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BIOMASS & BIOENERGY

A mathematically-based framework for evaluating the technical and economic potential of integrating bioenergy production within pulp and paper mills

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ABSTRACT

To overcome declining markets and low-cost competition, Canadian pulp and paper (*P&P*) mills are considering the diversification of their product platform. Investing in bioenergy is emerging as a promising way to boost the sector. In this paper, we present a mathematical programming approach to evaluate the profitability of bioenergy investments in the case of a *P&P* mill, while assessing technical and associated economic risks. The mill, called the integrated forest biorefinery (*IFBR*), could produce a set of high-value bioproducts from biomass generated in the mill or supplied from outside. *P&P* activity generates residues, such as black liquor and pulp sludge, which could be used to produce bioenergy. *P&P* activity should then be well managed, by considering the possibility of temporarily stopping the production of *P&P*, while assuming the costs associated with the shutdowns. The objective is to develop a mathematically-based approach for investors and stakeholders, within the forest sector that aims to optimise the value creation network of the *IFBR* and to maximise the profitability of future investments in bioenergy, while optimising the existing *P&P* activity.

1. Introduction

The increased value of the Canadian dollar, the US housing crisis and low-cost competition have led to significant losses within the Canadian forest industry. Pulp and paper mills, in particular, are struggling to maintain their competitiveness, due to reduced pulp and paper demand, increased competition from emerging countries operating with low costs and the continued substitution of online media for paper based products [1]. Integrating new high added-value products is seen as a promising solution to allow *P&P* mills to evolve towards a competitive business model by transforming a conventional mill to an *IFBR* that, in addition to pulp and paper products, produces a wide range of products including electricity, steam and biofuels, from biomass ([2,3]).

Biomass is considered to be an abundant renewable resource that encompasses all organic materials of vegetable or animal origin. It includes forest woody residues (forest harvesting residues and mill residues), agricultural residues and municipal solid waste [4]. By using mill residues and supplied biomass, *P&P* mills could reduce and even supplant

Abbreviations: IFBR, integrated forest biorefinery; *P&P*, pulp and paper.

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the use of fossil energy by using biomass to fill the power, heat and steam needs of the mill, while diversifying their product portfolio by integrating high-value bioenergy products. In addition, a major part of industrial biomass residues comes from the *P&P* industry and forest management [5], such as black liquor and paper sludge, which provide near-zero cost raw materials [6]. Converting these residues into bioenergy products would not only help the company diversify its product portfolio, but also reduce its waste disposal costs.

So, *P&P* mills already have an available logistical infrastructure and a set of generated residues for processing biomass in order to produce higher-valued products [3]. This predisposition of *P&P* mills to host bioenergy investments makes the integration of such investments more advantageous, in terms of investment costs, than building a bioenergy stand-alone plant [7].

Biomass can be used to produce a set of high-value products including bioenergy, biomaterials and biochemical products [8]. In this work, we are interested in the bioenergy pathway. Bioenergy is a source of energy obtained from the decomposition process of organic materials in biomass, and by the combustion of combustible materials released, which encompasses biofuels, power and heat [9]. To produce bioenergy, a set of technologies is already available. In Ref. [10], the principal avenues to convert biomass into bioenergy are presented, including all available pathways to produce heat, electricity and biofuels.

The *IFBR* business model is seen as a promising pathway to help *P&P* companies face the economic and market-related challenges. Environmental policies and community pressure regarding greenhouse gas emissions could greatly affect the business model of the P&P sector. Considered as big greenhouse gas emitters, *P&P* mills could be forced to seriously reduce their emissions if political and social pressures increase. *IFBR* transformation would help *P&P* mills be well prepared for eventual changes, as it contributes to the supplanting of fossil energy and reduces greenhouse gases. On the other hand, as energy supplying represents almost a quarter of the *P&P* mill operational costs, the uncertainty related to energy prices would be a major factor in operational profitability. By allowing the mill to become energy self-sufficient, the *IFBR* may represent a viable solution and a hedge against the energy market uncertainty.

An *IFBR*, in the case of the *P&P* sector, would integrate bioenergy production into conventional *P&P* activity by using supplied and plant-generated biomass and transforming it into high-value bioenergy products. Fossil energy and power needs, as natural gas and electricity, could be supplied from outside or satisfied internally by bioenergy production, allowing the *IFBR* to be energy self-sufficient.

Heat and electricity cogeneration is already a tradition in Canadian *P&P* mills. In 2009, more than 51% of the thermal needs and 22% of the electricity needs of Canadian *P&P* mills were generated from biomass cogeneration, which places the *P&P* sector as the first sector using biomass cogeneration in the whole of Canada, with 31% of the total cogeneration capacity [11]. Mill residues as black liquor and on-site biomass residues are principally used to produce cogenerated electricity and heat, which is not always the most valuable way to convert that biomass [8]. One of the advantages of transforming *P&P* mills *into IFBR*s is to optimally balance the use of biomass between the different available bioenergy pathways.

In Fig. 1, we present the value creation network of a standard *IFBR*.

The biomass supplied could be industrial residues from other forest mills like sawmills and other *P&P* mills, including chips that could be used for both *P&P* or bioenergy production, agricultural residues from farms, forest residues generated by harvesting activity, or even urban waste residues from municipalities. The technologies considered in the *IFBR* are *Fermentation* to produce *Bioethanol*, *Pelletisation* to produce *Pellets, Pyrolysis* to produce *Pyrolysis Oil*, *Digestion* to produce

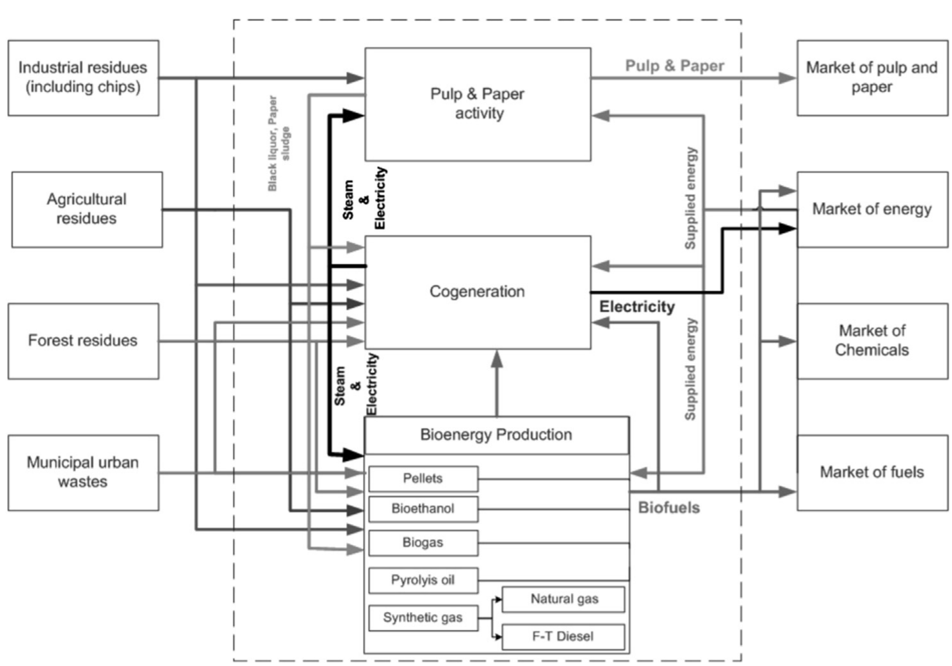

Fig. 1 – *IFBR* value creation network.