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Canada

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Industrial Energy Efficiency and Complexity

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Outline

- A short overview of energy usage in North America (Canada)
- Some particular (selected) aspects of INDUSTRIAL energy issues
- The challenges faced by industrial decision makers
- The NATURE of those challenges
- Musing on the role that R&D may play to help resolve these issues
- In short some data, many questions.....very few answers 😊





The Energy Picture

Some facts





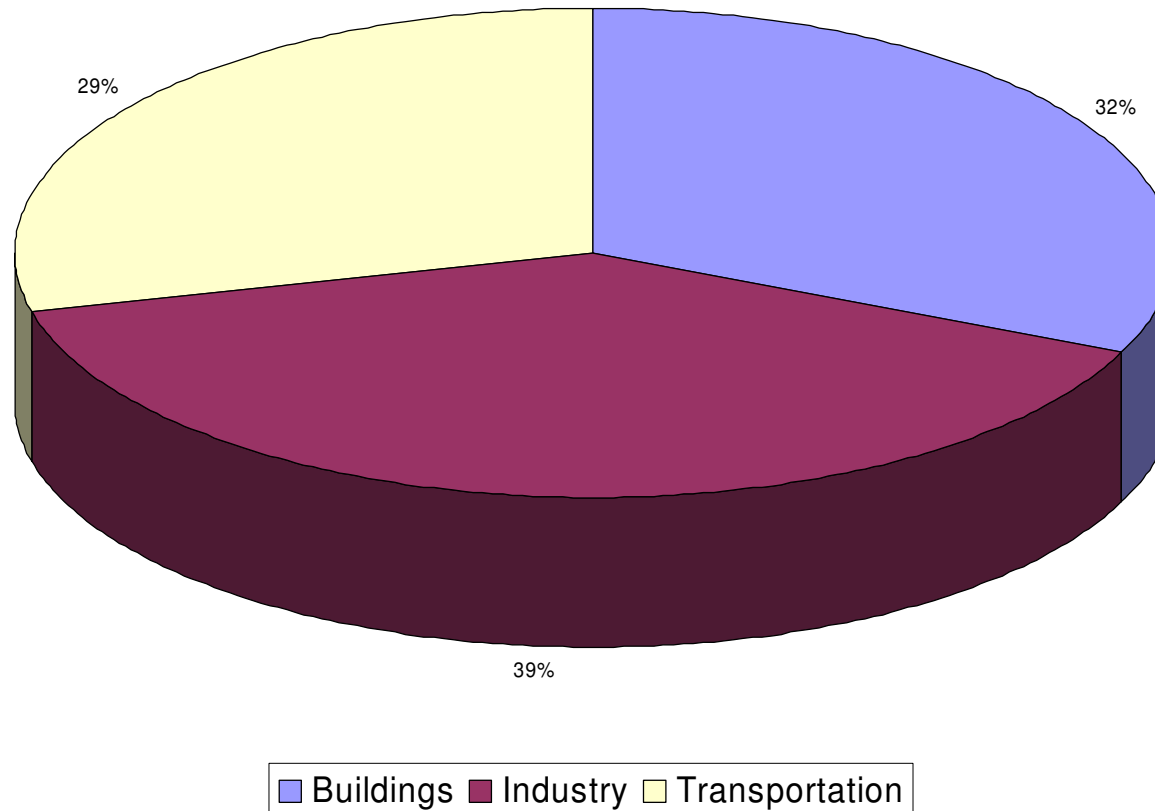
The Energy Picture

Where or how do
we use energy in
our lives?



