A Method for energy optimization and product quality improvement in manufacturing processes

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Context

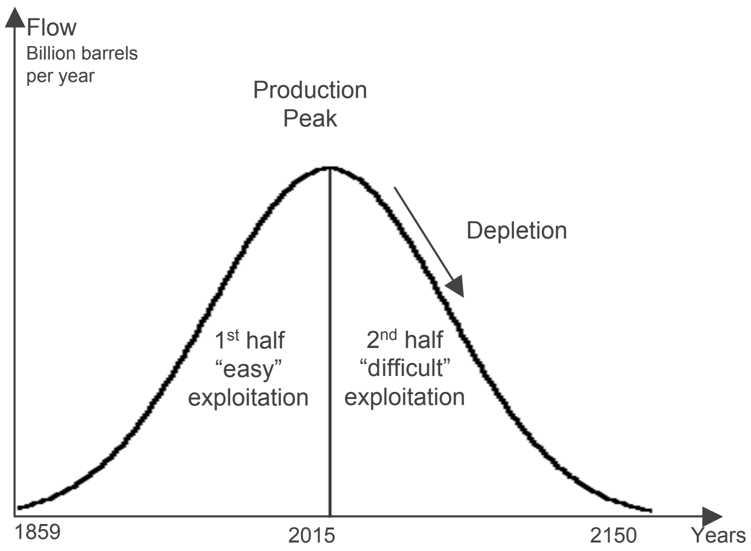
1 Context

I. Environmental and political context

- Earth temperature increased by 0.6 K during the 20th century
- Human activities contribute significantly to greenhouse gas emissions
- Kyoto Protocol aims at decreasing GHG emissions by 5% referred to the 1990 level

II. Oil production peak

- Estimated by 2015
- Decrease in productivity by 2% per year
- Increase in demand by 1.6 % per year
- → Availability decreasing by 3.6% per year



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An overview on existing energy optimization methods in industry

2.1 Process Integration by Pinch analysis

I. Goal

- Improvement of energy efficiency in industrial processes in order to minimize total cost (operating and investment costs)

II. Composite curves

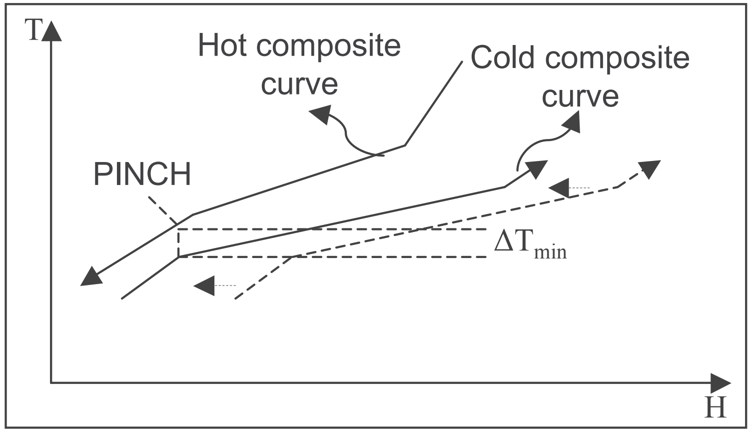
- Determine cost optimal process pinch
- Analyze heat exchange between heat flows in processes

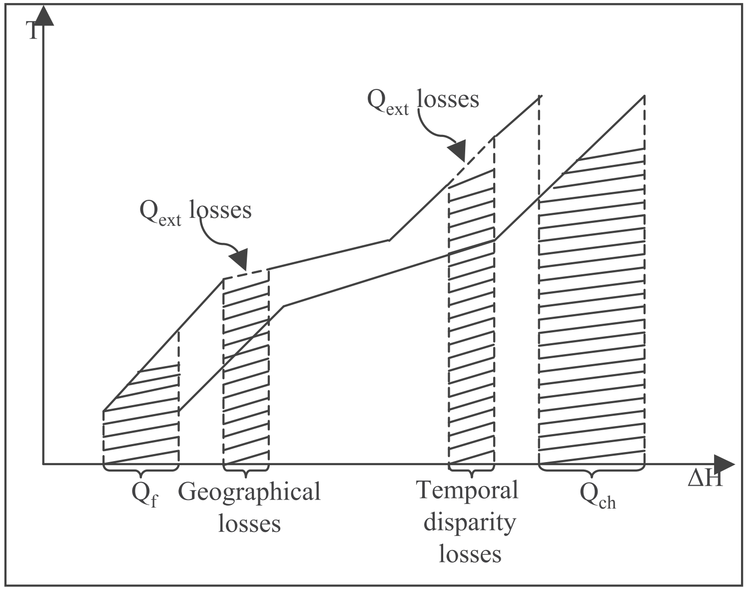
III. Advantages

- Overall vision of the process
- Economic optimization of heat recovery and heat exchange within the process

