NATURAL RESOURCES CANADA - INVENTIVE BY NATURE

Process Integration Basics

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Industrial Systems Optimization Program, CanmetENERGY

CanmetENERGY
Leadership in ecoInnovation

Natural Resources Canada | Ressources naturelles Canada

Canada

CanmetENERGY Across Canada

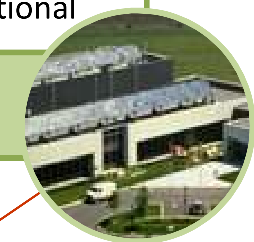
CanmetENERGY is the principal performer of federal non-nuclear energy science & technology (S&T)

- 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:

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

Varennes



Areas of Focus:

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

Devon

Areas of Focus:

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

Ottawa

CanmetENERGY-Varennes
Industrial Systems Optimization Program

Heat Management

Develop knowledge and tools to minimize industrial waste heat generation and support the use of advanced heat recovery and upgrading technologies

- Optimize energy-intensive processes
- Optimize heat recovery networks
- Improve process operations
- Maintain high performance over time

Combined Heat and Power (CHP)

Develop knowledge and tools to support the optimal design and operation of industrial CHP systems

- Identify and select best design and retrofit options
- Establish performance indicators
- Identify and select best operating conditions
- Automate the detection, diagnosis and fault correction to maintain high performance over time
- Develop pathways to support optimal integration of CHP systems in industrial facilities

RD&D ACTIVITIES → **Demonstration**

Biorefinery

Develop integrated biorefinery pathways, knowledge and tools to support the development and optimal integration of biorefinery technologies

- Pre-treatment and fractionation platform
- Lignin platform
- Sugar platform
- Thermochemical platform
- Assessment of economic viability
- Assessment of environmental footprint

Outreach & Capacity Building

Build the capacity of industry, engineering community and decision-makers to use a systems approach for implementing solutions that increase plant's efficiency and profitability

- Raise industry awareness
- Promote the undeniable benefits of systems analysis
- Develop innovative software solutions
- Provide training and technical support to engineers and students
- Assess impacts

IMPACT

CanmetENERGY-Varennes
Our Products and Services

SYSTEM ANALYSIS SOFTWARE

INTEGRATION

Identify heat recovery opportunties in your plant

EXPLORE

Discover the power of data to improve operation

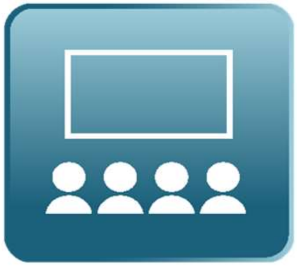
COGEN

Maximize revenues from cogeneration systems

I-BIOREF

Evaluate biorefinery strategies

SERVICES



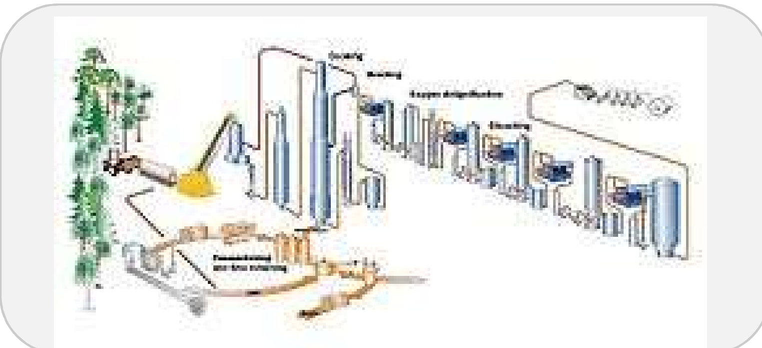
TRAINING

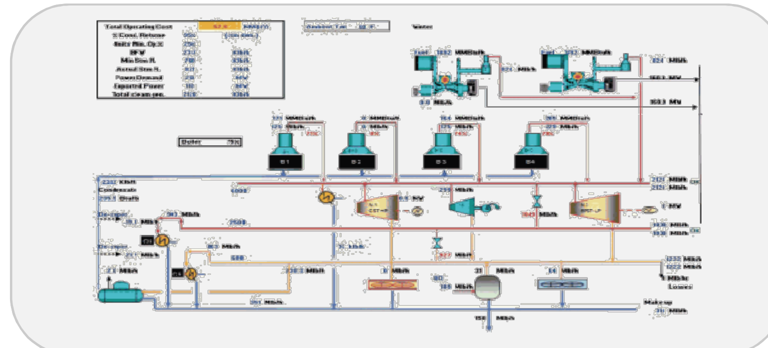
Attend workshops with world class experts

KNOWLEDGE

Access to publications and industrial case studies

Introduction

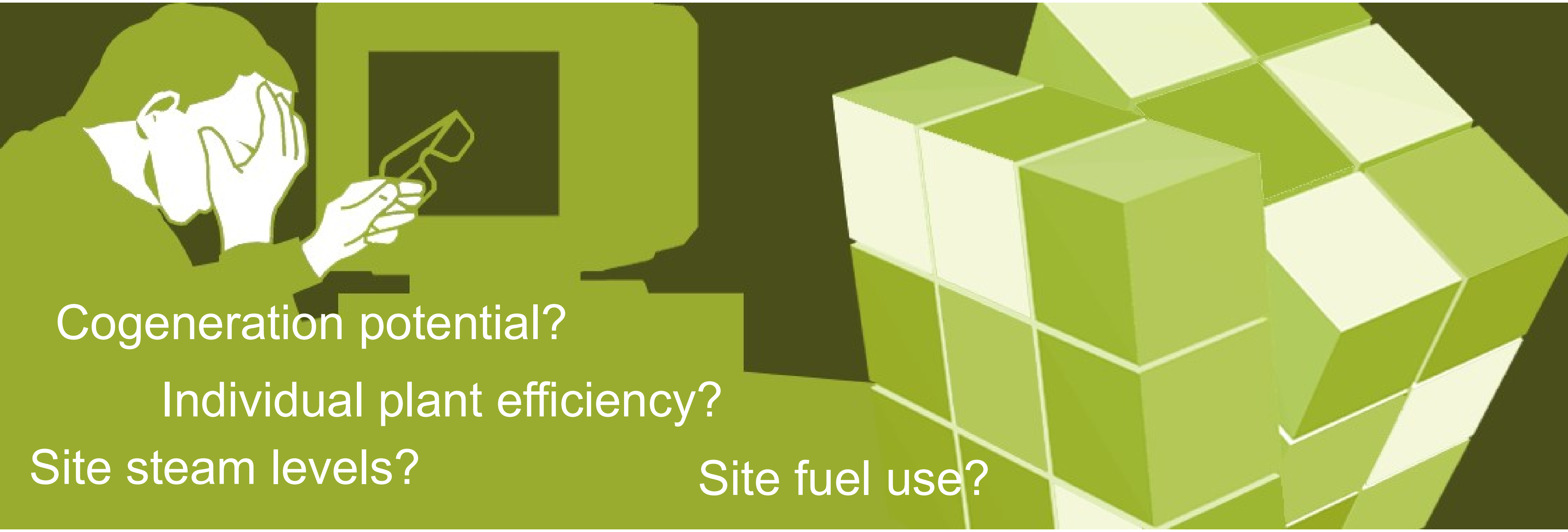




- Industrial facilities = process plants and site utility system
- Utility system provides the required amounts of heat and power for the process
- Heat requirements depend on technologies and heat recovery systems in process plants

Process plants and site utility system are integrated. Numerous constraints related to energy, environment, capital, technologies, operations need to be considered.

Design Issues



Install steam generator?

Gas turbine? HRSG, supplementary firing?

New boiler?

