NATURAL RESOURCES CANADA - INVENTIVE BY NATURE

Supporting the Transformation of Forest Industry to Biorefineries and Bioeconomy

IEA Joint Biorefinery Workshop, May 16th 2017, Gothenburg, Sweden

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CanmetENERGY

CanmetENERGY

Three Scientific Laboratories across Canada

CanmetENERGY is the principal performer of federal non-nuclear energy science & technology (S&T):

- Fossil fuels (oil sands and heavy oil processing; tight oil and gas);
- Energy efficiency and improved industrial processes;
- Clean electricity;
- Buildings and Communities; and
- Bioenergy and renewables.

Areas of Focus:

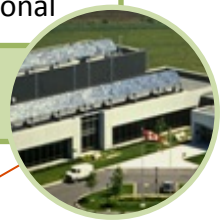
- Oil sands & heavy oil processes
- Tight oil & gas
- Oil spill recovery & response

Devon

Areas of Focus:

- Buildings energy efficiency
- **Industrial processes**
- Integration of renewable & distributed energy resources
- RETScreen International

Varennes

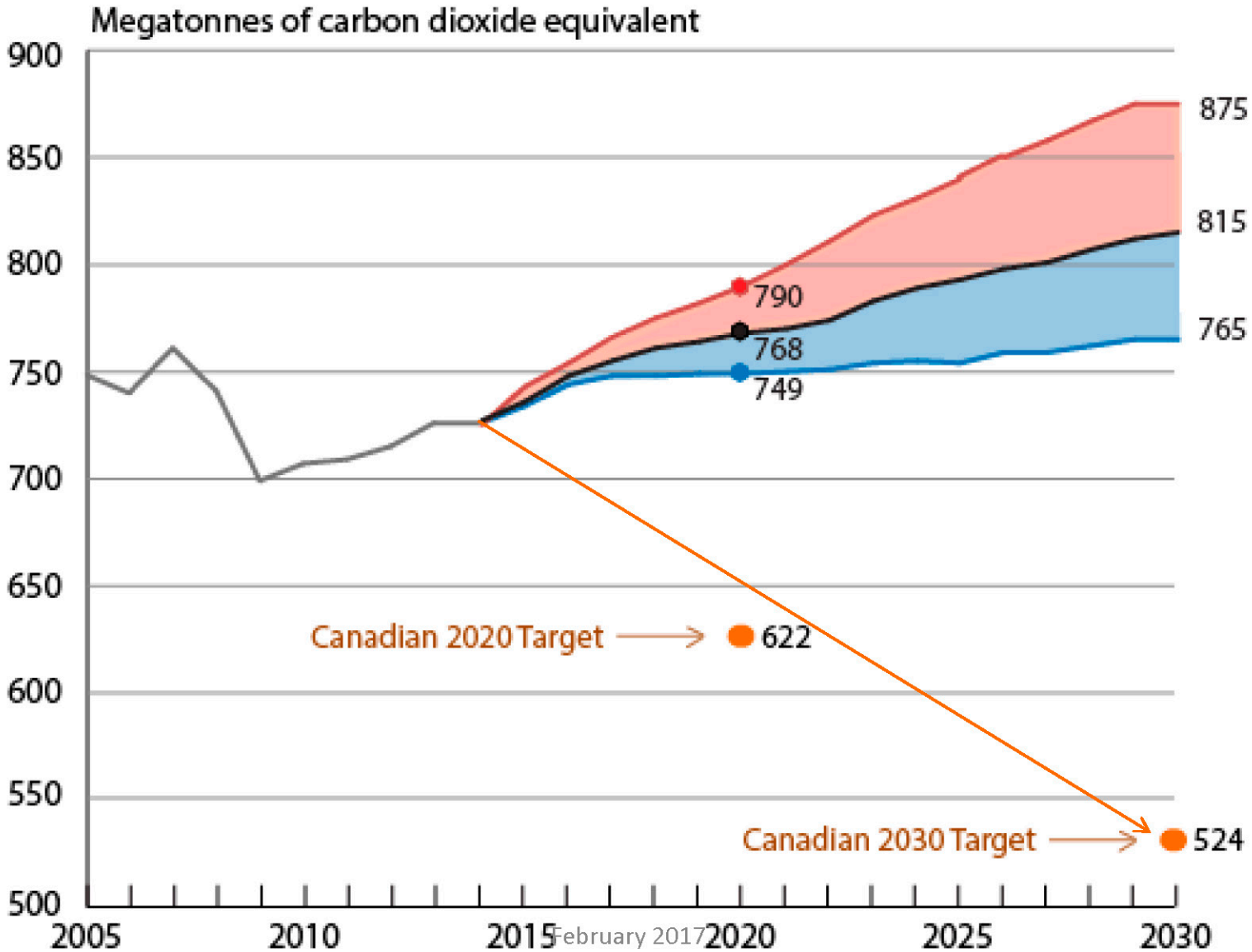


Areas of Focus:

- Buildings & Communities
- Industrial processes
- Clean fossil fuels
- Bioenergy
- Renewables

Ottawa

Canada's Climate Change Commitments



Source: ECCC

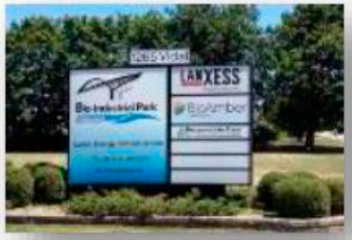
Canada has unique bio-based advantages

- Canada has one of the largest biomass resources in the world (agriculture, forest, marine)
- World-class forest sector innovation system based on strong collaboration

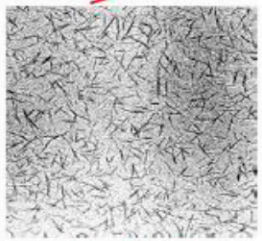
And has…

An abundance of skilled labour

Mature forestry fibre supply infrastructure and secure property rights



Emerging clusters that draw upon existing infrastructure



A technology advantage in several areas (eg. cellulose nanomaterials, agri-breeding and agronomics

Strong and broad-reaching S&T and academic network

CanmetENERGY-Varennes

Industrial Systems Optimization (ISO) Program

Research

Knowledge

Industrial projects

SYSTEM ANALYSIS SOFTWARE

INTEGRATION

Identify heat recovery opportunties in your plant

EXPLORE

Discover the power of data to improve operation

COGEN

Maximize revenues from cogeneration systems

I-BIOREF

Evaluate biorefinery strategies

SERVICES

TRAINING

Attend workshops with world class experts

KNOWLEDGE

Access to publications and industrial case studies

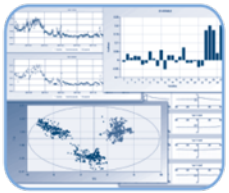
Knowledge Transfer

Process Optimization in Pulp and Paper Industry

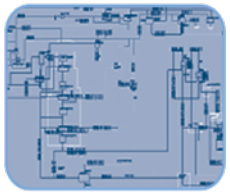
Approach Combining Several Systems Analysis Tools