IV. Pinch analysis limitations

- Batch processes imply time differences
- Spatial discontinuity of heat flows
- Technological difficulties with respect to some materials
- Transformation process "taken as granted"
- Heavy and expensive tool





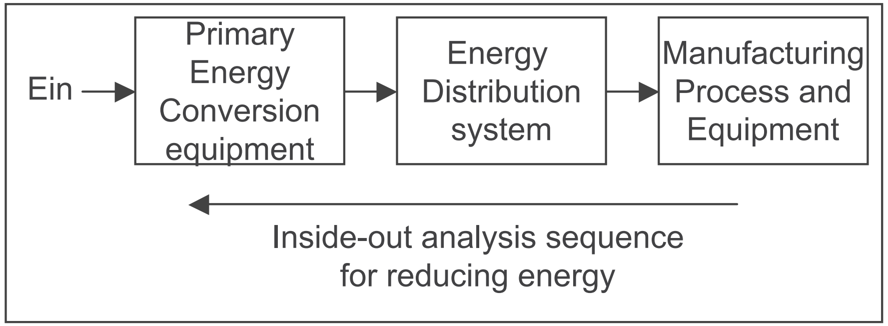
2.2 The Kissock “inside-out” approach and the Frazier method

I. Kissock “inside-out” approach

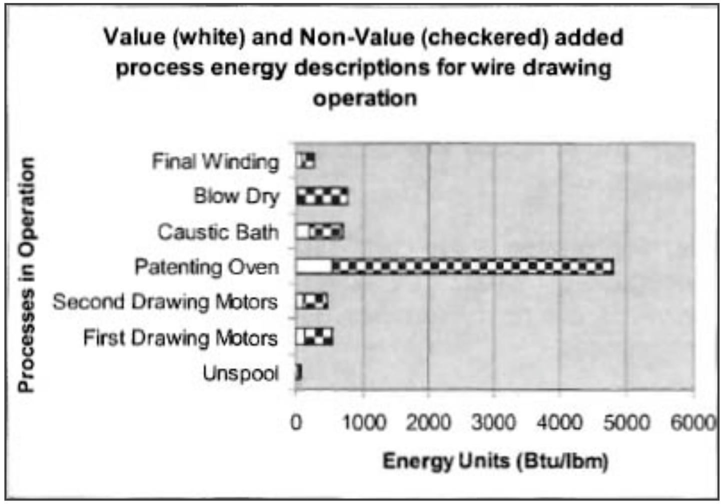
- Basic criteria : process requirement
- Exergy-based analysis of equipment
- Identification of the best suited energy source for the process
- Limitations: transformation process “taken as granted”

II. The Frazier method

- Basic requirements: Minimum Required Energy
- Process energy flow mapping
- Minimum Required Energy : Value added energy
- Losses: Non value added energy
- Technical energy management method leading to incremental improvements
- Limitations: transformation process “taken as granted”



Schematic representation of the inside-out approach *[Kissock et Hallinan, U.DAYTON]*



[Frazier, Oklahoma State University]

2.3 Key issues from literature review

I. **The existing methods do not allow comparison of alternative processes to the current one**

II. **The existing methods consider the actual process as “granted”, so the potential radical improvements are out of the scope**

III. **An analysis method has to be developed focused on the product itself in order to define the most efficient transformation processes**