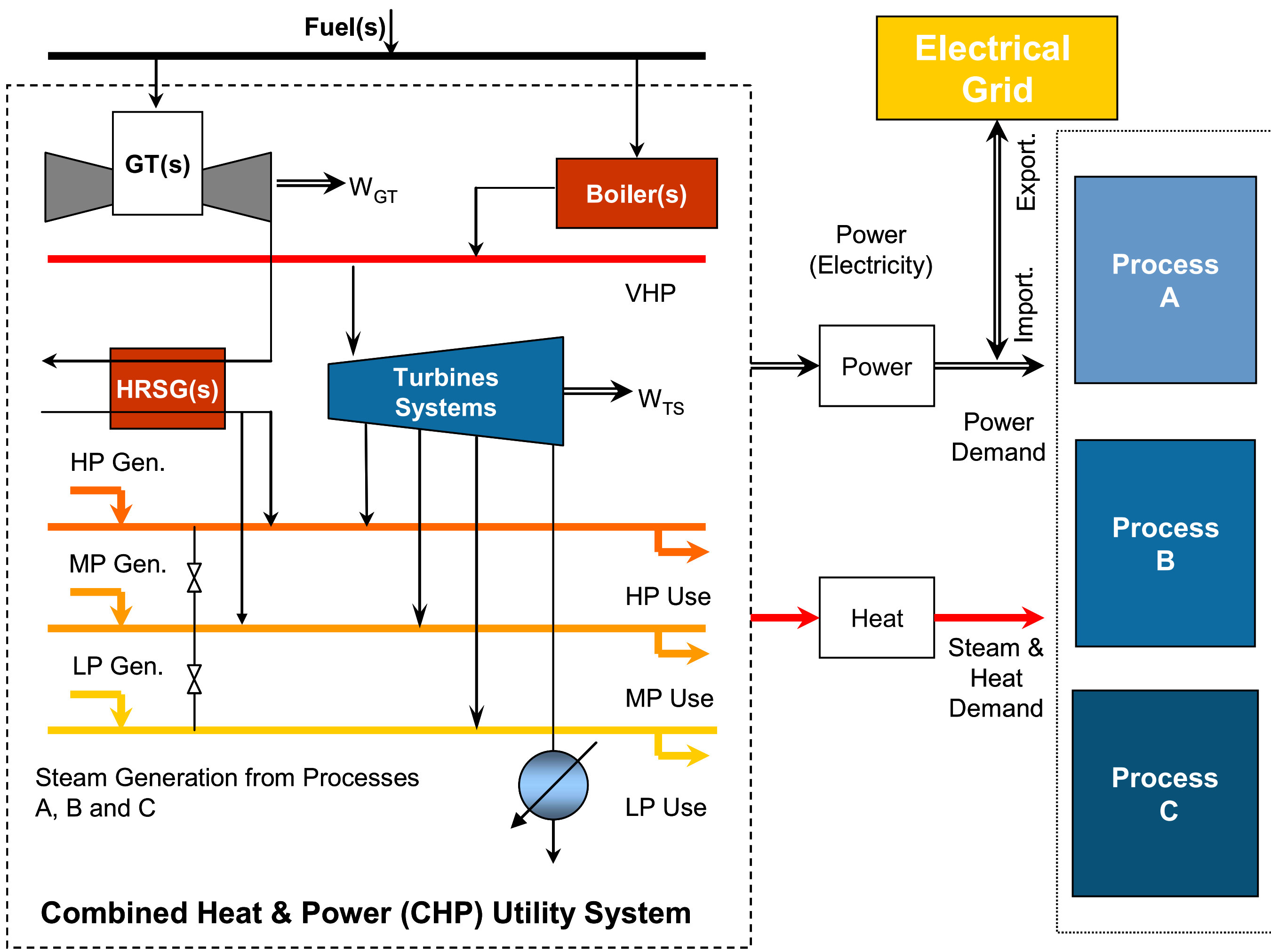
New turbine?

New heat exchangers, and where?

Feedwater and condensate return preheating?

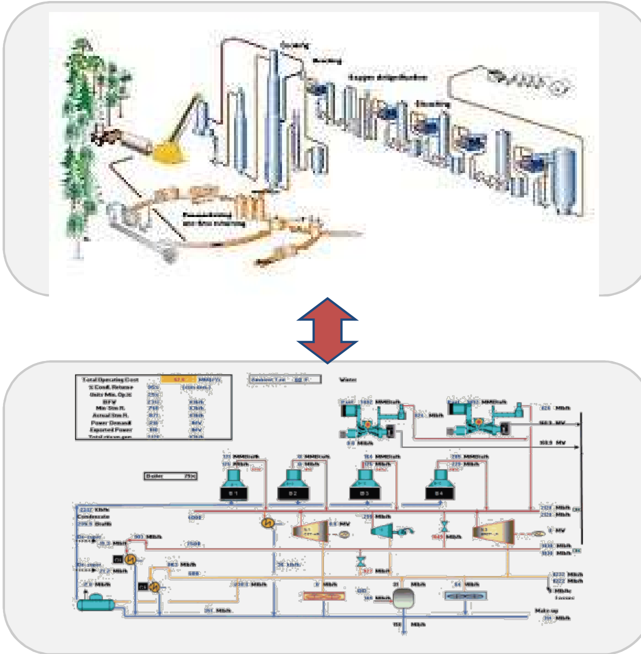
Provide heat, power at minimum cost?

A Complex Problem



Process Integration

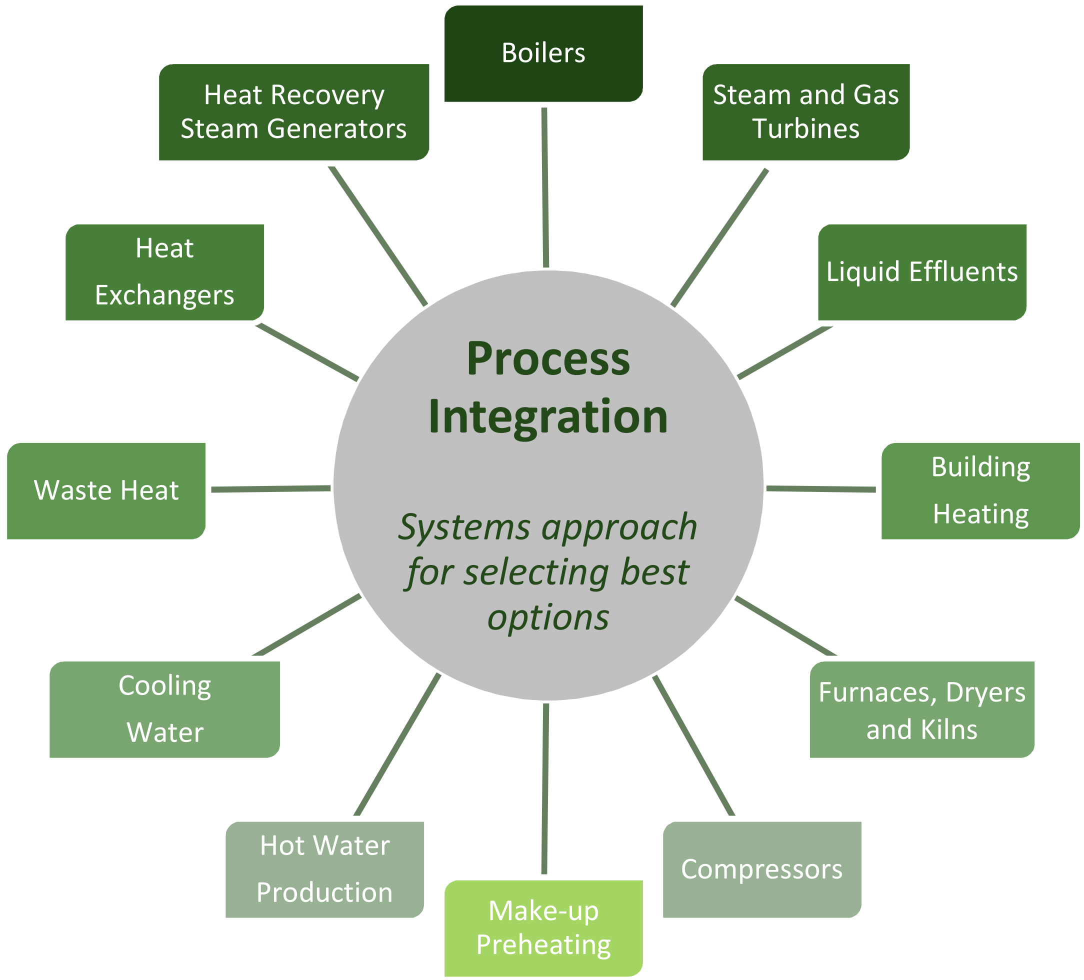
- **A site-wide (systems) approach** for analysing energy flows, for identifying and correcting inefficiencies in complex industrial processes, and for optimizing utility systems
- Looks at the global process, and the **interactions** between its different parts rather than solely considering individual operations



