BIOMASS (TO BIOETHANOL) SUPPLY CHAIN DESIGN AND OPTIMISATION

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ABSTRACT

Biomass is a flexible energy source that can be used for production of heat, power, transport fuels and biomaterials. The increasing interest in biomass energy and biofuels has been the result of many benefits such as the potential to reduce GHG emissions, energy security, the capacity to convert a wide variety of waste into clean energy and the prospects for rural and regional development.

One of the most important success factors for the increased biomass utilization is the structure of the respective supply chain and the selection of the converted – final energy form (heat, and/or power, and/or biofuels) according to the demand profile and the resources based allocation. Despite the significant development of biodiesel in our country, another extensively used biofuel, bioethanol, is not produced in Greece so far.

The objective of the present work is to make a preliminary design of biomass to bioethanol supply chain and more specifically to focus its attention on the raw materials collection and the production plant preliminary design.

More specifically, in the present work the residual biomass raw materials suitable for bioethanol production that are available in exploitable rates are identified and are located in the Greek map.

Then the various bioethanol production processes and technologies – depending on the type of raw materials - are analyzed and assessed.

The residual biomass raw materials identified may also be processed for heat and/or power generation, in addition to bioethanol production. Therefore, the integrated biomass exploitation supply chain is analyzed and the various parameters affecting its efficiency are evaluated.

Special emphasis is given on the design organization of the raw materials (biomass) collection network. Based on the existing experience from other supply chain networks, the present work makes a suggestion for the organization of the collection network that is feasible and may also be applied in other similar cases.

Keywords: bioethanol, biomass, raw materials collection network

1. Introduction and background of the work

The sector of transportation is responsible for the 20% of total GHG emissions in Europe and consists the second biggest source, after the sector of public electricity and heat production. Over the last decade, despite the continuous amelioration of vehicle efficiency, the emissions of the sector of road transportation were increased at approximately 14% (EEA, 2012).

These rates, along with the 2020 climate and energy package that the European Commission has announced, make the production and use of biofuels a worthwhile option. Biofuels are "eco-friendly", compared to conventional fuels, have lower emissions of CO, PbO, SO2, CO, NOx, etc. and can be used in diesel and otto engines, as a mixture with conventional fuels. In addition, the production of second or third generation biofuels does not compete food production and attributes to rural and regional development (EC, 2009).

Two are the most commonly known biofuels; biodiesel and bioethanol. Biodiesel can be used to substitute diesel and bioethanol to substitute petrol. Bioethanol can be easily produced in areas that afford or produce sugars, starch and cellulosic substances. Bioethanol can generate up to 900 litters per acre whereas biodiesel can generate up to 116 litters per acre. Bioethanol's production cost is reduced at high rates and can reach a price of 0.18 € per litter (CRES).

In Greece, there are several companies that produce biodiesel but not one that produces bioethanol, although the country has been traditionally cultivating sugars, wheat and corn. Examining all the above, the present work will carry out the preliminary design of a biomass to bioethanol supply chain in the region of Greece, in order to encourage future perspectives in such investments.

2. Feedstock & production processes

2.1. Feedstock Classification

By the term "feedstock", the raw materials, to supply the bioconversion to bioethanol process, are described. According to J.K. Saini *et al*., there is a variety of raw materials that are used for this purpose and can be classified into three categories;

- Feedstocks that contain sugars (sugarcane, sweet sorghum)
- Feedstocks that contain starch (corn, wheat)
- Feedstocks that contain cellulose or hemicellulose (wood, straw, agricultural residues)

Second generation bioethanol comes from raw materials that are not edible. Raw materials that are used for second generation bioethanol production are categorized into four categories (J. K. Saini *et al*.);

- Forest residues
- Municipal solid waste
- Agricultural residues
- Energy crops

Residual biomass comes from either farms or forests. Forest residues are used mostly for heat production, converted usually into pellets. Contrariwise, agricultural residues are not exploited in such a way and may be used as bioethanol production feedstock.
As stated in the Annual Agriculture Statistics for the year 2012, arable fields cover the 52.7% of the agricultural land in Greece. This rate corresponds to 19,389 thousand acres, from which 11,238 thousand acres are grains. Grains include the crops listed in table 1.