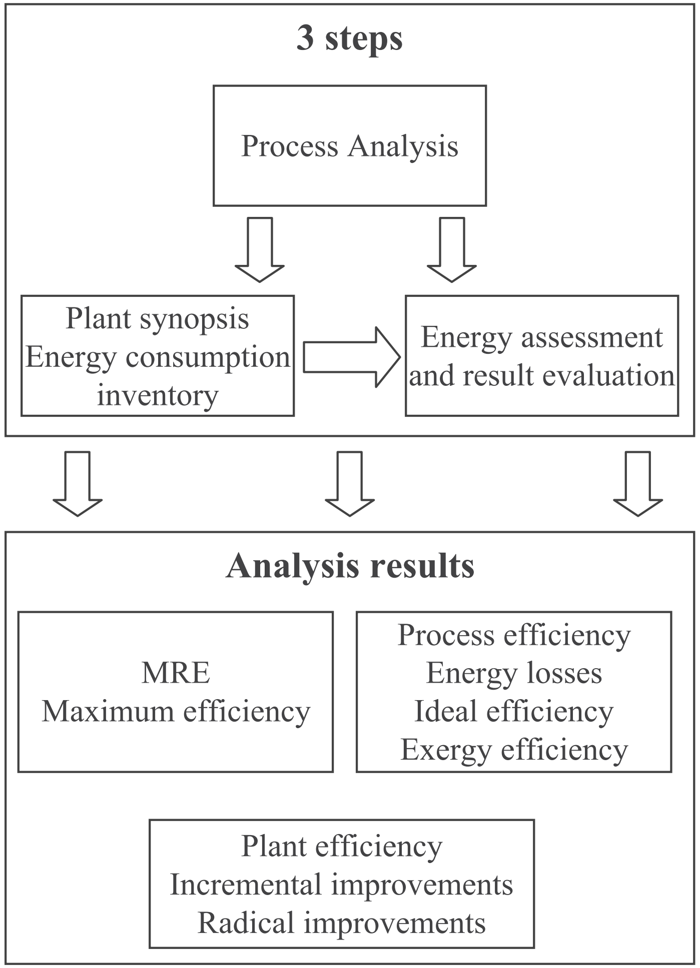
3

The Process Energy Analysis (PEA)

3.1 The 3 steps of PEA

The 3 steps

- Process analysis
  - Molecular and energy analyses of transformation process
  - MRE based on product quality and plant productivity
  - Best transformation process and BAT
- Manufacturing plant synopsis and energy consumption inventories
  - Process mapping (process transformation operations)
  - Inventories of energy and mass fluxes
  - Plant energy exchange model
- Energy assessment and results evaluation
  - Analysis of energy losses
  - Incremental improvements
  - Radical improvements



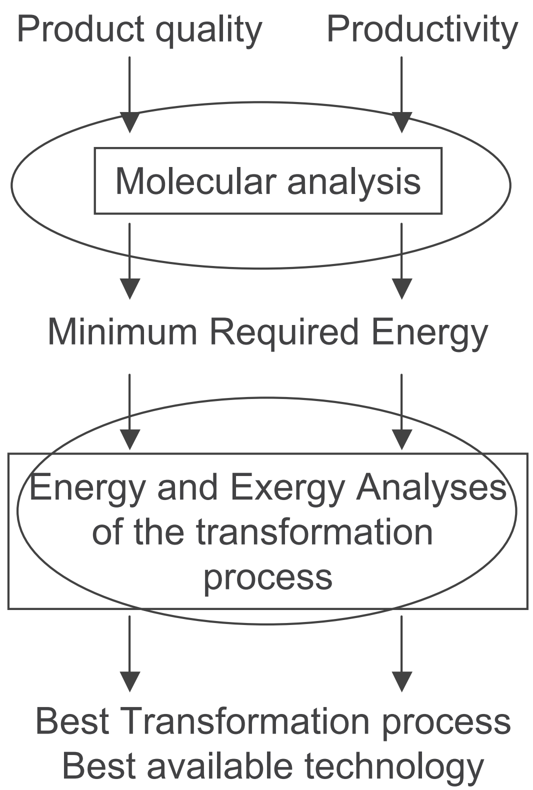
3.2 Process analysis

I. Molecular analysis

- Basic criteria: Product quality and plant productivity
- Determine Minimum Required Energy