- A global analysis of the entire process (or plant):
  - Determines where heat is being used, where it should be recovered throughout the facility, and how it should be produced
  - Ensures that process plants and site utility system are designed in a synergetic way that maximizes overall site benefits

Process Integration is recognized as **best available technique** for efficient heat management (thermal energy production/use and power generation) in industry

Process Integration



Production schedules | **Fuel and power prices** | **Contractual constraints** | **Equipment availability and performance** | **Process data** | **Environmental constraints**

Processes that Can Benefit from Process Integration

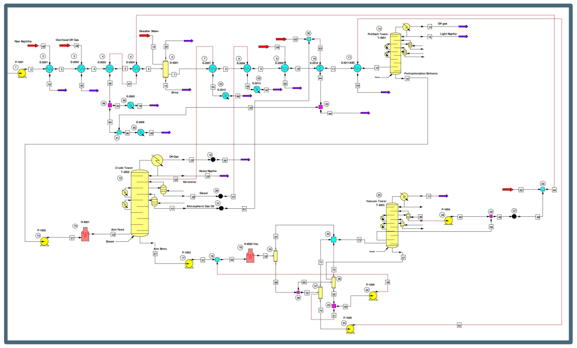
- Industrial processes with complex energy systems having several of the following characteristics:
  - Energy-intensive process equipments (e.g., furnaces, dryers, evaporators, distillation columns, reactors)
  - Complex utility system with several headers, boilers, ST, GT, HRSG
  - Many process heat exchangers
  - Large process steam usage
  - Large hot water usage
  - Large compressors for refrigeration, process gas or compressed air
  - Thermal energy use over 100,000 GJ/yr (or over 2,500,000 m3/yr in natural gas consumption)



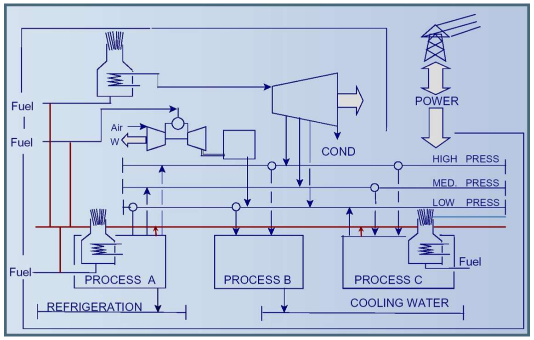

Benefits of Process Integration

- Process Integration can be used for:
  - Plant energy optimization, notably thermal energy production / utilization, and power generation
  - In retrofit, expansion projects or new facilities
  - Individual process, several processes and utility systems or several industrial facilities (i.e. eco-industrial parks)

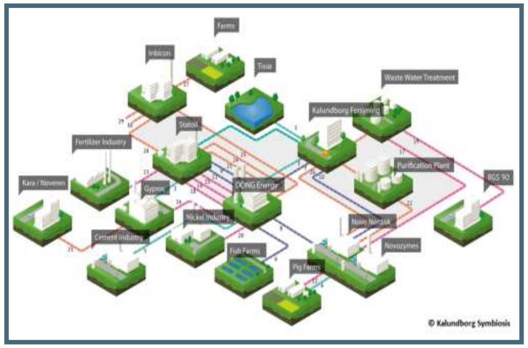
Process unit



Site: processes + utility system

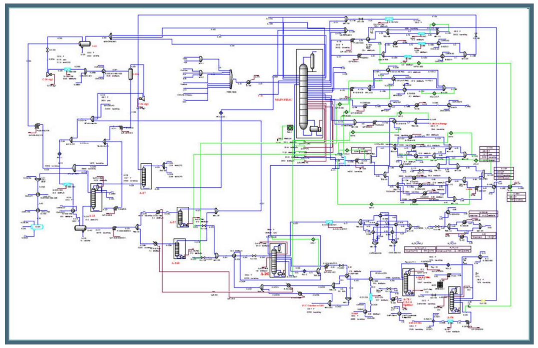


Industrial park



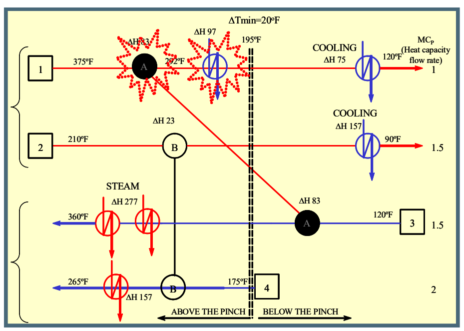
Process Integration Tools for Energy-Efficient Industrial Facilities

Best results when combining tools



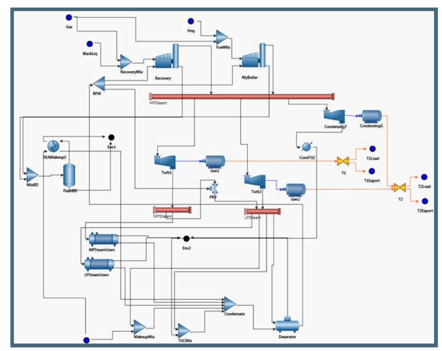
Process Simulation

To represent process operations, obtain validated data, identify abnormal situations and assess what-if scenarios



Process Heat Integration

To optimize heat recovery systems and reduce process thermal load



Utility System Modelling

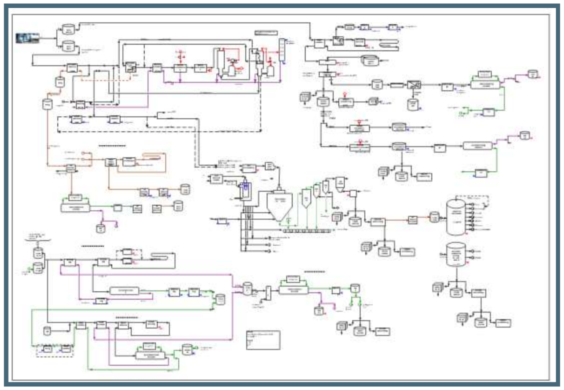
To reduce operating cost and emissions, to maximize profitability, to properly select and size heat and power equipment

Process Modelling, Heat and Mass Balance

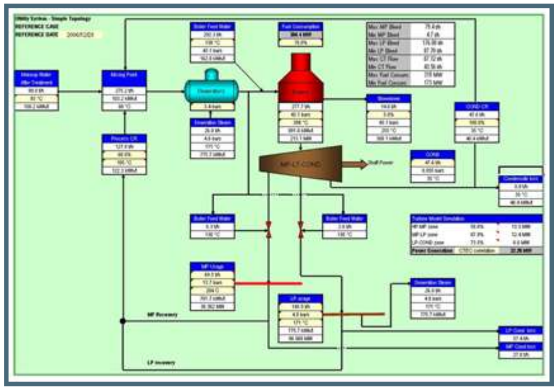
- **Process modelling:** in process simulation platforms it is possible to develop detailed and accurate models of complex industrial processes
  - Provides an accurate representation of the plant current operations and an in-depth understanding of energy use
  - **For energy purpose**: flows, temperatures and amount of energy exchanged in each piece of equipment in which heat transfer occurs are determined
  - Helps revealing operating problems that can be solved cost-effectively in most cases (i.e. low-cost operational improvements)
    - Water tank overflows, heat exchanger fouling, excessive flow rates, set points, etc.
    - Faulty sensors providing wrong measurements

Process Modelling, Heat and Mass Balance

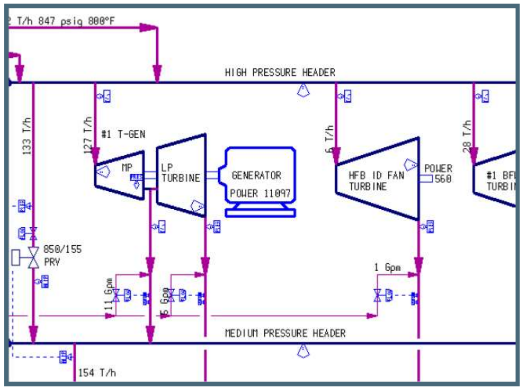
- Depending on the complexity, process models and energy & mass balance may be performed using a spreadsheet or a process simulator
  - E.g. Aspen Plus, HYSYS, UniSim, PRO/II, CHEMCAD, Petro Sim, CADSIM, WinGEMS, apiMAX, etc.