Canadian Energy Usage by Sector 2002

Canadian Energy Usage by Sector 2002



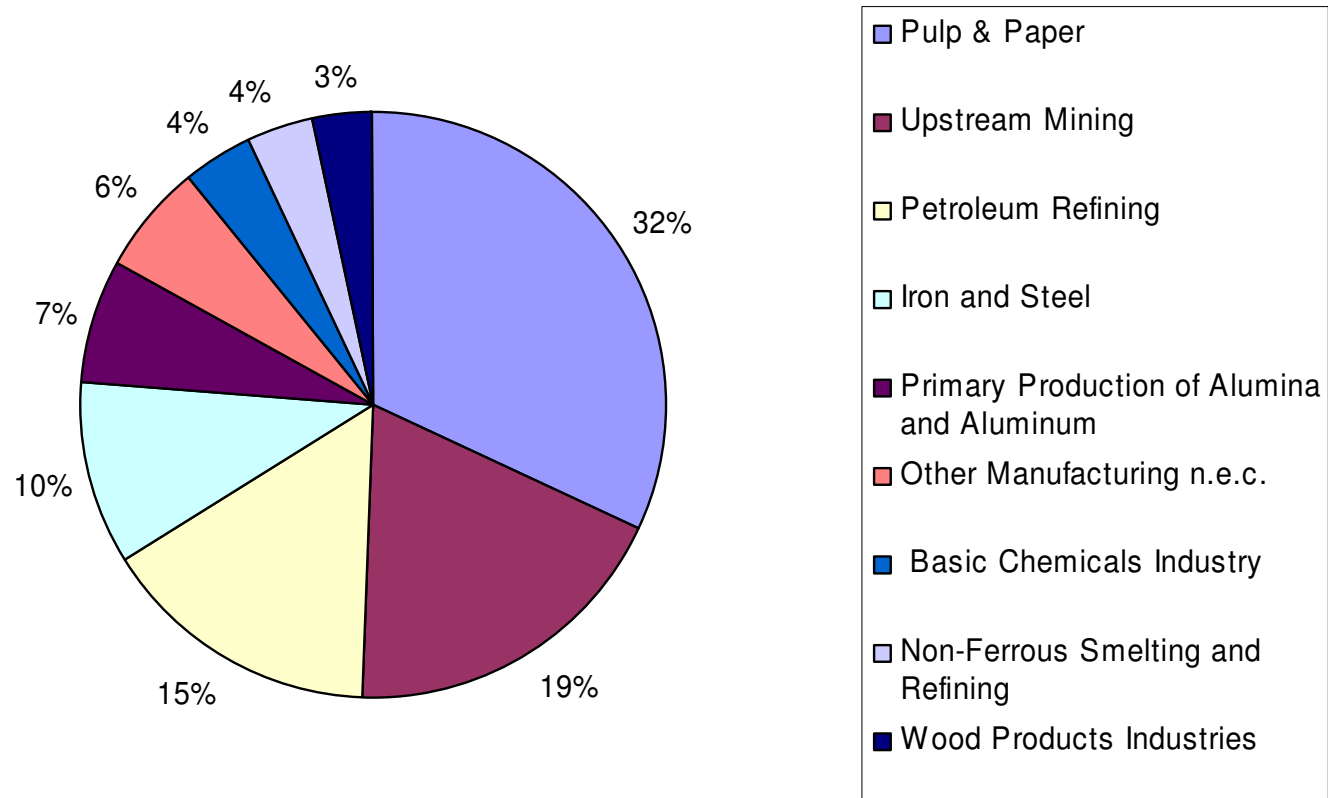
The Energy Picture

- From a sustainable development point of view these three sectors are equally important
- While some energy R&D may affect more than one sector, others need to address specifics of a given sector
- We'll now turn more specifically to industrial energy issues