II. Energy and Exergy analyses

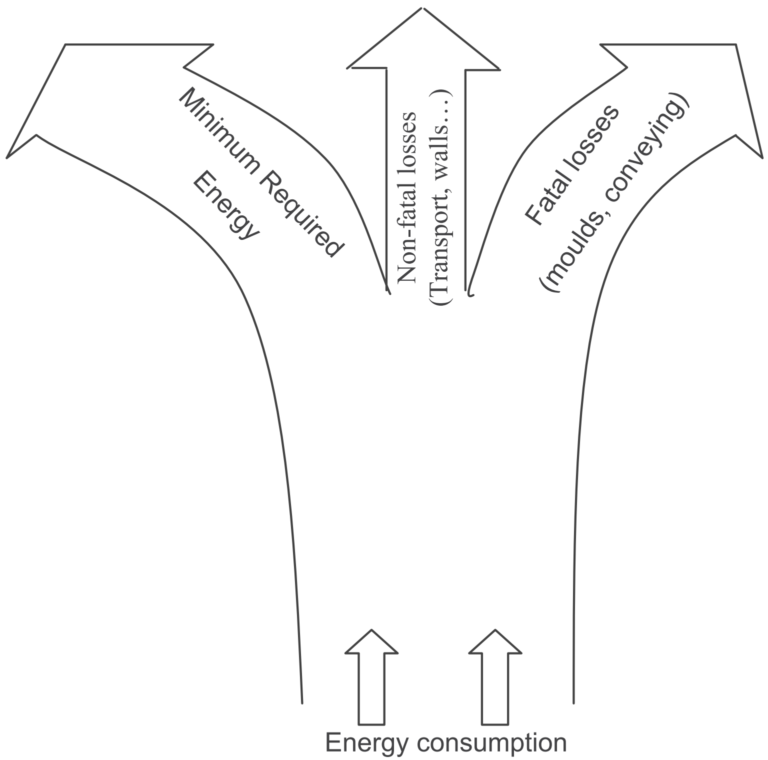
- Determine best suited transformation process
- Determine the energy sources at the highest temperatures
- Determine maximum energy efficiency



3.3 Analyzing data

I. Energy Losses

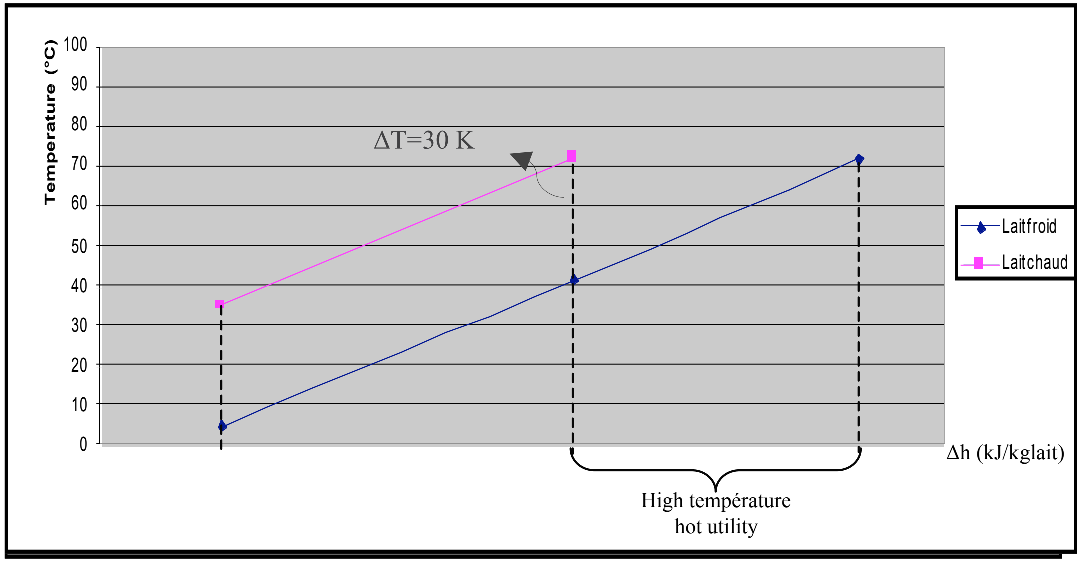
- Non fatal losses
  - Losses related to system malfunction
  - Elimination of non fatal losses does not affect the actual process
  - Incremental energy improvements
- Fatal losses
  - Energy needed for ancillary needs linked with the actual process
  - Mould heating, conveyor heating…etc.
  - Irreversibility losses
  - Elimination of fatal losses requires changing the actual process
  - Radical energy improvements



3.4 Example step 1 (milk pasteurization for cheese production)

I. Molecular analysis

- Eliminate harmful pathogenic bacteria
- Development of bacteria is limited at low temperatures
- Storage up to 1 week possible without pasteurization
- Pasteurization must then be followed by cooling to 35°C
- MRE: Energy to heat milk from 5 to 35°C



