THE ROLE OF PROCESS INTEGRATION FOR GREENHOUSE GAS MITIGATION IN INDUSTRY

PI AND NOVEL TECHNOLOGIES AND SYSTEMS: BIOREFINERIES

ABSTRACT

Can process integration be used to achieve "radical" GHG emissions reduction, in connection with the implementation of the forest biorefinery? Yes – but only if PI studies are carried-out by experts knowledgeable in both the analytical methods, have a practical understanding of the biorefinery and core process technologies, can express the impact of improved energy management to the biorefinery business plan – and if there is some good luck and timing. This presentation will outline some thoughts on this question, and introduces a new PI technique we have termed the "Bridge Method", which is suitable for identifying the potential for improved energy management in the complex context of biorefinery implementation.

Forest Biorefinery Context

The so-called biorefinery represents an important opportunity for the Canadian forest products sector, and more broadly, forestry companies in North America and Western Europe. Bioproducts (biofuels, biomaterials and biochemicals) can represent new revenue streams for companies, as the demand for products in several traditional industry segments such as newsprint and printing/writing papers continues to decline. At the same time, the biorefinery represents an opportunity to renew certain mill facilities that are expected to survive in the longer-term, and even prosper, producing traditional products in addition to bioproducts.

No forest companies have yet "transformed" their businesses to the bioeconomy – perhaps the Finnish company UPM might be considered the leader in this context – however many companies are progressing. UPM considers that about 20% of their revenues come from their biorefining division. Through this and other restructuring, UPM about doubled EBITDA for essentially constant revenues over the period 2003-2014. Transformation implies significant risk. However this risk can be mitigated to a good extent using advanced business and engineering analytics, including process integration techniques.

Several forestry companies are beginning to settle on their transformational strategies, to be implemented in a phased manner, seeking transformation over many years and many phases.

Some 1st and 2nd quartile mills have begun to implement "**integrated**" biorefinery solutions, where in order to have available the primary biorefinery feed stream, it is necessary to continue to produce traditional pulp and paper mill products. Recent examples include (a) lignin precipitation at the Domtar fluff pulp mill in Plymouth SC, the Stora Enso market pulp mill in Sunila FI, and the West Fraser market pulp mill in Hinton AB, and (b) hemicellulose extraction at the Cascades corrugated medium mill in Cabano QC, and announced for the Fortress specialty cellulose mill in Thurso QC.

In the longer-term, several forest product companies are looking at "**exit**" biorefinery strategies. In this case, large new sources of wood fibre would be consumed for essentially parallel processing streams. The wood supply, power island and effluent treatment are typically common between the traditional and biorefinery processes, however the design is made considering that eventually, traditional products will no longer be produced. Having said this, a phased implementation is still essential; more specifically, the cash flow from the existing products for the near- and intermediate terms is essential to ensure the economic viability of the new business model.

Other drivers are essential for catalyze transformation commitments by forestry companies, especially to mitigate the significant technology, financial and market risks implied with forest sector transformation. Natural Resources Canada (NRCan) has had two rounds of funding for the so-called IFIT program that has supported up to 50% of initial transformation phase projects. More recently, the federal government has announced important initiatives related to innovation in clean technology, and Canada is now committed to significant GHG emissions reduction. These announcements will hopefully be a catalyst to help accelerate forest sector transformation.

Process Integration in the Forest Products Sector with Biorefinery Implementation

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In general, North American pulp and paper facilities have had **limited success** at justifying low capital cost mill-level projects for incremental energy use reduction. Information from American Process Inc (API) of Atlanta, based on their recent studies, is that "practical" energy use reduction projects identified potentially result in a 17% thermal energy use reduction using a payback of 2 years at current energy costs. Depending on the situation, mills today typically don't implement mill-level projects that provide a 1-year payback. As a result mainly of the low cost of energy in North America, resulting in a passive approach to energy management mixed with occasional short-term bursts for energy reduction projects when oil prices spike – pulp and paper mills in North America continue to use significantly more auxiliary steam than their counterparts in Europe where energy prices are significantly higher.

PI might be described as having had **relatively good success** in the forest sector. It has been applied for many years, in particular by "expert" boutique consulting companies such as API, and in Canada by the CanmetENERGY research centre in Varennes. The relative success (or not) of PI might be attributed to (1) the fundamental challenge of justifying mill-level incremental energy use reduction projects, coupled with (2) an unreasonable expectation of PI studies. Many mill energy managers believe that PI is an expensive and complex methodology that at its conclusion, confirms the energy use reduction projects they already had in mind before the study began.