Innovation Through Integrated Solutions

EXPLORE



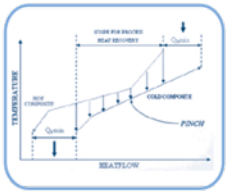
Operation Analysis & Improvement



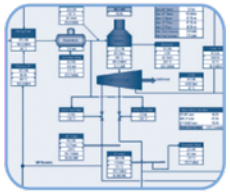
Technology Integration

I-BIOREF

INTEGRATION



Heat Integration



Utility Systems Optimization

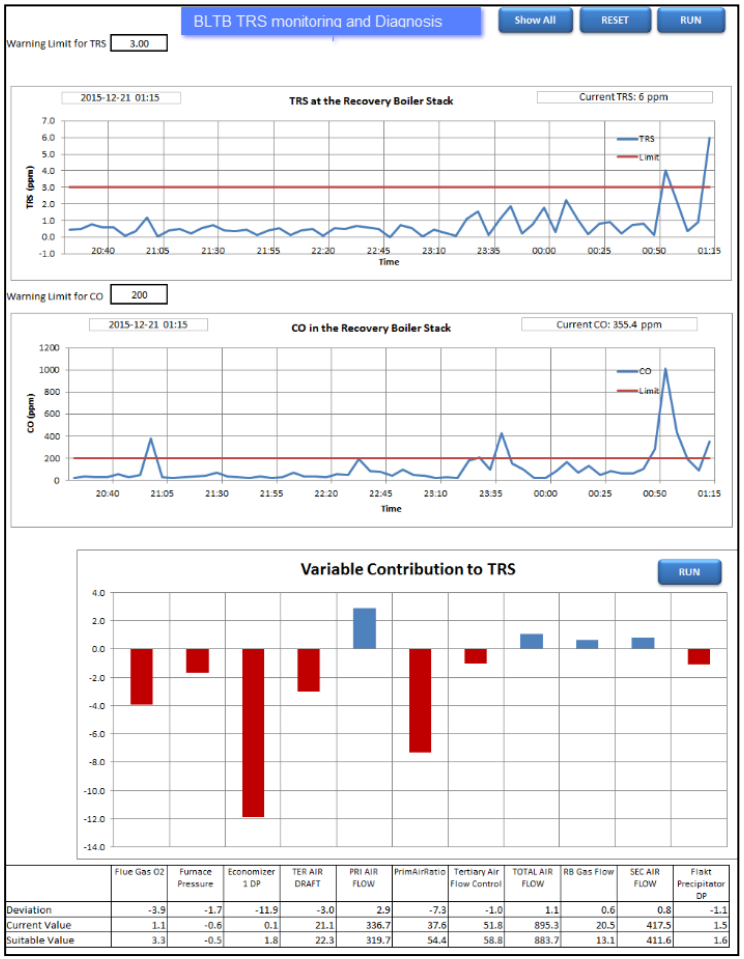
COGEN

Water Network

Process Optimization in Pulp and Paper Industry

Advanced Data Analytics