Table 1: Fields of Grain Cultivation (EL.STAT, 2014)

Grains	Thousand Acres
Wheat	6,883
Barley	1,279
Rice	308
Maize	2,117
Other	652

For the year 2007, the total production of grains was 11,738.4 thousand acres, allocated per geographical region in figure 1. Macedonia, Thessaly, Central Greece and Thrace have the biggest production of grains and, consequently, of residues (EL.STAT, 2012).

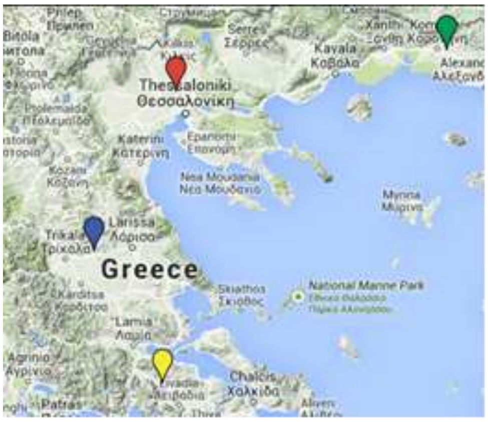

Figure 1: Regions with the biggestproduction of Grains in thousand acres

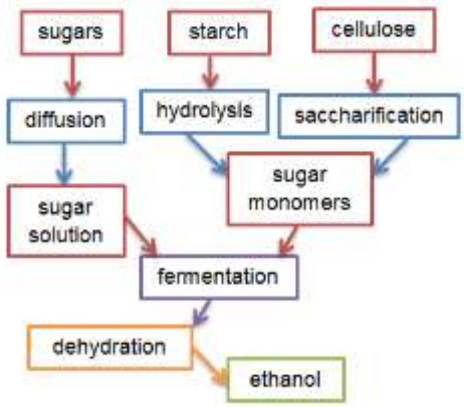

Figure 2: Production Process Diagram

2.2. Production Processes

Bioethanol is produced by converting biomass via fermentation and consists of three basic stages. At stage I, biomass is converted into sugar monomers. This stage depends on the type of raw materials being used. Materials that contain sugars are being pulped by mechanical pressure in order to produce sugar solution. If starchy materials, the process to derive sugar monomers is dry milling, followed by hydrolysis or saccharification. When the materials contain cellulose or hemicellulose, cellulose is converted into glucose via enzymatic saccharification. Next, at stage II, ethanol and carbon dioxide are produced from the sugar monomers by fermentation with yeast. Finally, – stage III – the fermentation liquid is distilled in order to separate ethanol and after dehydration, a high concentration biofuel is collected (B.R&D, P.R. Lennartsson *et al*, J. K. Saini *et al*.).

3. Biofuels supply chains

The term ''supply chain'' means the flow of materials, information and services from the production of raw materials to the production plants, until the final disposal of the product is obtained.

The supply chains of residual biomass for electricity, heat and biofuels production consist of the same states, except the production state. The states mentioned are the following:

- Collection of biomass; comprises the selection of the territory that the desirable feedstock is grown and then harvested by proper means, according to the type of raw materials.
- Pretreatment; is the conversion of raw materials to higher energy density biomass by milling and drying, in order to obtain an efficient transportation but also facilitate the production process.
- Transportation; transport the biomass from the fields to the plants in the most economical and efficient way.
- Storage; storing the biomass indoors, outdoors or in tanks, before the conversion treatment.
- Production Process; is different depending on the desired final product.
- Distribution; to consumers by tracks or tankers.

The production process, as mentioned, differentiates due to the final manufactured products. Biogas is used for electricity production and is obtained with thermochemical or biochemical conversions. Respectively, for heat production, pellets, a compressed form of biomass, are used (S. Chung & M. Farrey, E. Iakovou *et al*.).