3.4 Example step 1 (milk pasteurization for cheese production)

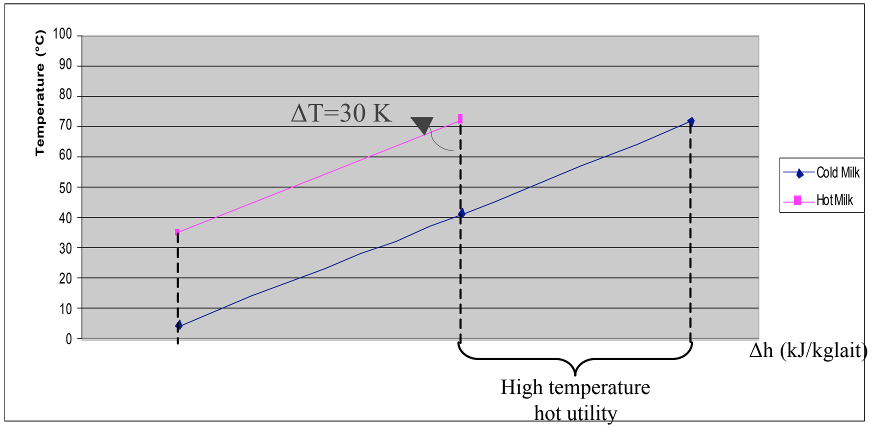
II. Energy and exergy analyses

Composite curve analysis

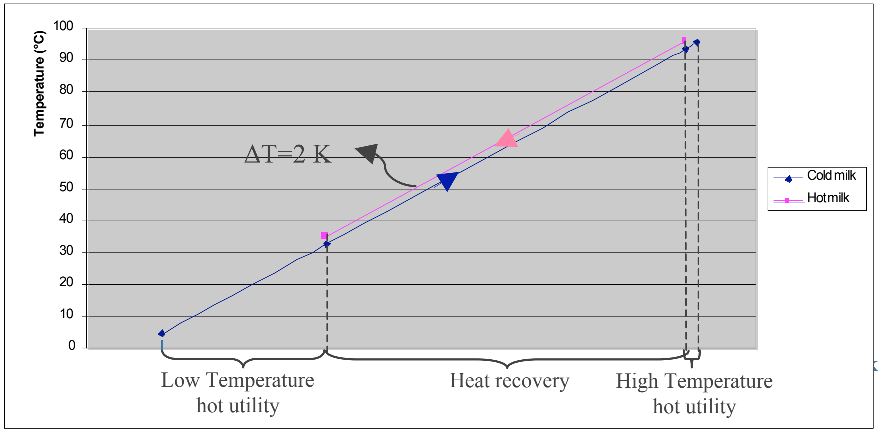
- ΔT ≤30 K → Constant heating needs
- $\Delta T_{min} \uparrow \rightarrow Q_{HT} \uparrow$
- $\Delta T_{min} \downarrow \rightarrow Q_{HT} \downarrow$

Best available techniques and energy ratios

- Minimize the high temperature need
- Air-to-water heat pump. Heat production at 35/37°C
- $$COP_{PASTO} = \frac{MRE}{W_{comp}} = \frac{MRE}{Q_{HP}} \times \frac{Q_{HP}}{W_{comp}} = \eta_{HX} \times COP_{HP}$$



a) Milk composite curves with 30 K pinch



b) Milk composite curves with 2 K pinch

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Conclusions and future working program

4.1 Conclusions

- **PEA application determines energy saving opportunities that cannot be identified by classic energy analysis methods**

- **Transformation process analysis leads to define accessible MRE**

- **In most industries, it is common to take the transformation process as "established forever". The PEA method allows comparing several processes for producing a defined product with similar quality in order to define the lowest achievable energy expense**

4.2 The future working program

- Reference PEA for each industrial process: similar exhaustive approach as IPPC (Integrated Pollution Prevention and Control)
- Best transformation process and Best Available Technologies for a given product
- Processes have to be studied under dynamic simulation in order to take into account energy losses along the time
- The MRE has to be defined for each and every process taking into account the mass flow rates of raw materials, by-products, effluents, and product itself
- GHG and pollutant emissions have to be integrated into the PEA