Spreadsheet - Process

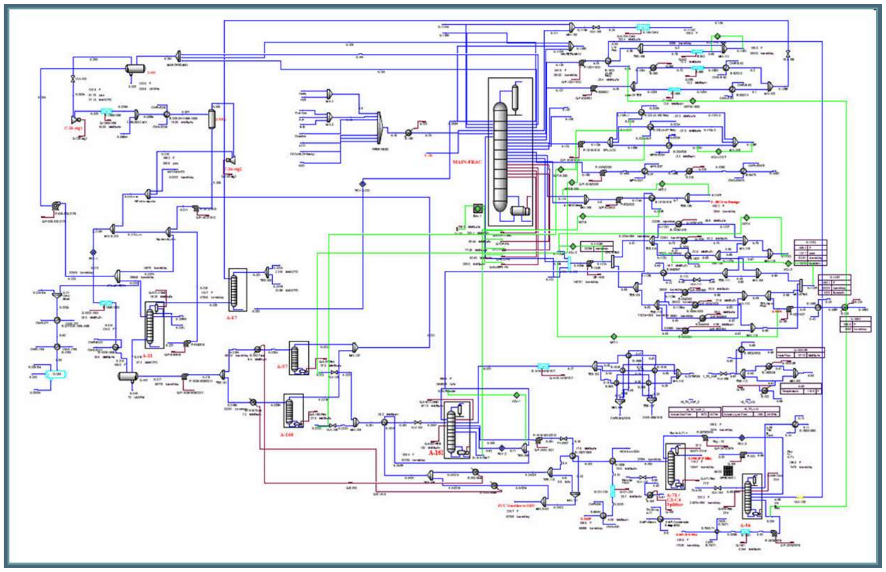


Spreadsheet - Utility system

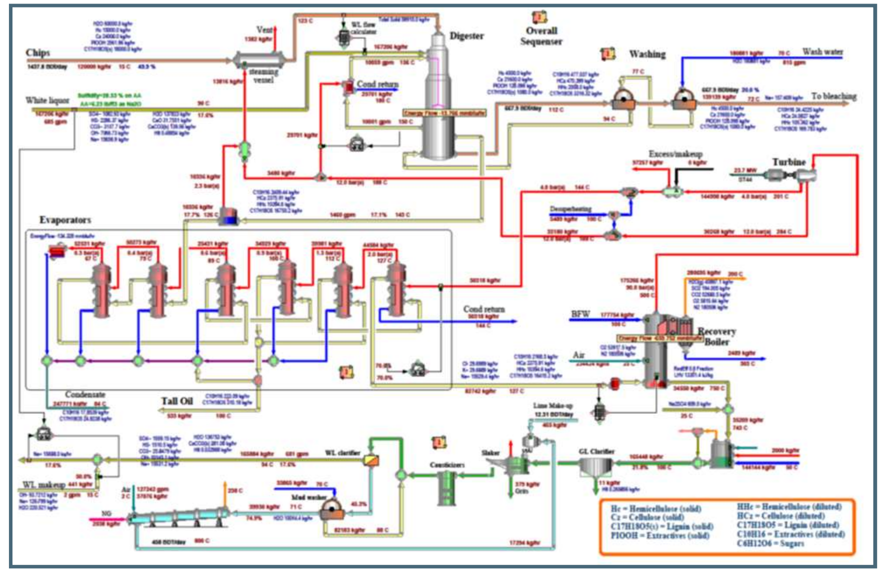


Commercial process simulator

Process Modelling, Heat and Mass Balance

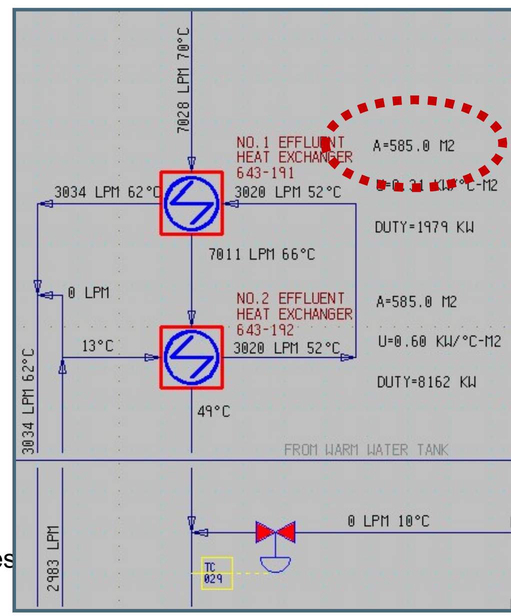


Commercial process simulator



Commercial process simulator

- Accurate representation of the plant current operations
- Powerful tool to identify operational issues, to assess impacts and what-if scenarios
- Validated data for heat integration to reduce process thermal load



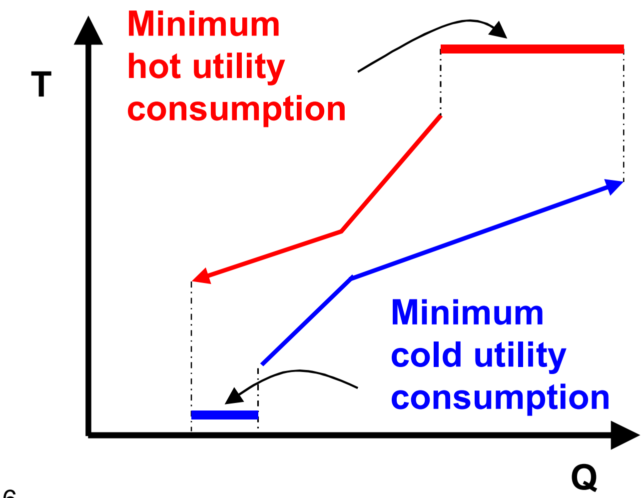
Courtesy of Pragmathic and al., CSChE 2002

Calculated U well under specifications
➔ **Fouling**

Heat Integration and Pinch Analysis

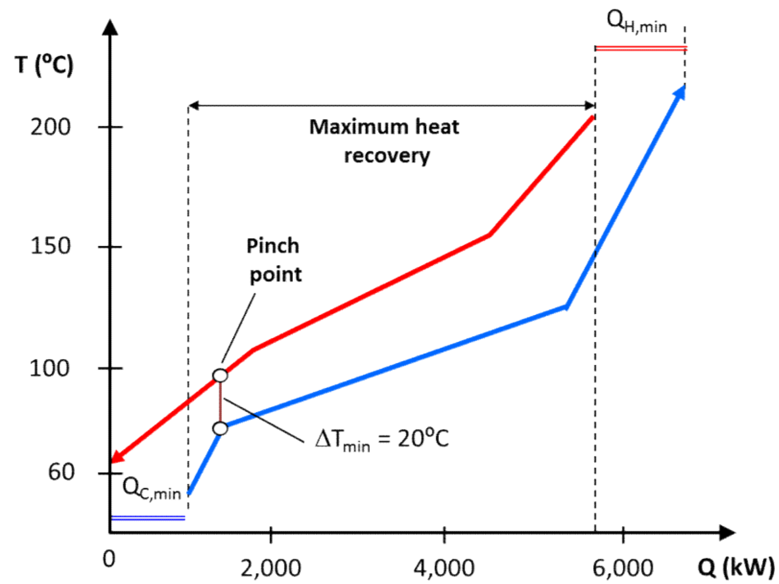
- **Pinch Analysis:** a powerful tool to optimize heat recovery and reduce thermal energy use in complex industrial processes
  - By establishing:
    - The minimum energy consumption (hot and cold utilities) a process needs to operate, i.e. **energy targets**
    - The optimal utility levels that minimize cost, i.e. **utility targets**
    - The cogeneration potential
  - By designing **optimal heat recovery networks** that minimize energy use while satisfying process constraints

Pinch analysis is based on a powerful graphical representation: **the Composite Curves**