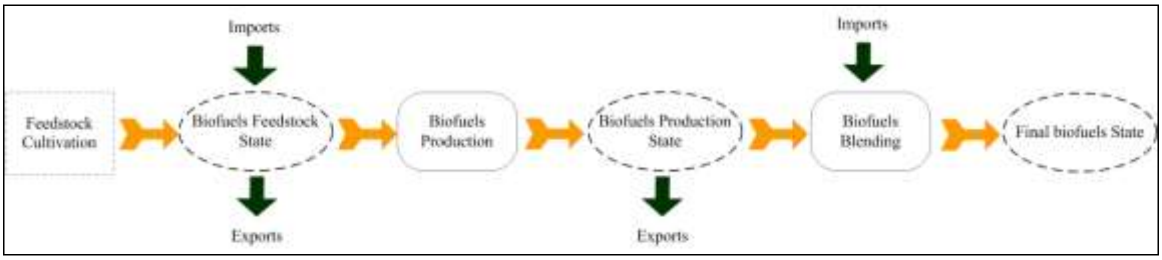

Figure 3: The biofuels' supply chain (C. Papapostolou *et al*.).

Each stage mentioned above is or constitutes a parameter, and their integrated behaviour should be analysed and evaluated, aiming maximum efficiency.
First of all, the selected feedstock should be grown in such a manner to increase its yield and reduce its cost. The main challenge is to identify a sustainable and cost-efficient farming technique for each different raw material. Thereafter, an optimum logistic strategy should be performed, in order to ensure stable supply of quality feedstock and ergonomic transport. Managing stable supply is a hard issue as agricultural irregularities are non-easily predicted. The form of biomass after the pretreatment affects the mode of transportation used and the delivery network, which is of great interest. The conversion process techniques should be advanced but of low cost, providing high quality biofuels – or other desired products such as biogas – and exploitable by-products. At last, in the case of biofuels chain, biofuels are transported to refineries or blending stations, where the selected final blend must be compatible with the existing car technology (B.R&D, S. Chung & M. Farrey).

Only by an integrated efficient supply chain, biofuels could satisfy their demand and compete the cost of petroleum based fuels. On top of this, the supply chain must obtain a positive net energy balance with low carbon footprint, to meet the original necessity of biofuels use.

4. Results – suggestion for a raw materials supply chain for bioethanol plant

Existing experience in biofuels' supply chain, indicates the integration of Geographic Information System (GIS), an information network that links the croplands of the feedstock, the infrastructure of the transportation and the consumers' demand. After acknowledging those data, means of transport, such as pipelines, rails, trucks even barges are chosen, depending on the geographical locations (S. Chung & M. Farrey).
Choosing agriculture residues, as bioethanol feedstock, due to their massive and easily available quantities, the bioethanol supply chain can have the following pathway;
Agricultural residues from grain cultivation could be collected from the regions of Macedonia, Thessaly and Thrace and delivered to a central location in Macedonia, maybe in Serres. Residues would be converted into a more energy-dense form, in the territory of their production by its farmers and then transported by trucks to a single conversion plant. For small-scale conversion plants, as reported by the Biomass Research & Development, transportation by trucks may always be the preferred method. The pretreated biomass could be kept in suitable storages, at or near the conversion plant, that would maintain its quality and provide a steady supply. After hydrolysis, the derived sugars, carbohydrates and lignin would convert to bioethanol and exploitable by-products via fermentation. Then bioethanol could be sold to refineries, from which it could be distributed to customers in a proper blend with conventional fuels. A company assigned with specialized logistics could organize the whole operation for its beneficial results (B.R&D).

5. Conclusions

This paper presents a theoretical approach of bioethanol – from agricultural residues – production plant preliminary design and therefore it includes issues that can be examined and presented in further work. Further work should include economic and technical evaluation of the presented collection network and supply chain and an optimisation of its parameters.

To conclude with, similar work could be performed for different kinds of biofuels, for various feedstocks or extended suggestions for biomass supply chains for electricity or heat production.

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