Method for Combined Water-Energy Recovery in Industrial Processes

Motivation & Objectives
The energy efficiency of the craft mill is strongly interconnected to the correct management of water and energy in the mill. Furthermore, main works in water-energy optimization in pulp and paper industry are insight-based approaches limited to local sections of the mill as they lack a global vision of the process. It results in lack of an effective systematic approach that is able to reach the optimal solution for the whole process. Besides, one of the difficulties developing a combined water-energy optimization is the lack of data on the contamination levels of the water flows, which makes it difficult to find water recycling opportunities. A linear superstructure has been previously proposed by Renard (2011) to address these difficulties through a MILP approach. The objective of this project is to improve this superstructure by addressing Non-Isothermal Mixing (NIM) with linear programming. Furthermore, the superstructure is adapted to kraft mill processes.

Assessment of the initial superstructure
The weaknesses and strengths of state-of-the-art methodologies have been established and compared with Simultaneous Optimization of Water and Energy (SOWE) methodology. A benchmarking analysis has been carried out using an example from Savulescu et al. (2005b) based on available literature, it resulted in:

- **Key points of SOWE**:
  - SOWE is the only methodology which considered process thermal streams.
  - Its linear superstructure guarantees the optimality.
- **Main limitations of SOWE** are:
  - Heat exchanger network is not designed.
  - Non-isothermal mixing is not considered properly as the methodology has the highest number of thermal streams among the other ones. (NIM has the potential of reducing number of thermal streams which results in fewer heat exchangers)
  - The superstructure is not well-suited to be utilized in pulp and paper processes.

NIM and adaptation to pulp and paper processes have been addressed in this work.

Evaluation of the new superstructure
- **Evaluation of the new superstructure** using 4 examples from the literature.
- All examples comprise water sources and demands and the objective is to reach the minimum utility consumptions. Dong’s example is a multi-contaminant problem.

Number of thermal streams is lower compared to other conceptual, linear or nonlinear superstructures which reinforces the innovative approach of SOWE in addressing NIM.

Conclusions
In the context of this work, the simultaneous optimization of water and energy methodology in industrial processes has been further developed. First, a benchmarking analysis has been carried out to explore the state-of-the-art methodologies with their strengths and weaknesses. Non-isothermal mixing definition has been improved in SOWE superstructure by adding several mixers in parallel before water demands. Each mixer is connected to the demand through a heat exchanger. NIM can then occur at the inlet of each mixer. This reduces the number of thermal streams in the network which in turn results in reducing the number of heat exchangers. In all case studies performed in this work, the number of thermal streams is reduced as compared to other methodologies, which reinforces the fact that the improved SOWE superstructure considers NIM properly. Multi-contaminant definition is also added to the superstructure and the results are verified by a series of tests on examples from the literature. SOWE methodology has the potential to compete with state-of-the-art non-linear mathematical formulations. Global optimum is guaranteed due to its linearity. Future works should be based on multi-objective optimization of the superstructure, linear programming of the water treatment units and adding the heat exchange network to achieve the final design of the superstructure.