Biorefinery implementation has great potential for radical GHG emissions reduction including (1) certified forest management that is increasingly recognizing the increase in naturally-disturbed wood with global warming (forest fires, insect and disease outbreaks, drought, wind throw and floods), (2) delivery of products that sequester carbon such as wood buildings, archive papers, etc, and (3) delivery of bioproducts that are substitutes for fossil-based products. Beyond these 3 potential opportunities for radical GHG emissions reduction, those companies that implement their biorefinery strategy well will exploit the opportunity to restructure their energy use profile and site-wide energy configuration to have a "return on energy" in addition to the biorefinery project return, and associated GHG emissions reduction.

Biorefinery implementation thus potentially represents a unique opportunity for improved mill energy usage – both in the core business processes as well as in the new biorefinery processes. The fundamental opportunity lies with the opportunity for incremental investment in the biorefinery processes targeting energy management, potentially providing a disproportionately high return due to energy reconfiguring. Biorefinery implementation is a high risk proposal, and higher returns are expected by forestry companies when compared to capital investments in the core business. The more energy inefficient the mill currently is, the greater the potential for improving the biorefinery return through the application of PI.

At the same time, energy use reduction associated with biorefinery implementation is complex:

- Significant new revenue streams accompanied by attractive returns will generally be realized by companies that are first-to-market or early-to-market, which increases the emphasis on unique partnership and opportunities at the supply chain level.
- Energy use reduction needs a strong climate policy in support of it to capture the attention of strategy decision-makers, who are generally focused on the business context, have limited resources, and who will resist a dilution of the focus on energy issues.
- Biorefinery implementation will occur over many phases, which is accompanied by uncertainty, and this makes the energy strategy more complex to commit to at the early phases.
- Biorefinery implementation involves integrating new production processes with an existing production process. This is a complex retrofit context.
- Biorefinery processes are at different levels of development from pilot to demonstration scale, and only a few are today at the commercial scale. Biorefinery strategies are typically accompanied with high levels of uncertainty regarding process performance as fundamental as process yields, and consequently, also energy performance.

There are several key factors for success in the application of PI with the forest biorefinery strategy to help achieve “radical GHG emissions reduction”, for example:

- **Timing:** PI should be applied once the strategy is set and the company seeks to improve the return on targeted biorefinery strategies, once they have been tentatively confirmed based on business plans.
- **Biorefinery Process Expertise:** The biorefinery processes to be implemented, by phase, should be defined including a good understanding of their technical uncertainties and the implications of these to their energy performance.
- **Core Business Process Expertise:** The biorefinery integration strategy with the existing processes should be clear, including the process risks to the core business resulting from the biorefinery processes.
- **Expertise in the Application of PI Methods:** Classical PI methods require a high level of expertise in order to apply. Further, there remain limitations of existing PI methods, and must be considered when placing energy program recommendations into their appropriate context.
- **Understanding of the Biorefinery Strategy Business Case:** A strong appreciation of the issues of technology and market risk associated with the biorefinery business plan are essential to be able to context the potential for “return on energy” with the biorefinery strategy.

Introducing the Bridge Method for Energy Analysis

Our research laboratory began to conduct product and process design projects and apply systems analysis methods for biorefinery strategy evaluation in the mid-2000’s. Through our exposure to the biorefinery transformation context, it became obvious that energy use reduction would in many cases be either (a) critical to improve the business proposal of high-risk biorefinery transformation strategies, or (b) provide an important opportunity for energy use reduction at the time of biorefinery implementation, making the core business more competitive for the longer-term. In 2010, we began a project to explore the best ways to address the energy challenge in an open-ended manner. We had used traditional PI in several case studies, but did not consider ourselves as “highly-expert” in PI.

We embarked using the "classical" context of a PhD project. We listed the needs for energy analysis for biorefinery transformation including for example that the biorefinery context is that existing and greenfield designs are implicated, site-wide energy analysis is critical especially for mills with existing cogeneration, that we sought practical recommendations that would be well-received by industry partners, and that there is uncertainty in the energy efficiencies of the biorefinery processes. At the same time, we reviewed the "classical approaches" reported in the literature for PI, through to the state-of-the-art retrofit PI methods developed at Chalmers.

Resulting from that analysis and the interpretation and application of basic thermodynamic concepts, we have developed a modified approach to PI that we believe is particularly suitable for biorefinery implementation – that can of course be extended to other similar analyses at the site level where different industrial facilities are clustered.

The method is explained in detail in the 7 references below, and will be summarized briefly in the presentation.

References

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