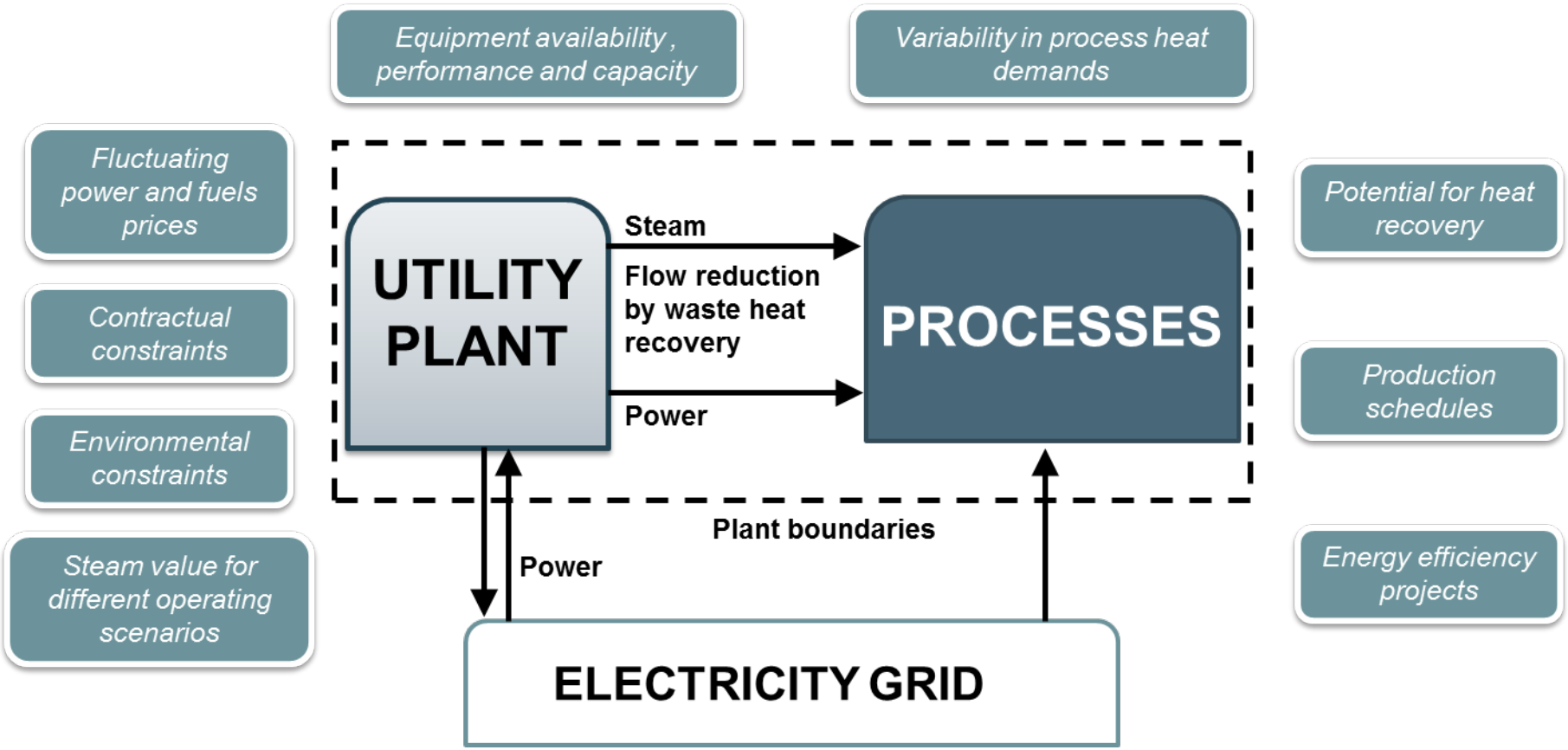
- Valuable process knowledge is hidden in historical database
  - Large amount of data is available in mills
  - Difficult to fully understand the links and interactions between data
- Data analytic techniques can help extract this knowledge
  - Statistical analysis to explain process variability and improve operation
  - Statistical models to maintain performance over time