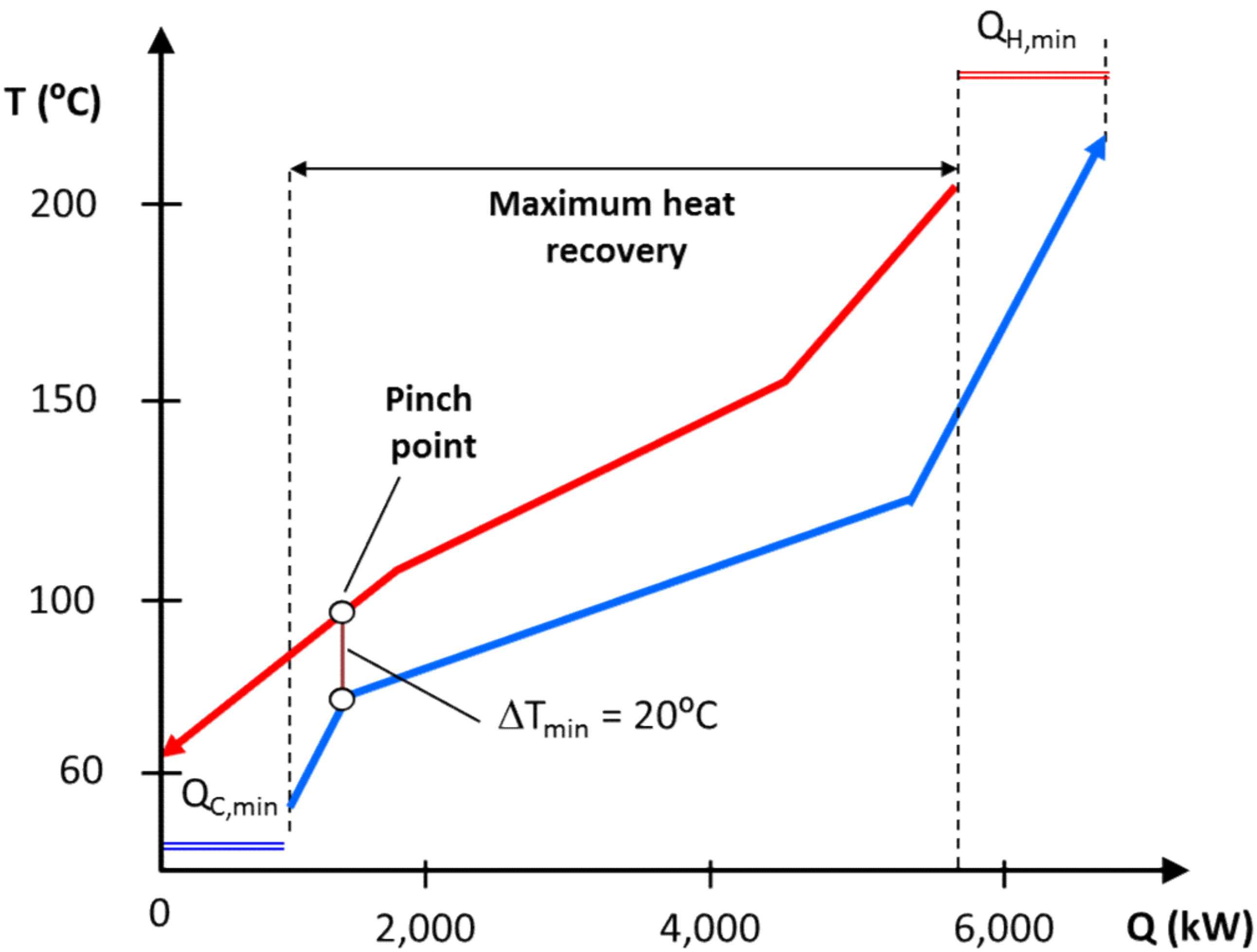


Heat Integration and Pinch Analysis

- **Composite Curves:** a powerful representation of all the heating and cooling requirements of the process on a T (temperature) vs. Q (heat load) diagram
  - **Cold composite curve** is a graphical representation of all the heating requirements (cold streams or heat sinks) in the process
  - **Hot composite curve** is a graphical representation of all the cooling requirements (hot streams or heat sources) in the process



Heat Integration and Pinch Analysis

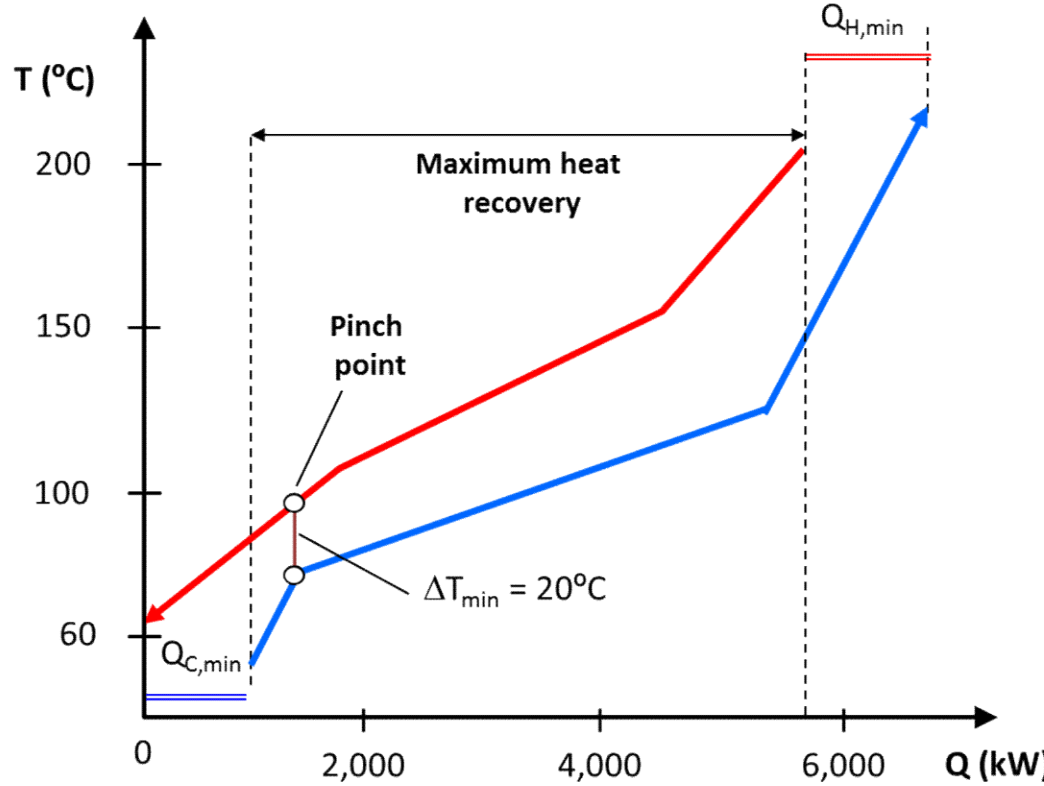


What we learn from composite curves:

- External heating is only required above the pinch point (**hot utility target**)
- External cooling is only required below the pinch point (**cold utility target**)

Heat Integration and Pinch Analysis

- Fundamental rules of Pinch analysis (**Golden Rules**)
  - Do not use cold utility above the pinch point (heat deficit region)
  - Do not use hot utility below the pinch point (excess heat region)
  - Do not transfer energy between hot and cold streams across the pinch point

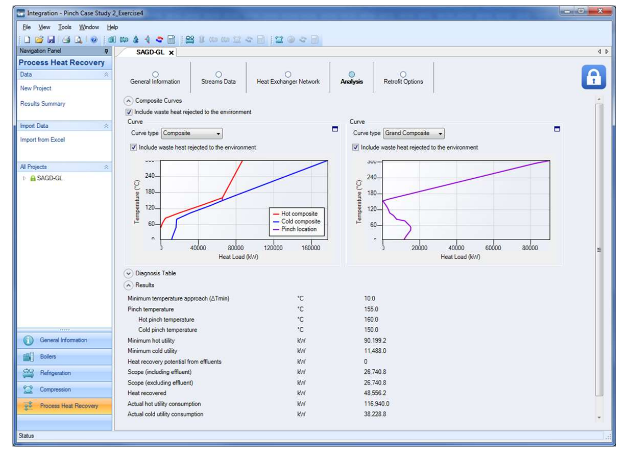


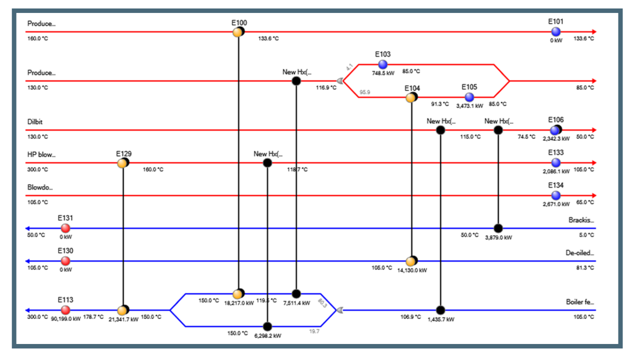
Rules for optimizing heat recovery systems, new or existing
In existing facilities: diagnosis of heat exchanger network and potential for improvement

