Mission Integrated Biorefineries

Summary Report for Workshop on Energy & Conversion Process Efficiency Program to reduce production cost (Action 3)

Context

On July 13, 2023, the Canadian Forest Service (CFS) at Natural Resource Canada (NRCan) in collaboration with Brazil, the Netherlands, and the European commission, hosted a workshop in the context of Canada participation to Mission Innovation Integrated Biorefineries Mission The workshop focus was on Action 3 of the roadmap defined as "Energy & Conversion Process Efficiency Program to reduce production cost". The main purpose of the workshop was to better understand and focus future activities to support Action 3 goals. A secondary goal of this workshop was to maintain motivation and engagement following June 1 introduction to Mission Innovation workshop and support future collaboration.

Participants and survey

Participants from each of the Mission participating members (Brazil, Canada, India, the European commission, the Netherlands, and the U.K.) were selected and invited to attend. Forty-three participants attended the workshop with over 40 participants for most of the workshop, demonstrating the strong interest for the subject.

A pre-workshop survey was sent following the invitation and 16 responses were received. Survey was used to start and support the conversation around the main problems or aspects the Mission needs to focus on to improve the efficiency or performance of biorefineries. This information helped NRCan focusing the conversation and has been confirmed in large part during the workshop.

Presentations summary

Four presenters were invited to the workshop, 2 from Brazil, one from the Netherlands and one from Canada.

R&D for Advanced Biorefineries Sustainable Aviation Fuel Technologies.

The first presentation was by Mateus Ferreira Chagas from the Brazilian Biorenewables National Laboratory (LNBR) at the Center for Research in Energy and Materials and focuses on Sustainable aviation fuel (SAF). Brazil is large ethanol producer, even larger than gasoline with 29.7 billion litres in 2022 but lack biodiesel production capacity with only 6.3 billion litres compared to 45.5 billion litres of diesel. Brazil is now looking at how to domestically produce SAF. With its competitive advantage and knowledge of sugars, sugar-based technologies have the potential to play a critical role compared to HEFA.

SAF still needs to have its production cost reduced, its competitiveness can be measure by GHG abatement cost. In Brazil, ATJ pathway has already the potential to provide an abatement cost 3 times lower than HEFA using soybeans but is still very costly compared to ethanol. In this context new pathways mostly based on sugar can, but also on soybean oils, are considered for improvement with a particular interest for pathways generating the coproduction of hydroxy fatty acids.

Enerkem Biorefinery: Enabling second generation biofuels and chemicals for hard to abate sectors.

The second presentation was by Stephane Marie-Rose from the Canadian company Enerkem. For more than 20 years, Enerkem is developing its technology targeting feedstock that are rejected from recycling and composting programs or from industrial production. Its core platforms offer multiple pathways to key chemicals (ethylene) and fuels (SAF, Diesel), with the flexibility to produce the most attractive mix of products. Enerkem is for now focusing on the methanol route, but SAF is also seriously considered in the future.

Enerkem is developing two commercial scale projects to produce methanol. The Canadian Varennes Carbon Recycling plant is developed in collaboration with Shell, Suncor and Proman and with the support the Canadian and Quebec governments with an expected commissioning in 2025. The Spanish Tarragona Ecoplanta plant is developed in collaboration with Repsol and the support of the European Union with an expected commissioning in 2026.

MI webinar on Biorefineries efficiency improvement.

The third presentation was by Mateus Garcez Lopes from the Brazilian company Raizen, a joint venture between Shell and Cosan. Raizen is a world leader in ethanol and sugar production and has an integrated approach by controlling feedstock production, some of its renewable energy needs as well as a distribution network. With over 30 years of experience, from technology development to ethanol commercial scale production, Raizen is now developing second generation ethanol plants with a goal of 27 plants by 2034.

Cost Pinto is Raizen first second-generation ethanol plant with a production capacity of 30 million cubic meters. Having demonstrated the performance of its technology, Raizen is now focusing on the challenge of replicating its model with three additional plants to be commissioned by 2024 and an extra five to be built by 2028. Financial viability and site optimization are a critical part of Raizen business model as supported by offtakes agreements for the first 9 plants and the desire to increase business value by transforming lignin from a waste product to a new income stream.

