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TORREFIED BIOMASS IN BIOFUEL PRODUCTION SYSTEM

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Ukraine produces large amounts of crop residues every year, much which could be utilized to produce biofuel. However, efficient supply chains and system configurations are needed to make such systems efficient and cost effective. One option is to integrate torrefaction, power production and biofuel production into a single, coordinated system. This approach allows for high value product (i.e. biofuel), greater utilization of the energy content of the feedstock, and supply chain efficiency. Initial analyses indicate that revenues can be enhanced through this approach, and further analyses and optimization efforts could identify a sustainable approach to renewable fuel and power production for Ukraine.

The question of scale and layout remains of interest as well, and a thorough logistical study is needed to identify the most suitable configuration. Agricultural operations often benefit from smaller scales of operation, whereas fuel production processes tend to operate profitably only at very large scale. Thus, a balance must be struck between the needs of both ends of the supply chain. The processing center concept helps to balance those needs.

A system such as this also has potential to synergize with other agricultural production systems, such as the production of animal feed, fertilizer, and other bio-based products. The complexities of the Ukrainian agricultural market will need to be reflected carefully in any model that seeks to assess the system's potential. Presents a concept for coupling thermal pretreatment (torrefaction with biofuel and power production for the transformation of wheat straw into a value added product for Ukraine. Torrefaction provides supply chain savings, while conversion provides added value to the product. This paradigm has potential to utilize a widely produced waste material into a valuable source of energy and possibly other products for the country.

***Key words**: torrefaction, biomass, straw, renewable energy, processes.*

Introduction

Renewable energy development is a significant opportunity for the Ukraine and other countries, due to its positive attributes of reduced greenhouse gas emissions, local economic impact, and enhancement of energy security (*Shakya*, 2016; *Ciolkosz et al.*, 2017). The 2030 European strategy for low carbon development calls for 40 % of energy to be produced from renewable sources (*EU*, 2016). As part of that, a national task of Ukraine is "To increase the amount of energy from the renewable sources in a national energetic balance by means of introduction new capacity of the mechanisms which produce energy from the renewable sources".

In Ukraine total by-product gross output, which is suitable for use as biofuel, as of 2019 is 49915.8 thousand t., including that of grain crops by-product – 35954.7 thousand t. The estimation as of 2018 showed that by-production potential of the basic crops of plant growing which is available for energetic needs equals to 24738.3 thousand t. of fuel equivalent. The potential of grain crops by-production, available for energy generation equals to 17249 thousand t, of fuel equivalent. But not more than 3 % of this potential was used, leaving a very large amount of this renewable resource unutilized. This low utilization is caused in part by the lack of necessary equipment and technologies. Thus, the development of new technologies for biofuel production and their adaptation to the conditions in Ukraine is essential.

Other challenges that must be addressed for crop residues to be more widely used include the problems connected with biomass non-uniformity, high moisture content, low specific energy content, and low temperature of ash melting (*Golub et al.,* 2017; *Golub et al*., 2018).

One way to address this challenge is to thermally treat the biomass, using a process called torrefaction. Torrefaction is a mild thermal process in which biomass is chemically altered, causing its energy content to rise, equilibrium moisture content to drop, and grindability to improve while reducing the level of contaminants from the feedstock. Thus, torrefaction can have dramatic positive impacts on the quality and value of biomass, rendering it more suitable for use as an energy source (*Ciolkosz & Wallace*, 2011). While solid fuel combustion for heat and/or power are two notable applications for torrefied biomass, it also has potential to serve as a feedstock for liquid biofuel production (Sheikh et al, 2013; *Normark et al.*, 2016). Research has recently shown that torrefaction has a dramatic negative impact on glucose yield from wheat straw, but that additional processing, via alkaline pretreatment, can reduce this negative effect (*Memis et al*., 2020). Thus, potential exists to develop a biofuel sector that takes advantage of the supply chain benefits of torrefaction while still producing high yields of biofuel. In Ukraine, which is known throughout the world for its capability to grow wheat, the large supply of underutilized wheat straw could serve as a feedstock for such a system.

System Configuration

The supply chain for this system concept consists of three main process locations and two transport processes (fig. 1). In the first step, the biomass is collected from the field. The most likely format at this stage would be large bales (round or square). Following collection, the biomass is transported to a processing facility. This is likely to be a short haul transportation mode, owing to the low bulk density of the material. Upon arrival at the processing center, the biomass will be torrefied, ground and pelletized, and stored in pellet form. The processing center serves a vital role of rendering the feedstock more suitable for transport and providing storage so that the feedstock, available in the field over a short period of time, can be supplied to the conversion plant at a steady rate.

It is envisioned that multiple processing facilities would serve one conversion plant, though the optimum scale and layout remains to be determined. However, the torrefaction/ pelleting plant is likely to optimize at a scale between 50,000 and 100,000 Mg yr^{-1}, whereas a solid fuel power plant likely optimizes at a fuel use rate in excess of 1.0×10^6 Mg yr^{-1} and newer first generation ethanol plants are built on a scale of about 1.0×10^6 Mg yr^{-1}. Transportation to the process plant would be achieved by long haul truck or rail transport, at which point it is unloaded and subjected to conversion to biofuel, heat and power.

Discussion

The value proposition of this system is that the cost of torrefaction is compensated for by the reduced storage, transport and grinding costs relative to raw biomass. The approach is also superior to power-only systems, in that the biofuel produced has the potential to dramatically enhance revenues for the project. The system also provides a platform from which additional products can be produced at scale, including biochemicals, soil amendments and nutrients, and fiber-based products. In some cases, the product may be best suited for production at the torrefaction plants, whereas other products may be more appropriate for the conversion facility.