	Flue Gas O2	Furnace Pressure	Economizer 1 DP	TER AIR DRAFT	PRI AIR FLOW	PrimAirRatio	Tertiary Air Flow Control	TOTAL AIR FLOW	RB Gas Flow	SEC AIR FLOW	Flakt Precipitator DP
Deviation	-3.9	-1.7	-11.9	-3.0	2.9	-7.3	-1.0	1.1	0.6	0.8	-1.1
Current Value	1.1	-0.6	0.1	21.1	336.7	37.6	51.8	895.3	20.5	417.5	1.5
Suitable Value	3.3	-0.5	1.8	22.3	319.7	54.4	58.8	883.7	13.1	411.6	1.6

Process Optimization in Pulp and Paper Industry

Utility Systems



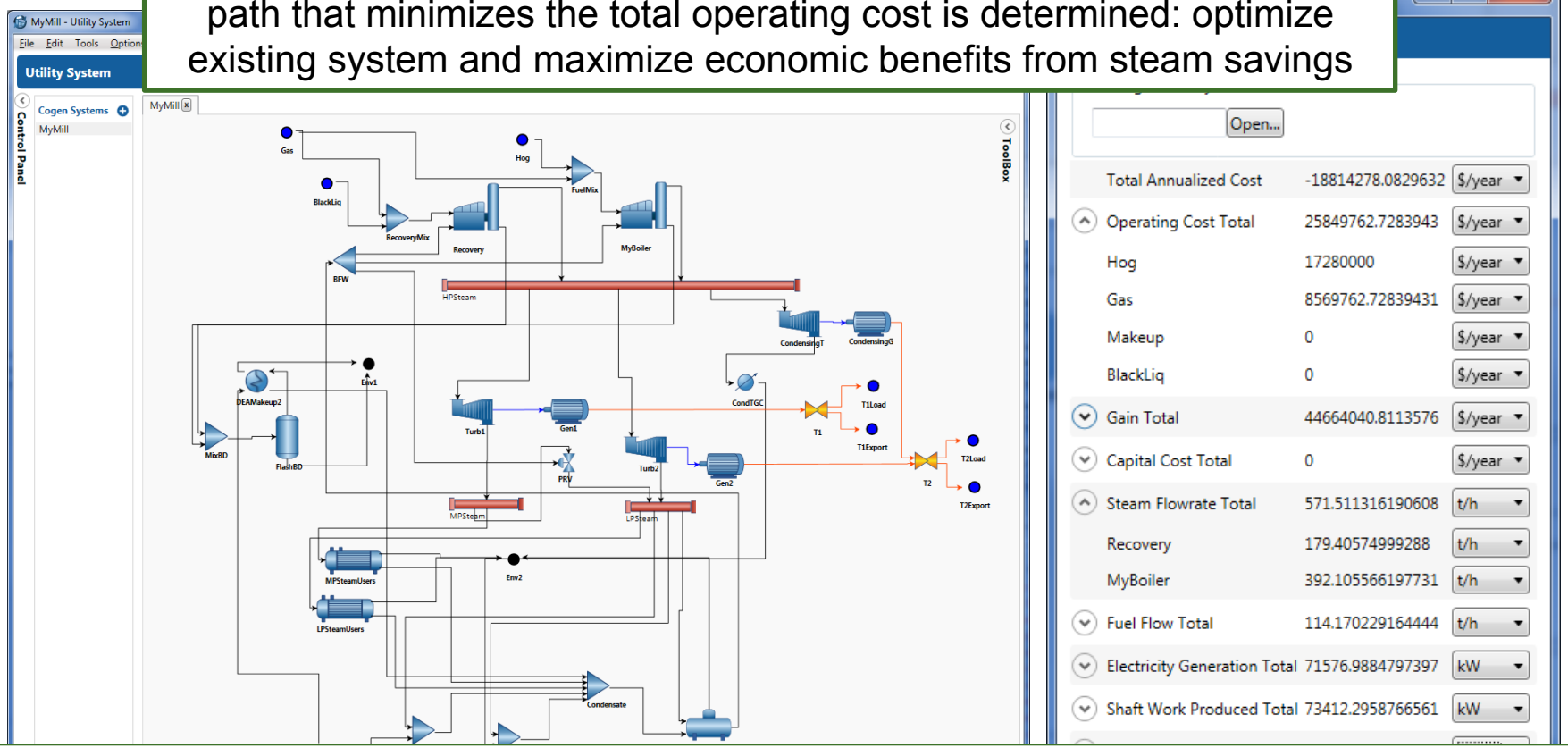
Most cogeneration systems are not used in an optimal way