Industrial End Use by Sector

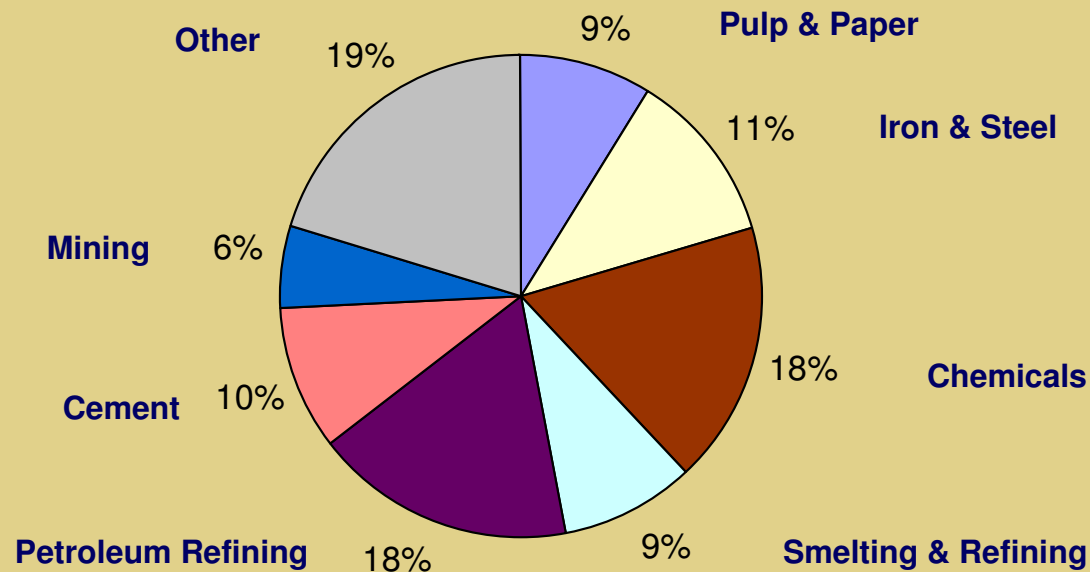
Masjor Industrial Energy Consumers 2002



Industrial Emissions by Sector

Total: 152 Mt CO₂/year (2020)

Distribution of CO₂ emissions by industry



Industry – The Focus

- There are over 45,000 industrial sites in Canada.
- But....



Industry – The Focus

Cumulative % of Industrial GHG Emissions vs % of number of plants

(For Sites Emitting More than 50 kt/y)

Data Source: Statistics Canada, Cat. No. 31-203)

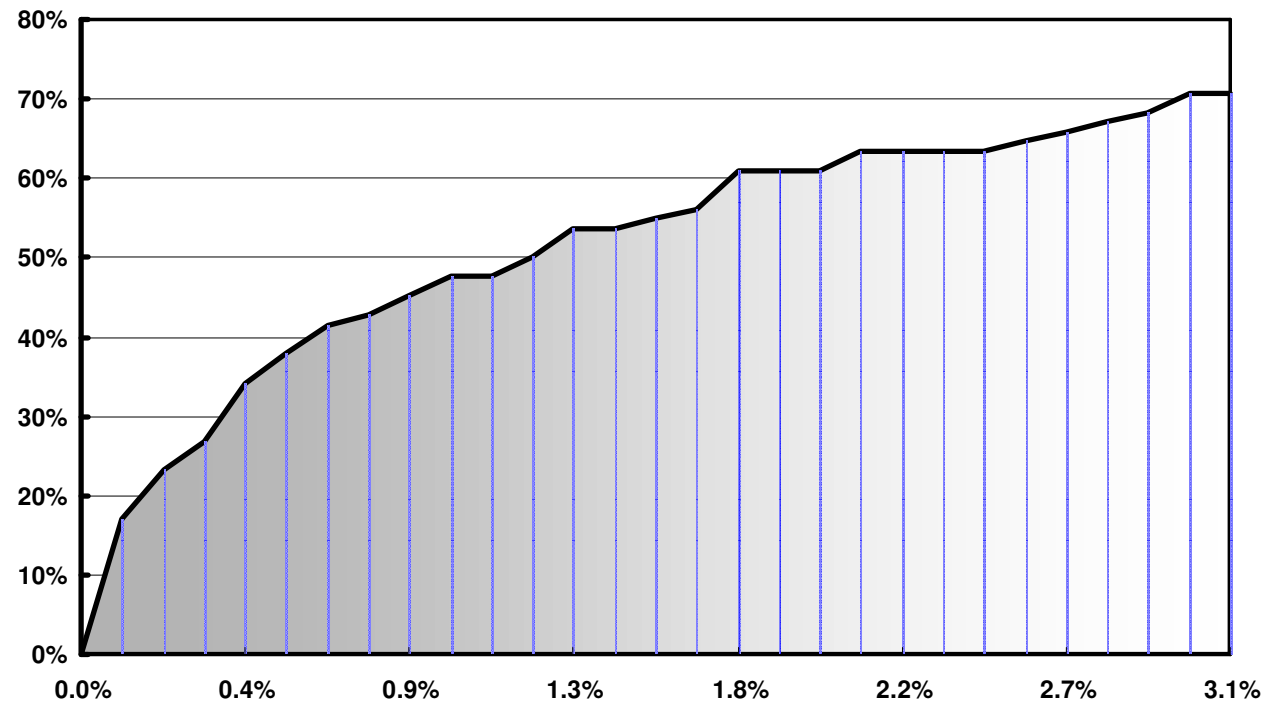


Figure 1 - % of total number of industrial plants in Canada

The Energy Picture

- Current estimates suggest that even the most mature and reputedly energy-efficient industrial processes may be using 10 - 20% more energy than necessary.
- Another study underlines that 75% of the equipment that will satisfy the industrial needs of north America in 2025 are installed today. Very, very slow equipment replacement rate.
- “...The opportunity resides in the effective application of existing technologies, the internalization of energy management behaviors and the optimization from an energy use perspective of industrial processes and their auxiliaries at an integrated systems level.”