Mission Innovation Integrated Biorefineries.

The last presentation was by Erik Pijlman from the Dutch company Recell, a company focusing on the production of high yield glucose, an intermediary cellulosic sugar to be used by future clients to produce for example biobased polymers, bioethanol and Mono-Ethylene Glycol (MEG). Recell technology is leveraging the abundant “tertiary” cellulosic waste with a low lignin content like drinking cartons, textiles, and paper sludges.

Recell is developing an up to 1000 tonnes/year demo plant with the ambition to achieve 50,000 tonnes/year in 2025. Recell success is also based on its capacity to leverage a large ecosystem of clusters, associates and partners.

Summary of key challenges

The main goal of the workshop was to better understand the critical problems or aspects related to energy & conversion process efficiency from stakeholders’ perspective.

Critical problems and aspects were divided into 3 categories, Efficiency through integration, Value added and Inputs and supply chains.

Efficiency through integration

A strong message heard from the participants is the importance of developing the right project, meaning putting together the right technology for the right feedstocks adapted to the national or regional policies in place but it is challenging.

Plant integration is central especially during scaling from demo to commercialisation as it is creating complexity with a potential impact on inputs use (energy, chemicals, feedstock, etc.) but also intermediary products recovery (especially with biochemical processes), and on final production. Integration has multidimensions and will depend on the process. For example, recycling energy or heat generated during one step and using them in another step of the process will require more on-site integration. Another example could be making a biorefinery project totally independent from the grid for its renewable energy or producing its own renewable hydrogen.

As opposed to the existing petro-chemical model where scale is the way to achieve efficiency and access to low-cost feedstock is not an issue, biorefineries business models are supporting the option of smaller projects located closer to feedstocks.

Integration could also be requiring complex feedstocks, feedstocks who will need extra processing steps pre-treatment and the use of pyrolysis.

More integration could also be seen as putting a larger part of the supply chain under the umbrella of the same project, an approach favored by Raizen. It is also supporting better standardization and is increasing the potential for replicability as experience is required to deploy multiple biorefineries.

Some countries have a competitive advantage for a specific feedstock or a long experience using that feedstock. In this context a better integration could be achieved by developing or adopting the right technology to the existing feedstock.

Value added

Efficiency can also be increased by creating more value from the production, by optimizing the product mix:

- High value/low volume products: small productions of high-value products, or;
- Low value/high volume products: large productions of low-value products.

However, increasing the relative importance of certain products may also require an increase in additional capex or from some inputs.

Value added can also be generated by reducing the cost or the use of certain inputs. Scaling-up of promising biorefinery technologies handling multiple feedstocks is a considered option to access a larger pool of feedstock permitting higher plant utilisation. However, this approach has also the potential to reduce efficiency as process optimization will be more difficult due to the need to accommodate feedstocks with variable characteristics.

Input switching and improvement could increase efficiency for example by increasing enzymes and catalysts efficiency or decreasing more general chemical consumption during the process.

CapEx plays an important role in the financial viability of a biorefinery. Cutting initial CapEx if possible, could achieve gains not achievable by improving conversion process. CapEx can be reduced by retrofitting existing oil based or bio facility, but also by adding a new line of products to existing activities, especially in the pulp and paper industry or for ethanol production from sugar cane.

Inputs and supply chains

Environmental performance but also final products cost are constrained by the availability of green inputs at competitive prices like renewable natural gas, renewable electricity and green hydrogen. Biorefineries have limited control over outputs produced by third parties, a solution being more on-site production (for example producing green hydrogen from water electrolysis using renewable electricity) or direct collaboration from the start of the project with an external supplier for example for hydrogen.

The environmental performance is also constrained by supply chains still in development or not integrated enough. Some companies have decided to have a better control of large part of the value chain, but this approach is more complicated for small companies. An alternative being the development of a large network of partners and collaborators as well as working with clusters as demonstrated by Recell.