While a full study of the technoeconomics of this system remains to be carried out, there are promising indications that torrefied biomass can be delivered to an end user at an equal or lower cost when analyzed on a "per unit energy" basis. Key variables in the analysis include feedstock cost, glucose yield, power generation efficiency, capital cost, operating cost, and incentives/supports for renewable energy production. Since many of these inputs are either unknown or highly variable, sensitivity analysis is needed based on a "most likely scenario" to determine the range of inputs that will result in favorable production conditions. The specific characteristics of the Ukrainian wheat production sector will also likely impact the optimum configuration of such a plant.

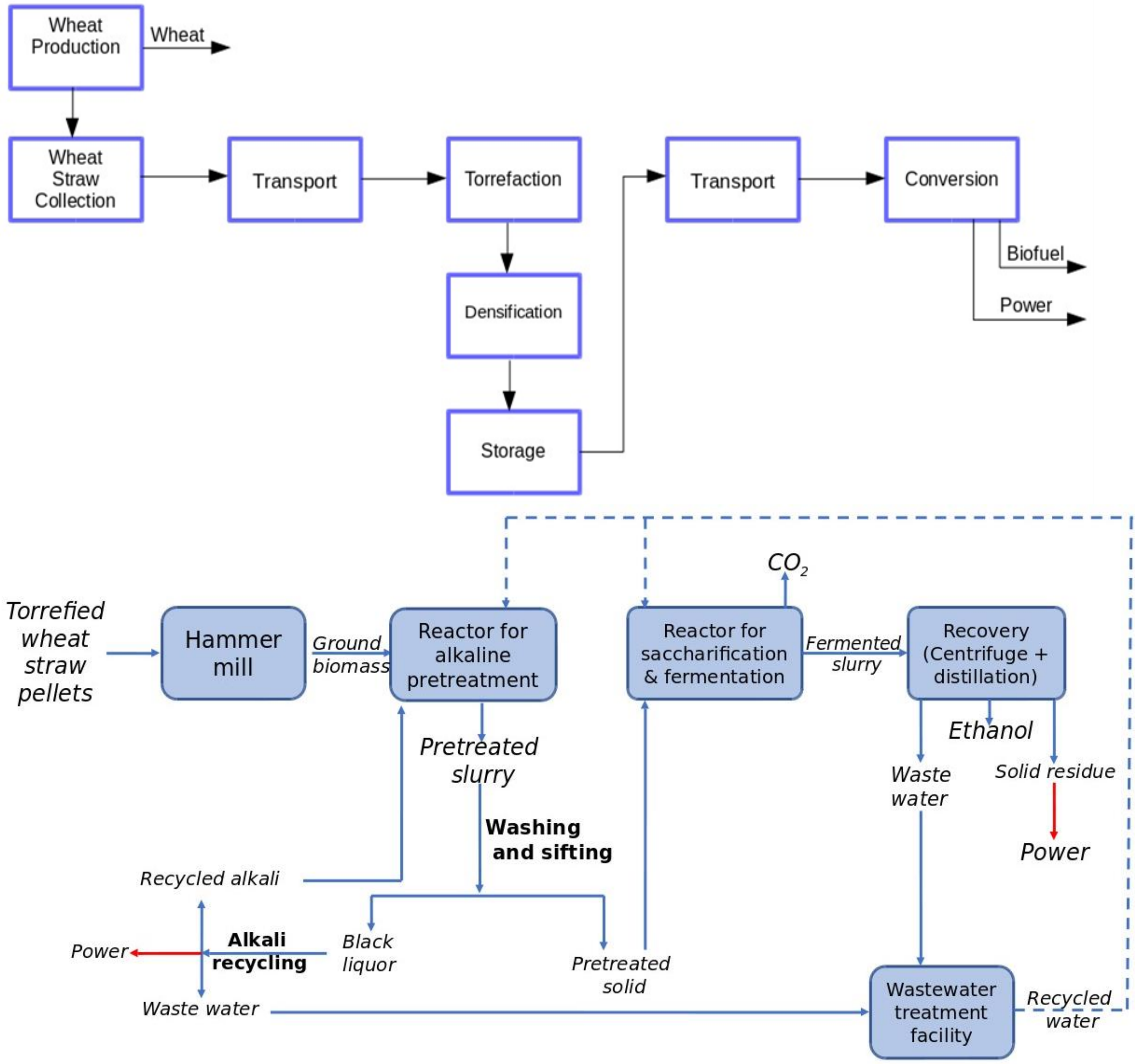

Figure 1. **Process Flow Diagrams of Supply Chain (top) and Conversion Process (bottom)**

Table 1. **Representative Productivity and Revenues, per GJ feedstock**

	Power only	**Power Plus Biofuel**
Feedstock Energy Input (GJ per Mg)	22	22
Biofuel Produced (litres)	0	300
Value of Biofuel	0	3564
Net Power Produced (kWh)	1650	840
Value of Power	1336	680
Total Revenue	1336	4244

Notes: Based on 14.85 Hryvnia per litre and 0.81 per kwh, wholesale prices; yield of 300 litres biofuel per Mg, 30 % power conversion efficiency, 10 % parasitic load for power, 20 % parasitic load for biofuel

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Conclusions

This paper presents a concept for coupling thermal pretreatment (torrefaction with biofuel and power production for the transformation of wheat straw into a value added product for Ukraine. Torrefaction provides supply chain savings, while conversion provides added value to the product. This paradigm has potential to utilize a widely produced waste material into a valuable source of energy and possibly other products for the country.

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