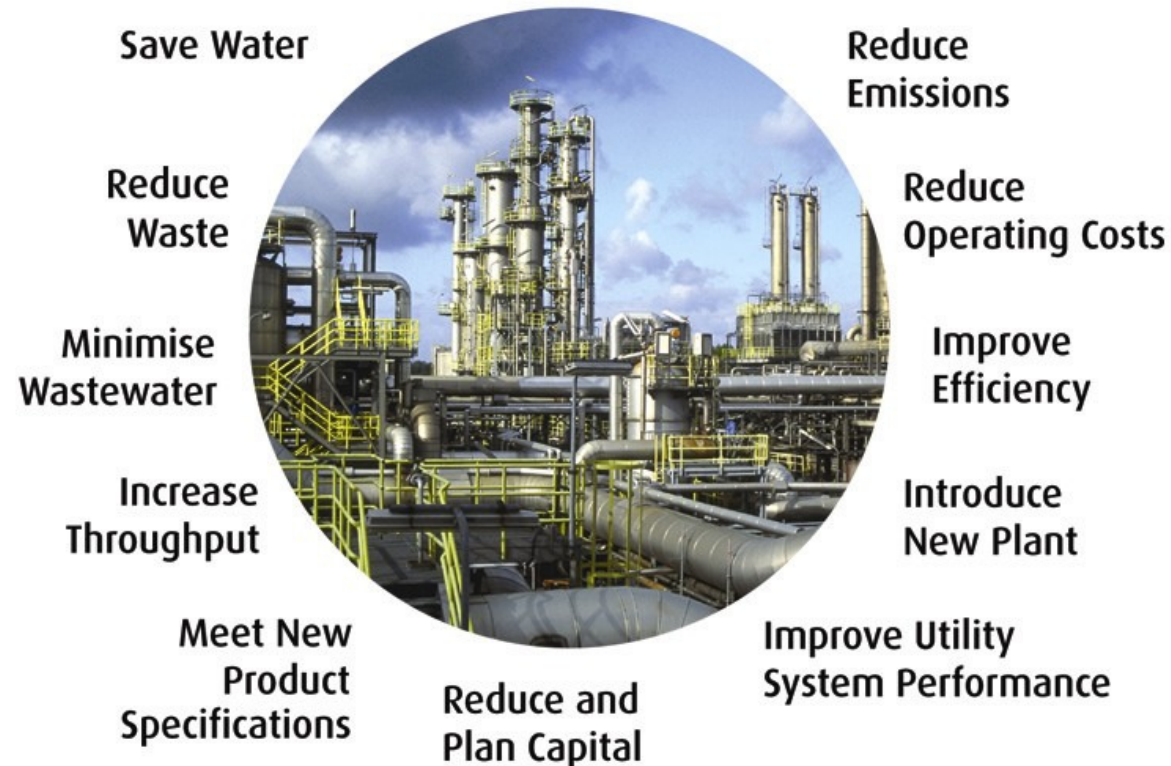
Industry Issues

The Challenges That Decision Makers Face

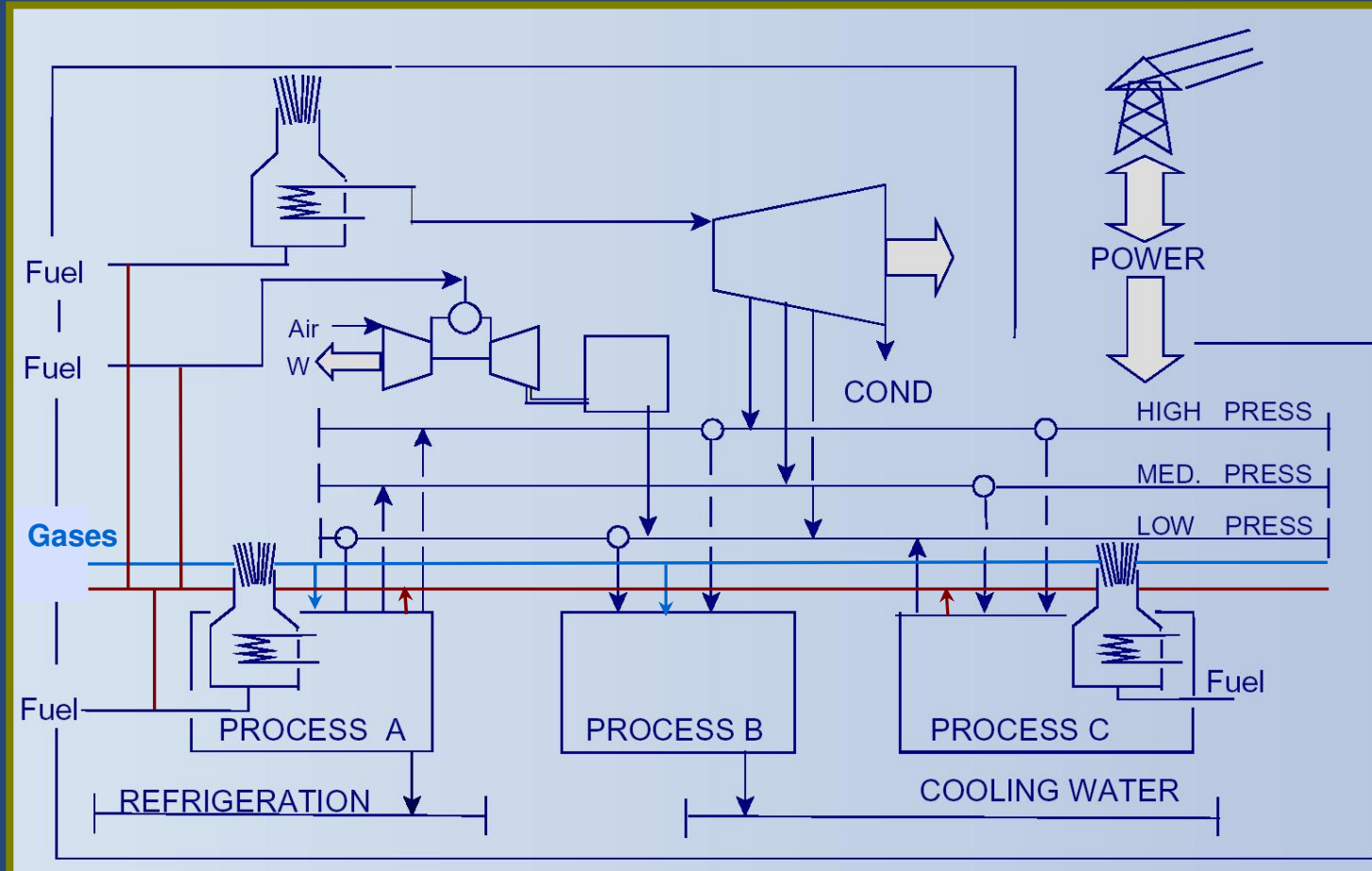


Industry Issues

Typical Site Issues



A typical Industrial Site



Industry Energy Issues



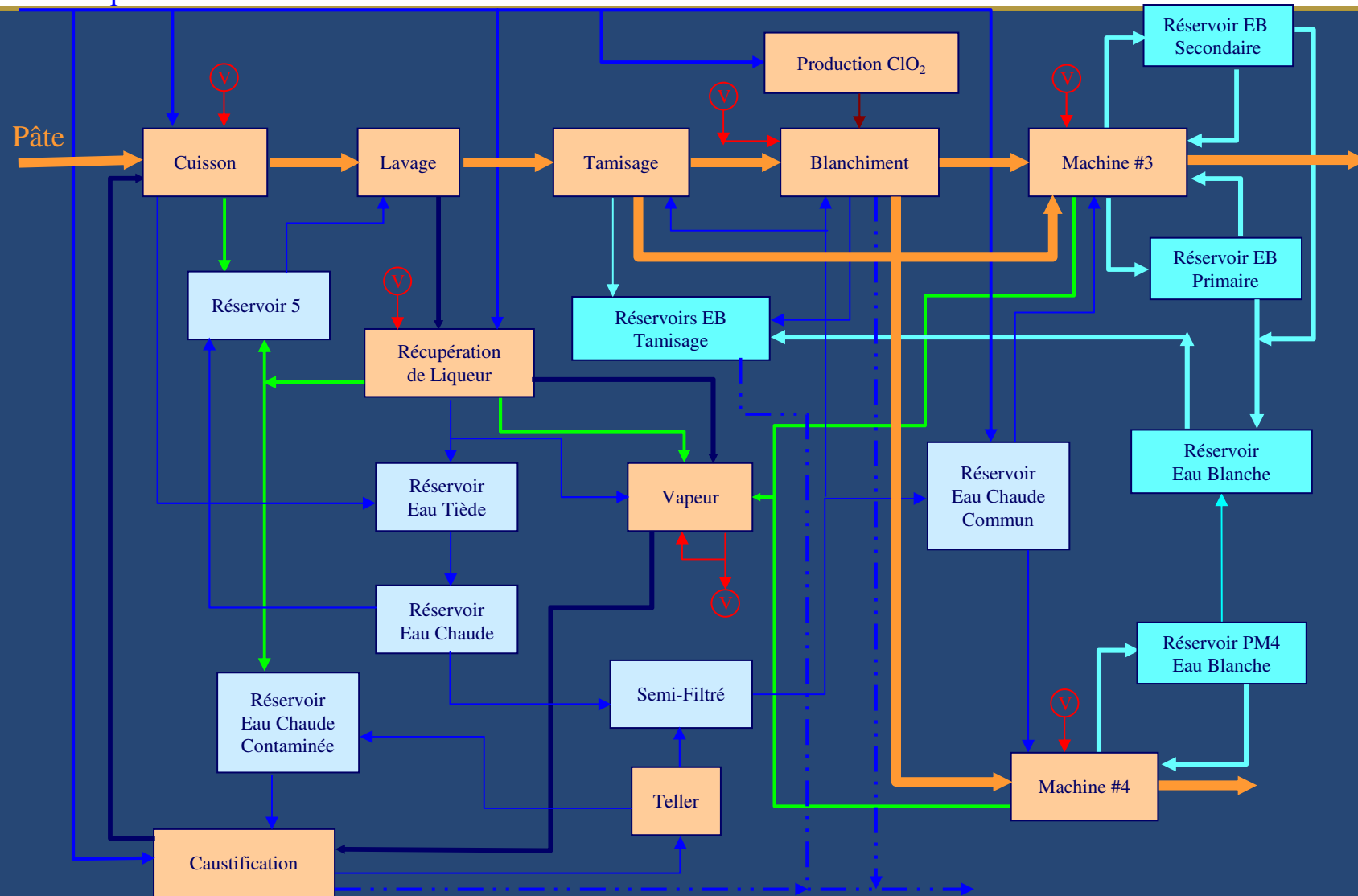
Cogeneration potential ?
Individual plant efficiency ?
Site steam levels ? Site fuel use ?

Install Steam generator ?
Gas turbine ? Heater ?
New boiler ? Heat exchanger? **...And where?**



Diagramme d'écoulement simplifié de Carton St-Laurent La Tuque

Eau Propre



Energy Policy Issues

Policy decision makers in government, financial stakeholders in the private sector and national industrial planners basically face similar dilemmas





Industry Energy Issues

**How do we find systematic approaches
to address energy efficiency issues in
large and complex systems?**





Complex industrial systems

Oh...by the way...what is a system?