Process Optimization in Pulp and Paper Industry

Utility Systems (cont'd)

COGEN

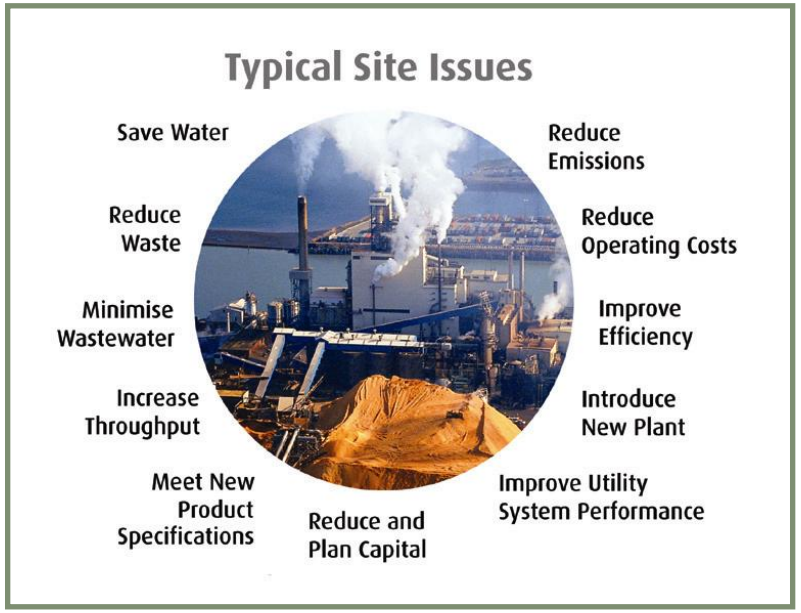
A detailed model of the utility system is used and the optimal steam path that minimizes the total operating cost is determined: optimize existing system and maximize economic benefits from steam savings



➔ Benefits will be maximized year-round by considering contractual, operational and environmental constraints on different time periods

Forest - Pulp and Paper Industry Context

- Pulp and paper industry is in an on-going transformation to increase profitability:
  - **Lower production costs** → Energy efficiency projects, reduce cost of GHG emissions, reduce losses, improve operations
  - **Increase annual revenues** → Install new turbines and produce additional "green" power
  - **Diversify production** → Change product grade; Add biorefinery technologies



Optimizing energy integration is essential to reduce operating costs, lower GHG emissions, add new revenues and prepare pulp and paper mills for the low-carbon economy.

Pulp mills are perfect host site for biorefinery technology integration!