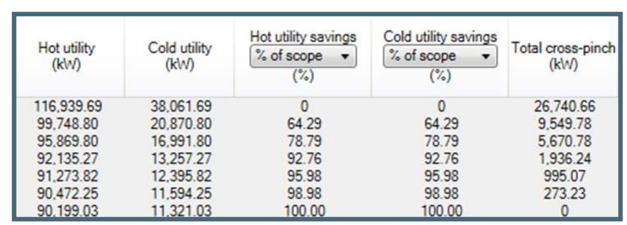
NRCan's INTEGRATION Software

- **INTEGRATION** is developed by CanmetENERGY to optimize heat recovery systems in industrial processes using Pinch analysis
  - Practical and user-friendly interface
  - Pinch analysis tools: composite curves, energy targets, diagnosis of existing heat exchanger network
  - Robust optimization capabilities, while considering a range of design and economic constraints
  - Step-by-step retrofit approach leaving the user in control of the number and type of modifications
  - Available to Canadian companies, free to process integration course participants

INTEGRATION





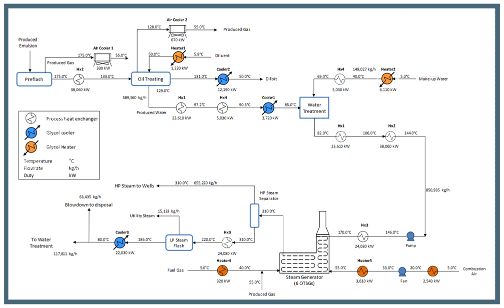


Hot utility (kW)	Cold utility (kW)	Hot utility savings % of scope (%)	Cold utility savings % of scope (%)	Total cross-pinch (kW)
116,939.69	38,061.69	0	0	26,740.66
99,748.80	20,870.80	64.29	64.29	9,549.78
95,869.80	16,991.80	78.79	78.79	5,670.78
92,135.27	13,257.27	92.76	92.76	1,936.24
91,273.82	12,395.82	95.98	95.98	995.07
90,472.25	11,594.25	98.98	98.98	273.23
90,199.03	11,321.03	100.00	100.00	0

Pinch Analysis Step-by-Step: Summary

Existing Plant or Simulation Model

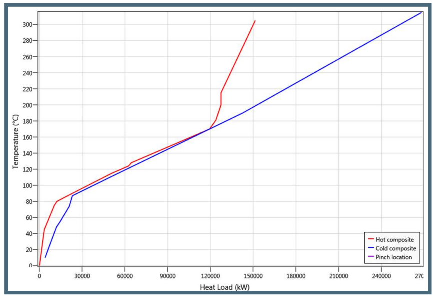
Simplified Process Flow Diagram



Streams Table

Stream Name	Initial Temperature (°C)	Final Temperature (°C)	Heat load (kW)
Produced emulsion from V-101	187.9	132.1	57,968
Produced water (V-110)	130	85	32,373
Produced water (V-112)	130	85	6,308
Dilbit	130	50	11,644
Steam to BFW tank	200	105	17,432
Blowdown	200	90	18,210
Evaporator blowdown	90.2	65	365
Dilution water	90.3	50	1,153
Produced gas	176.6	50	692
Boiler feedwater	103.9	300	234,662
De-oiled water	81.3	105	21,305
Fuel gas	-0.2	64	1,936
Brackish water	5	50	1,077

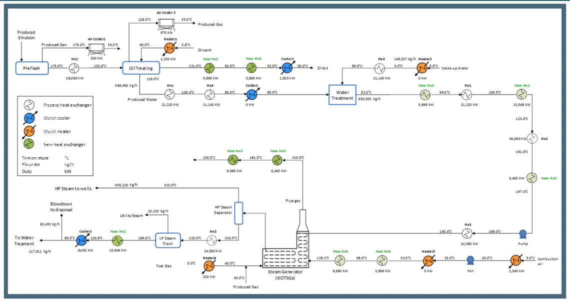
Composite Curves and Energy Targets



Energy Saving Potential and Sources of Inefficiency

E-461 & E-463	0	Steam to BFW tank	Cold Utility	0
OTSGs	22,468.4	Hot Utility	Boiler feedwater	27,033.4
Steam injection	9,982.0	Hot Utility	De-oiled water	9,982.0
E-114 A/B	0	Dilbit	Cold Utility	0
E-450	0	Evaporator blowdown	Cold Utility	0
E-330	0	Dilution water	Cold Utility	0
E-501	0	Produced gas	Cold Utility	0
HLS	0	Steam to HLS	Cold Utility	0
E-508	1,936.0	Hot Utility	Fuel gas	1,936.0
E-555	1,077.0	Hot Utility	Brackish water	1,077.0
Diluent heater	1,452.0	Hot Utility	Diluent	1,452.0
Air heater	11,999.3	Hot Utility	Combustion air	11,999.3
OTSGs air heater	22,998.7	Hot Utility	Combustion air	22,998.7

Improved Process Flow Diagram



Pinch Analysis: Summary

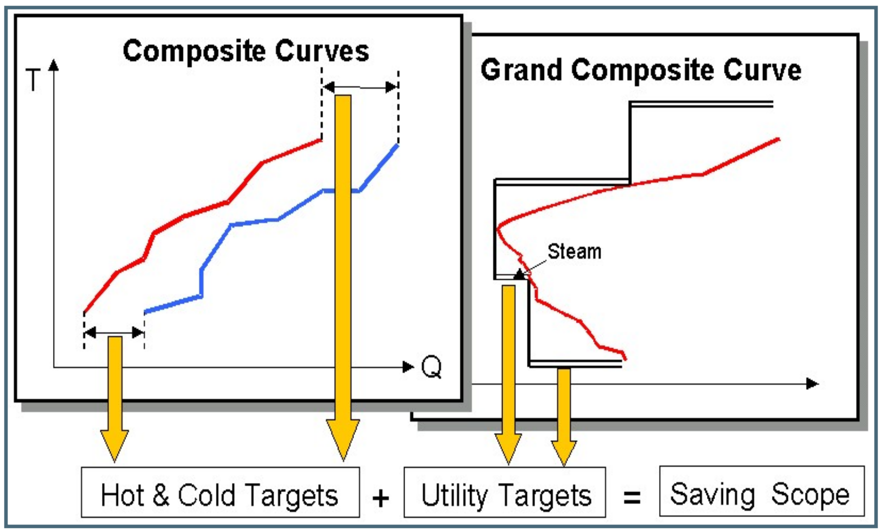
- Composite Curves provide **overall energy targets** and rules to develop heat exchanger networks that maximize heat recovery

BUT…

- In general, we have a choice of several hot and cold utilities
  - Hot utilities: flue gas, hot oil, LP steam, MP steam, HP steam
  - Cold utilities: steam generation (high temp. processes), air-cooling, cooling water, glycol, refrigeration
- Composite Curves do not clearly indicate how much energy should be supplied by different utility levels