Complex industrial systems

Operational definition (of the day)

- a "system" is a dynamic and complex whole, interacting as a structured functional unit in (or not far from) equilibrium
- information flows between the different elements that compose the system
- information flows from and to the surrounding environment across boundaries



Complex industrial systems

....and complexity?



Complex industrial systems

- Complexity definitions exist in
 - Information processing
 - Physical systems
 - Computer science
 - Social science (computational sociology)



Complex industrial systems

- **Complexity** is also often used as a shorthand for the field that developed in the late 1980s around the use of mathematical, physical and computational modeling of biological, economic and technological systems known as "**complex systems**" (complex adaptive systems, emergent systems)
- It is this definition of complexity we want to use when looking at industrial systems

Complex industrial systems

- **What makes a systems “complex”?**
 - Relationships between elements are
 - Short-range
 - Non linear
 - Feedback loops
 - Complex systems are open
 - The parts cannot contain the whole



Complex industrial systems

- **Features of complex systems**
 - Complex systems have a history
 - Complex systems are nested
 - Boundaries are usually difficult to determine
 - Emergent behavior



Complex industrial systems

- So we may see the optimization problem at hand as one which is **Multi-objective/multi-criteria** in nature.
- A problem which consists in finding a decision-vector that has to satisfy a defined constraint set and optimize the objective functions.
 - Objective functions:
 - Goal to be achieved by the decision-maker.
 - Defines a space of possible solutions to the problem.
 - Constraint set: defines the conditions, which have to be satisfied in this space