Conclusion and next steps

Based on the presentations and the input gathered during and after the workshop, the team responsible of the Energy & Conversion Process Efficiency Program to reduce production cost has a better understanding of the challenges related to Energy and Conversion Process Efficiency to reduce production cost. One critical conclusion of the workshop is the need to focus on broader aspects than energy, including for example material flows, and yield of conversion processes, and having a more integrative approach. The type of technology is also less critical than what expected, the focus being more having the right technology with the right feedstock in the right context.

Post-workshop, a short term and a long-term work plan will also have to be developed to help focus the work required until 2030.

Based on the workshop and participants comments, the following 7 critical problems or aspects related to energy and conversion process efficiency we discussed and ranked. Ranking is showing three well differentiated groups, with two top priorities (1 and 2), two important priorities (3 and 4) and less important priorities (5 and 6)[1].

1- Support better technology integration during scaling up from pilot scale to demonstration and commercial scale.
2- Support feedstock improvement by pre-treatment to improve conversion yield to bioproducts.
3- Support supply chain GHG reduction by better integrating biorefinery production and supply of inputs (recycling of heat, self-production of hydrogen, use of residues, etc.).
4- Support retrofit of existing of crude oil-based refineries or first generation biorefineries to improve performance or addition of new production lines for new products to support a better financial performance.
5- Support technology-feedstock matching, including potential technology transfer.
6- Support the improvement of enzymes and catalyst performance.
7- (Additional suggested priority) - Support the development of technologies to produce multiple products at the same facility (high-value and low value products) in order to maximize the conversion of biogenic carbon from biomass feedstocks into useful products.

[1] Dividing the six priorities into 3 groups of 2 is the pure result of scoring and not voluntary.

This workshop has also been used to start collaboration between international stakeholders, we will support this collaboration with for example quarterly presentations. India has already expressed its interest to host the next series of presentations and also a collaboration between India and the European Union to co-fund the Horizon Europe call on "the development of smart concepts of integrated energy driven bio-refineries for co-production of advanced biofuels, bio-chemicals, and bio-materials." The call opens on May 7, 2024, with a deadline of September 5, 2024. Funding & tenders (europa.eu)

The overall Mission will also be able to leverage the experience developed with the Workshop on Energy & Conversion Process Efficiency Program to reduce production cost approach for future actions.

ANNEX 1

Workshop on Biorefineries efficiency improvement agenda

Time	**Topic**	**by**
14:00	Welcome	Bruno Gagnon
14:05	Overview of Mission Integrated Biorefineries and goals related to the efficiency of biorefineries (Action 3 of the Mission's roadmap)	Bruno Gagnon
14:10	Presentation by Brazilian Center for Research in Energy and Materials (thermochemical biorefinery)	Mateus Ferreira Chagas
14:25	Presentation by Canadian company Enerkem (thermochemical biorefinery)	Stéphane Marie-Rose
14:40	Q & A	Bruno Gagnon
14:45	Break	
14:50	Presentation by Brazilian company Raizen (biochemical biorefinery)	Mateus Garcez Lopes
15:05	Presentation by Dutch company Recell (biochemical biorefinery)	Erik Pijlman
15:20	Q & A	Bruno Gagnon
15:25	Critical aspects to achieve Action 3 goals	Bruno Gagnon
15:55	Closing remarks and next steps	Bruno Gagnon

ANNEX 2
Question from the chat

Questions to Mateus Ferreira Chagas

- **Q: Hello Mateus, thank you for your presentation. After showing so many different routes to produce bioproducts, using many different feedstocks, what you feel is the most promising technology, and also what is problem related the enzymatic route? Talking about the enzymatic route you showed us, how can you feel this route can be more efficient? And how do you imagine this mission can help you to improve this route performance?**
    - R: Enzymatic processes are very good alternative process, the challenge is the scale up of processes, improving the efficiency and scale of the process. There are also good opportunities to convert biomass into SAF.