Heat Integration: Utility Selection

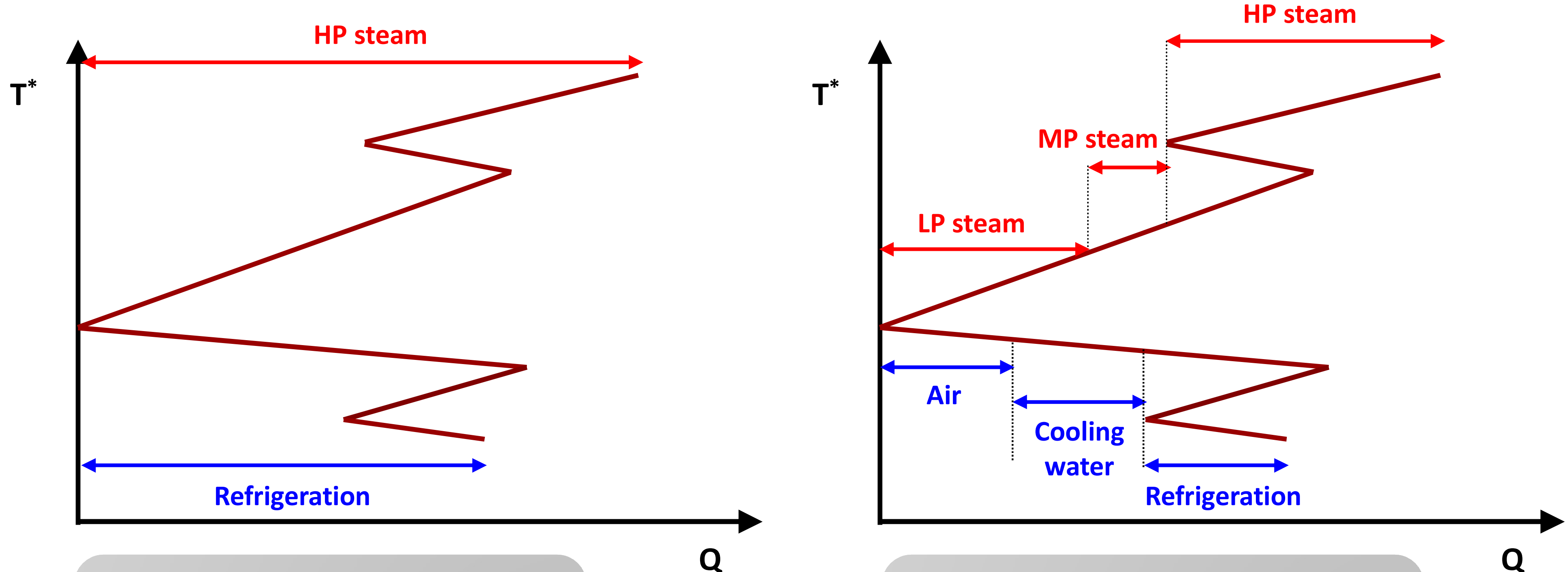
- How to reach energy targets with the best mix of utilities?
  - Hot utilities: we want to use the lowest level (i.e. the cheapest)
  - Cold utilities: we wat to use the highest level (i.e. the cheapest)
- The optimal utility mix is determined by the Grand Composite Curve (GCC)



The Grand Composite Curve (GCC), also referred to as Residual Energy Curve, helps select utility levels

Heat Integration: Utility Selection

- The GCC gives the hot and cold utility requirements of the process both in enthalpy (i.e. quantity) and temperature (i.e. quality)