Complex industrial systems

- Or more mundanely the question is :
- *How do we achieve a compromise between economic, energy and ecologic optima simultaneously on a dynamic basis, i.e. market price fluctuations, energy policy changes, production schedules, etc?*



Complex industrial systems

- The challenge is to incorporate
 - Traditional approaches involving simulations and more generally operations research.
 - “Soft” systems views that tackle systems that cannot easily be quantified, especially those involving people interacting with each other or with "systems". (policy, economics, sociology)
 - Evolutionary systems approaches with a capacity to evolve over time and have multidisciplinary perspectives of systems.

Complex industrial systems

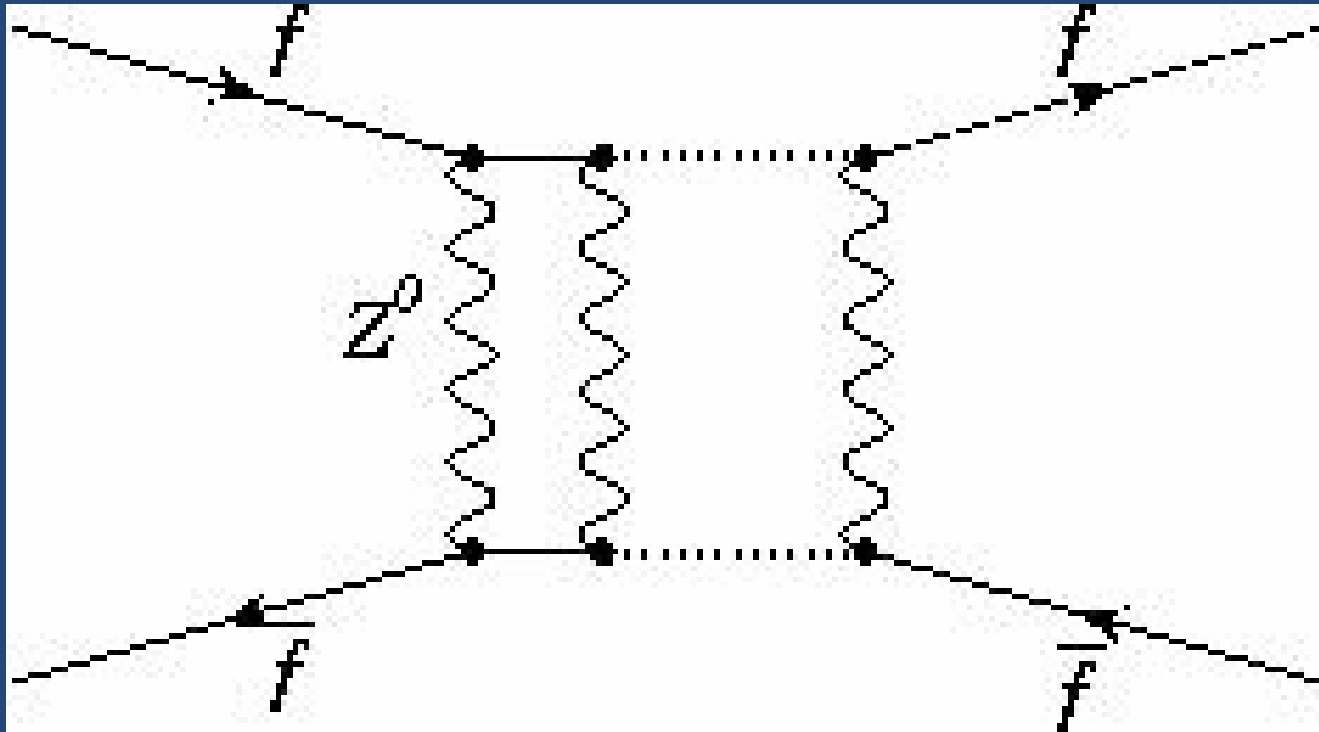
- We will need systems approaches that are
 - Constructivist i.e. which seek to understand “Big Picture”
 - But that also embrace the values of reductionist science by understanding the parts
 - To finally come to the understanding of the complex relationships that enable 'parts' to become 'wholes'.

An R&D Strategy...

- BEG, BORROW OR STEAL !
 - There is an immense opportunity for cross fertilization between different disciplines that needs to be exploited.
 - An example.....