- **Q: Mr. Mateus, very interesting presentation on new SAF routes. Is there any data on preliminary cost economics on new routes compared to HEFA & ATJ routes.**
    - R: Converting ethanol into HYC - ethanol is most economic, but if we want to provide fuels to another markets like aviation, we must think that its necessary to deoxygenate the molecule and create HYC. AGT is a good alternative then. More opportunities for ATJ in Brazil as we have a good source of biomass like sugarcane. We must look for solutions locally and results can be diff for reach region.

- **Q: Hi Mateus, any idea how ethanol to jet part cost compares to the cost of producing ethanol?**

- **Q: Excellent presentation Mateus. Any update on SAF production using 2,3 Butane diol as precursor molecule?**

Questions to Stéphane Maris-Rose

- **Q: Question for Stephane, what is your main challenge with the Ecoplanta project?**
    - R: Compared to economic challenges, the key challenge is the need to find the right feedstock to match the economy; feedstock needs to meet the requirement, (for example feedstock biogenicity) as a raw material.

- **Q: Thanks for your presentation, Stephane. You talked about new investments that your company will do. So, can you tell us about the investments related to theses new investments? What about product costs in relation to traditional ones.? Order of investments related to the plants and the order of products produced – trad products vs by products.**
    - R: Cannot answer the question on investment, but for methanol as the basic molecule, we need considerably more investment.

- **Q: TO Stephane: impressive results from Enerkem, where do you see next steps, and what kind of govt support would you like to see?**

- **Q: How efficient are the biobased conversion processes, w r t yields and cost?**

Questions to Mateus Garcez Lopes

- **There was a reference to a 18% ROACE, do you consider it is a minimum to attract investors? Or a higher return is required for more risky/new products like second gen ethanol?**
    - R: Low commercial risk as seeking long term offtake for products; main risk is to build the plants in a timely manner.

- **Q: Mr. Lopes, Thanks for excellent presentation. How are you utilising lignin residue, is it for power/process steam generation or any value addition product pathway in integrated biorefinery approach.**
    - R: To reduce the water content and generate power and steam within the boilers.

- **Q: Dear Mateus, thank you for your interesting presentation. What innovations/improvements are needed to expand the deployment of your biorefineries?**
    - R: Trying to attract strategic partners that also hold large amounts of biomass – this is a key bottleneck to continue building additional plants; discussing with partners in Brazil and US to deploy this tech further.
- **Q: Mateus – how can MI be of help to speed up the strategies and scale up?**
    - R: Not sure what tools MI has to support this, but main challenge right now is related to regulation. On the commercial side – this is more regulatory and political framework of the energy transition; tropical countries could play a bigger role in the transition especially related to agriculture, but the political and agricultural frameworks can be a roadblock; we need to consider this in the global, inclusive role in the transition.
    - Regulation, tariffs in importing countries.
    - Difficult for companies like Raizen to drive the energy transition who tend to be considered as

Questions to Erik Pijlman

- **Q: Question for Recell: Do you need off-take agreements with large chemical companies, or your chemicals are treated as commodities**?
    - R: Both are possible, but the aim is to be in close operation with larger industrial partners -believe that we have an additional value in the product – premium product should be appreciated; so preferable the latter

- **Q: Question for Recell: if your process stops after the hydrolysis step as feedstock for other processes can the glucose compete with sugar prices?**

  R: Full scale aim is to be competitive with sugar prices; it is waste based so is a technical advantage as we don't have to deal with lignin; other benefit is that price levels are typically lower than others in the market.

- **Q: Congratulation for the presentation, Erik. Do you also use or plane to use other waste materials from cellulosic production (wood bark, fiber waste. Biological sludge and primary sludge)?**

- R: Quite a broad scope of input, but the key decision point is that they don't want the lignin involved; for example – wood as it involves lots of lignin; mainly focused on fibre produced from post consumer waste.

- **Q: For Recell: What you feel as a big challenge from moving to demo/commercial scale? Looking the process/colors, in which part do you feel the problems will be concentrated?**