Optimizing Existing Assets in Pulp & Paper mills:
FPInnovations – CanmetENERGY Successful Partnership


West Fraser QRP


Canfor Taylor


Resolute Gatineau


Resolute Alma


Resolute St-Felicien


West Fraser Cariboo


Kruger Corner Brook


Domtar Kamloops


Port Hawkesbury Paper

$50M+ in savings/revenues


Zellstoff Celgar Castlegar


Alpac Boyle


Resolute Thunder Bay

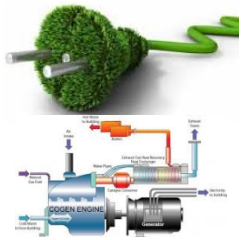

Kruger Brompronville


AV Cell Nakawic

Forest Biorefinery R&D Program

- **Objectives**
  - Develop updated biorefinery and bioenergy **technology map**, as well as **current and emerging market trends** of bioenergy, biofuels, biochemicals, and biomaterials
  - Develop **systems engineering models and decision-making tools** to evaluate the most promising biorefinery products/technologies that, when optimally integrated to an existing industrial site, will result in radically improved economic performance and environmental footprint
  - Develop state-of-the-art **retrofit and design solutions** to enable the transformation of traditional forest markets through incremental implementation of biorefineries

Biorefinery Focus Areas



Bioenergy

- Technological intelligence
- Data analysis
- Cogeneration

CFS, FPInnovations, pulp and paper mills

Biofuels

- Markets
- Bioenergy La Tuque

CFS, BELT, UQTR, FPInnovations, Polytechnique Montréal, Université Laval, VTT

Biochemicals

- Markets
- Rich-Sugar streams
- Biobutanol
- Organic acids

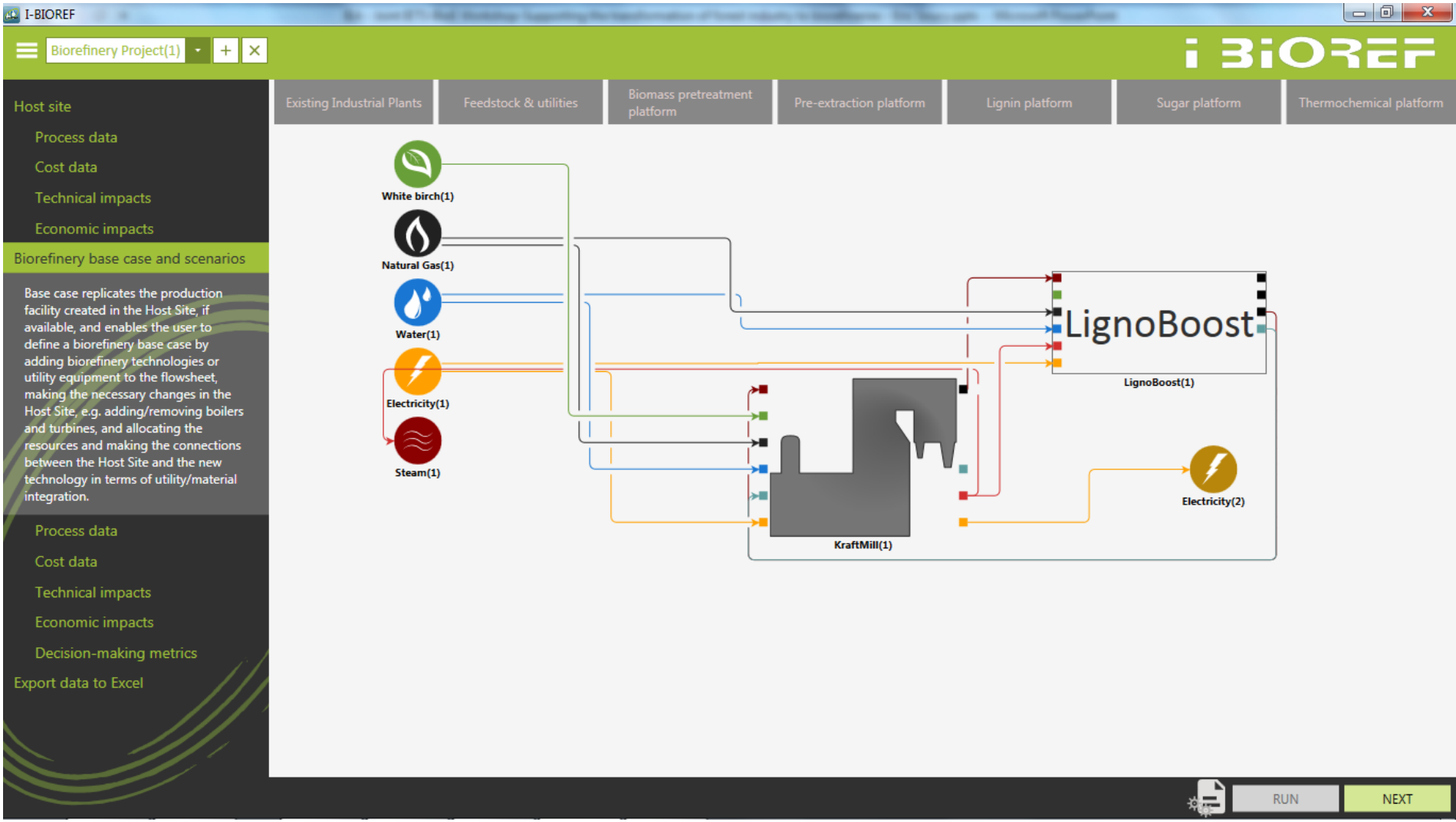
CÉPROCQ, CRIBIQ, UQTR, Forestry COOPs

Bioplastics Biocomposites

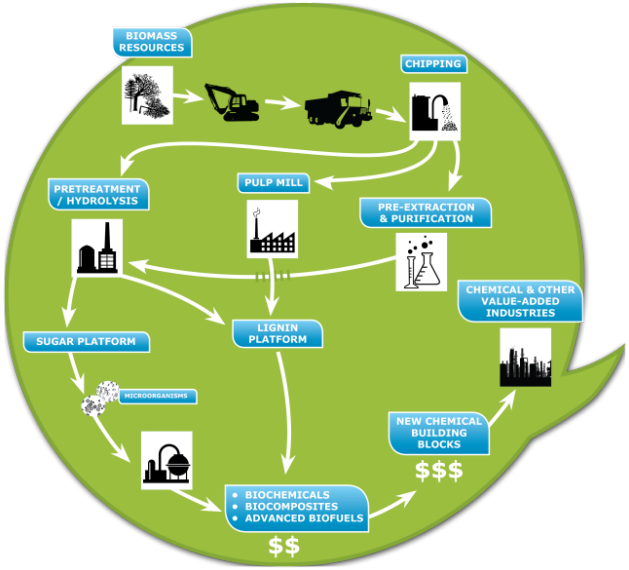
- Markets
- Tannins
- Lignin-based polyols
- Carbon fiber

