gaseous biofuels. The results of quantitative analysis of microeconomic and demand side impacts are based on 17 feasibility studies (including crop production, vegetable oil extraction, biodiesel production, flash oil production, and CHP production using various liquid and gaseous biofuels).

The preliminary results of socio-economic analysis show, that esters are the most favorable of the compared liquid biofuels used in CHP production, then flash pyrolysis oils, and finally vegetable oils. When three gaseous biofuels used in CHP production are compared, waste methanization shows the best performance, followed by slow pyrolysis and gasification from wood. When compared together, gaseous biofuels generally represent a better choice than liquid biofuels, while the order within each group remains unchanged.

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