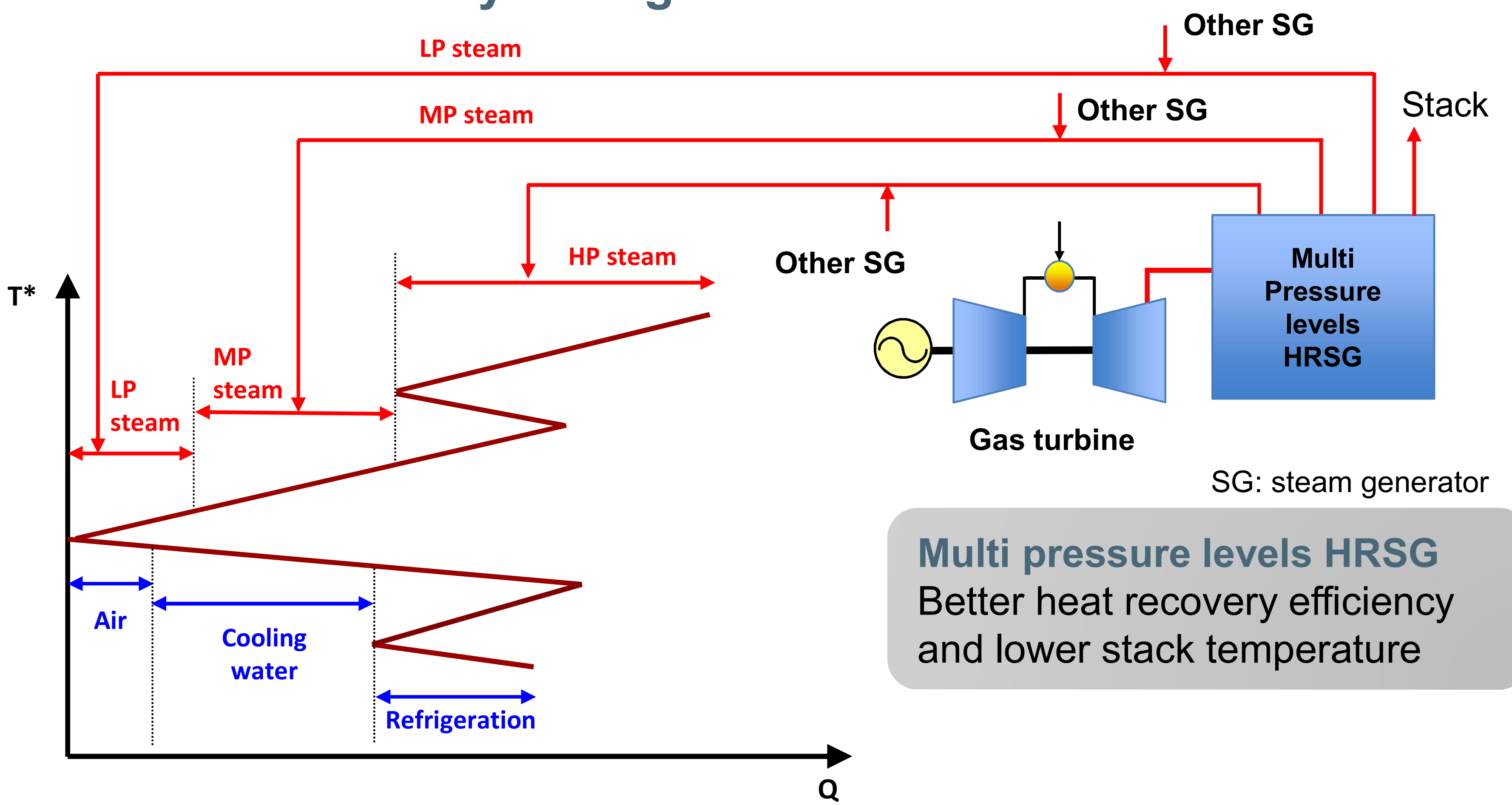


Situation 1: expensive use of utilities

Situation 2: optimal use of hot and cold utilities available at the site

Heat Integration: Utility Selection

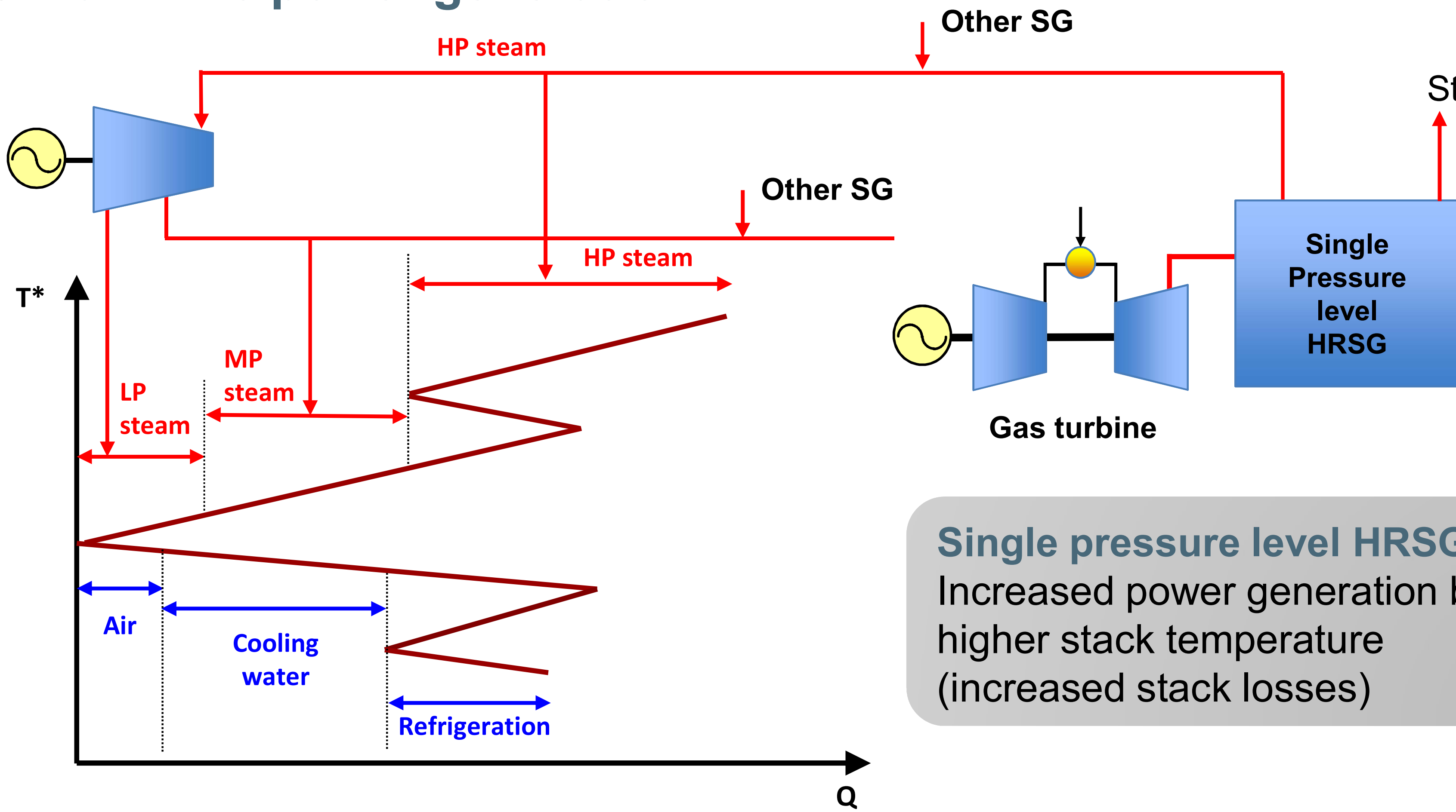
- Utility selection and gas turbine integration using the GCC to **increase heat recovery from gas turbine exhaust**



Multi pressure levels HRSG
Better heat recovery efficiency and lower stack temperature

Heat Integration: Utility Selection

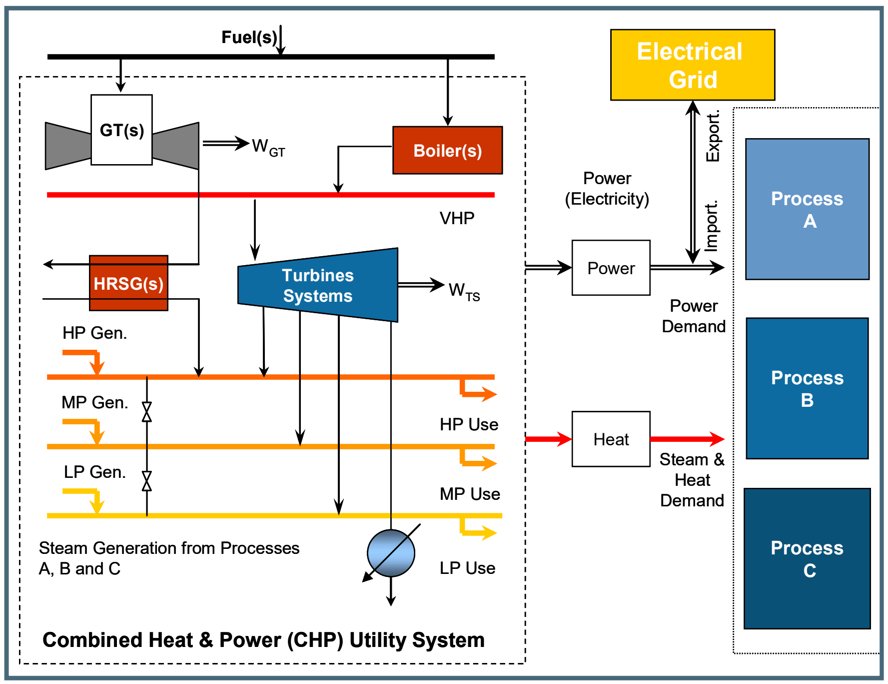
- Optimal utility selection and gas turbine integration using the GCC to **maximize power generation**



Single pressure level HRSG
Increased power generation but higher stack temperature (increased stack losses)

Heat Integration: Impact on the Utility System

- Increasing process heat recovery reduces steam demand, therefore impacting the site utility system
  - Existing system: new operating conditions must be defined
  - New system: the sizing of equipment is affected
  - Many constraints exist

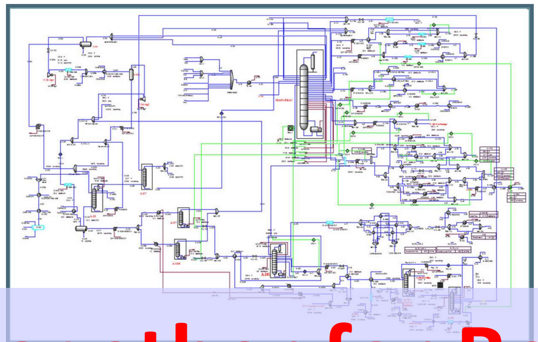


Impact of process heat integration (i.e. reduced thermal energy demand) on the utility system?

A combined heat and power modelling and optimization tool is needed

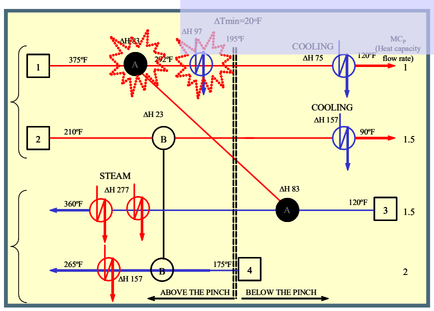
NRCan's **COGEN** software

Process Integration Tools for Energy-Efficient Industrial Facilities

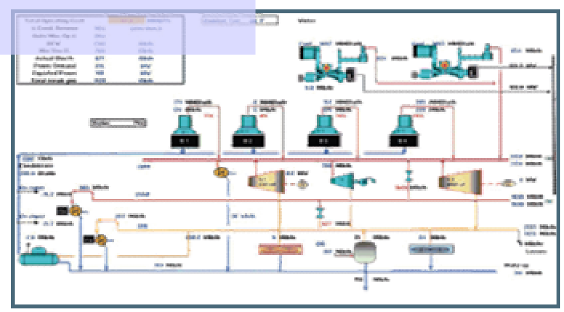


Process Simulation
To represent process operations, obtain validated data, identify abnormal situations and assess what-if scenarios

All together for Better Results



Process Heat Integration
To optimize heat recovery systems and reduce process thermal load

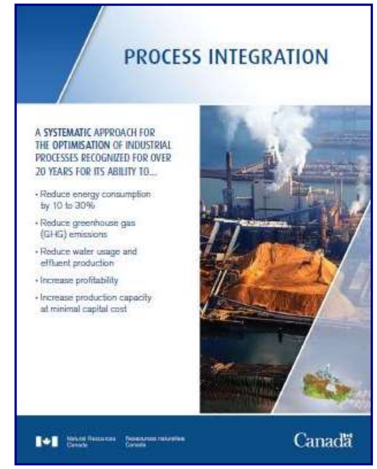


Utility System Modeling
To reduce operation cost and emissions, to properly select and size heat and power equipment

Conclusions

- **Process integration:** a powerful approach to optimize facility-wide thermal energy use at process and utility system levels
- Using process modelling, heat integration (i.e. Pinch analysis) and utility system optimization in combination: **a great opportunity!**
  - Evaluate the impact of heat integration measures on the design, sizing and operation of utility system
  - Support the selection of economically attractive energy strategies
- Recognized as **best available technique** for efficient heat management (thermal energy use and power generation) in large industries, in both retrofit and new design
- Natural Resources Canada and its partners are supporting Process Integration in Canadian industry
  - Incentives for studies
  - **INTEGRATION** and **COGEN** tools are available to Canadian companies, free for course participants

Thank you!



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