NRC, CRIBIQ, Forest COOPs, Domtar, Enerlab, Pure Lignin Environment Technology Ltd., Arbiom

I-BIOREF: A Biorefinery Pre-Feasibility Analysis Software



I-BIOREF: Why such tool?



- How can a company succeed in **identifying a strategy** to enter the bioeconomy that is **robust** for future market scenarios, and at the same time, yields high margins?
- What are the **benefits of integrating** a biorefinery technology into an existing mill?
- In an integrated biorefinery, what are the **impacts on the existing mill**?
- Under what conditions does a biorefinery project becomes **economically and environmentally viable**?

Make the analysis easier, faster and… cheaper !

Approach

Market assessment and technological intelligence

- Mapping of resources utilization in pulp and paper mills
- Data on available biomass and competitive pricing strategy
- Market data on bioenergy, biochemicals and biomaterials
- Critical review of Canadian bioenergy and biorefinery demonstration projects
- Extensive technological intelligence on biorefinery processes and innovations

Modeling, algorithms development, simulation, and experiments

- **Experiments**
  - Extractives
  - Pre-treatment/fractionation
  - Detoxification of cellulosic hydrolysates
  - Sugar extraction and fermentation
  - Lignin recovery from black liquor
  - Full characterization of lignin properties from various sources (up to 90 samples)
- **ASPEN Plus® Modeling**
  - Pre-treatment/fractionation
  - Lignin recovery
  - Sugar extraction and fermentation
  - Separation/purification
- **Multi-criteria analysis**
  - Technical performance
  - Economic viability
  - Environmental footprint
  - Risk assessment