A Feynman Graph



Fermion-Fermion scattering

A Bond Graph

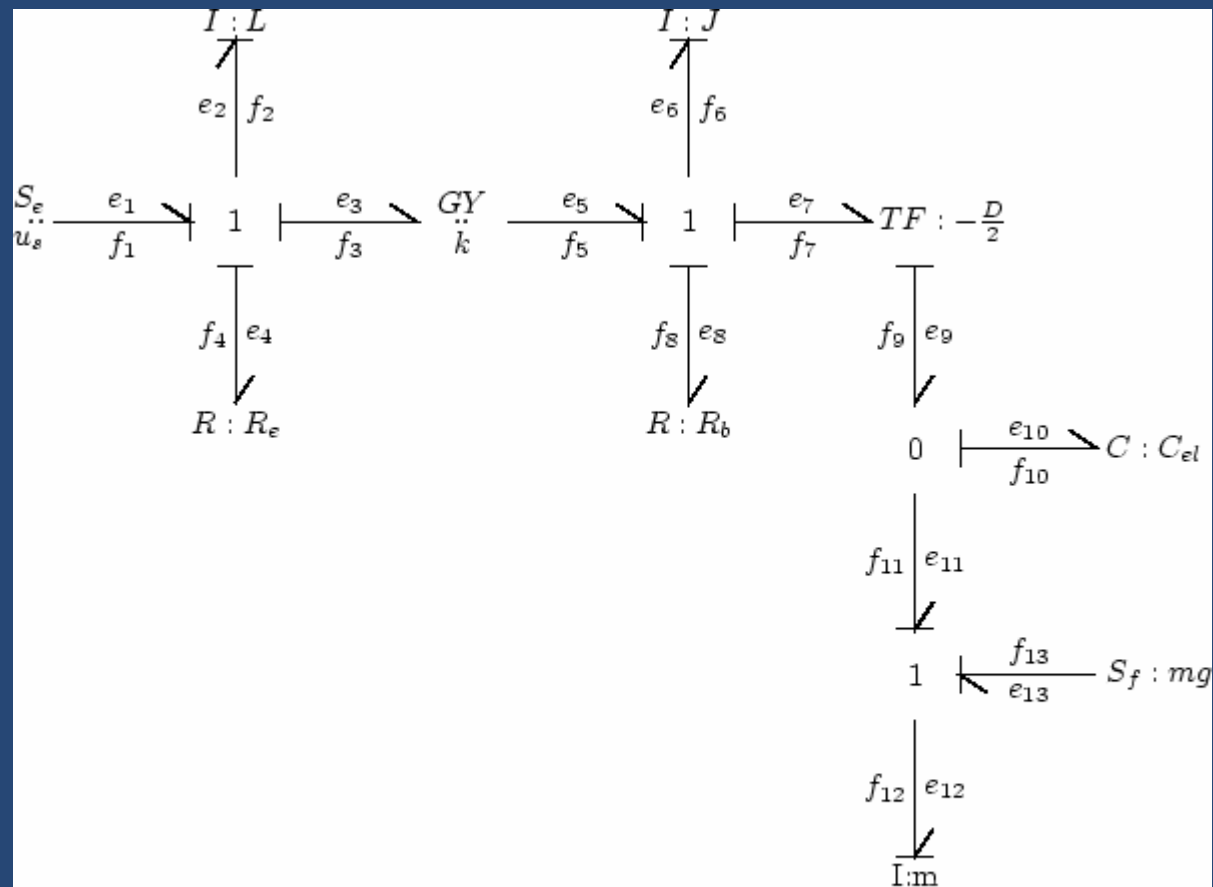


Figura 1.13: Grafo causal de enlaces de potencia del ejemplo 1.1

Feynman and Bond graphs

- Could the similarity be more than “skin” deep? Can we make it that way?
- Both based on conservations laws.
- Both have objects for “charge” and “currents” with similar descriptions.
- Both have descriptions for “nodes” that “transform something into something else”....
- Could some correspondence be established so that “theorems” or formalism could be “exported”
- Just a thought..... 😊

Conclusion

- There is a great need for approaches that promote fundamental understanding of complex industrial systems as much as solution finding
- Multi-disciplinary approaches will play a crucial role along with more traditional basic energy sciences
- Multi lateral collaboration between energy research stakeholders both within and between different countries is an essential component of any future successes.





THANK YOU FOR
YOUR KIND
ATTENTION