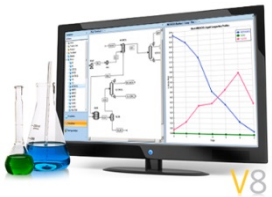
Computer Modeling, Simulation & Optimization of Integrated and Standalone Biorefineries

iBIOREF

Outputs:

- **Prefeasibility scenarios for integrated and standalone biorefineries**
- **Industrial case studies**
- **Guidelines, engineering rules and expert tips for designing and implementing biorefineries**
- **Knowledge, know-how and technology transfer**

I-BIOREF: Multi-Criteria Analysis



- Technical performance criteria
  - Utility and chemical consumption
  - Impacts on the utility and chemical consumption of the existing mill
- Economic viability criteria
  - Does the project meet the profitability thresholds?
  - Under which circumstances does it become profitable/unprofitable?
- Competiveness criteria
  - Access to biomass
  - Performance in a volatile market
- Environmental footprint criteria
  - Environmental impacts (LCA)
  - Energy and GHG intensities

- Modeling and simulation on Aspen Plus®
  - Pretreatment and fractionation of lignocellulosic biomass: Sugar recovery yield and energy requirements
  - Integrated system for diversified bioproducts portfolio
- Experimentation
  - Recovery of bioactive extractives
  - Pretreatment of lignocellulosic biomass
  - Fractionation of lignin
  - Lignin functionalities and colour
  - Fermentation of mixed sugars model and sugar stream extracted from lignocellulosic biomass

I-BIOREF Software: What it does?

- **I-BIOREF** supports decision-makers in selecting viable biorefinery solutions
- **I-BIOREF** evaluates the benefits of integrating commercially available biorefinery processes
- **I-BIOREF** provides several criteria to assess the biorefinery project from different perspectives
- **I-BIOREF** performs sensitivity analysis to evaluate the impacts on resources utilization

- **Comprehensive mass and energy balance, and chemical balance**
- **6 economic metrics (PBP, IRR, NPV, ROCE, ROI, EBIDTA)**
- **2 competitiveness metrics (CAB, RTMU)**
  - Competitive access to biomass
  - Resistance to market uncertainties
- **17 LCA-based metrics**
  - Mid-point impact category (carcinogens, respiratory inorganics, land occupation, etc.)
  - Damage category *(climate change, human health, ecosystem quality, etc.)*

- **Pulp and paper processes:** Kraft and TMP
- **Biomass pretreatment processes:**
  Steam explosion; Liquid hot water; Acid hydrolysis; Alkaline hydrolysis; Instant controlled pressure; Organosolv; Torrefaction
- **Pre-extraction processes**
  Supercritical fluids (e. g. CO_2); Hot water;, Enzymatic
- **Lignin recovery processes:** LignoBoost™; LignoForce™
- **Sugar streams conversion processes:** Detoxification; Fermentation; Separation/Purification
- **Thermochemical processes:**
  Gasification; Pyrolysis; Catalysis

I-BIOREF is not a process simulation software!

Forest - Pulp and Paper Industry
Concluding Remarks

- Process optimization is key to design highly-efficient Biorefinery pulp mills
- Leveraging on existing assets is key in supporting the transformation
- In retrofit situations, **steam and water savings of 10 to 20%** are possible cost-effectively. **Increased power generation** is also typical
- Develop a **long term vision for implementing energy saving projects and robust biorefinery technologies**:
  - Permits a gradual implementation that mitigate the implication of short-term modifications over long-term high impact solutions
  - Analysis of biorefinery pathways for integration at existing mills
  - Analysis of biorefinery pathways and how mill existing assets can evolve to reduce implementation costs, notably by debottlenecking key process equipments
  - Assessment of economic and environmental impacts of biorefinery technology integration into existing or new industrial facilities
- Decision support system includes knowledge-based systems and emphasizes flexibility and adaptability to accommodate changes in the environment and the decision-making approach of the forest industry
  - Opportunity to create a new IETS-Annex on ***"Decision Support Tools for Evaluating Bioeconomy Transformation Strategies"***

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Thank you for your time and attention!

For further information, please contact:

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