Combined heat and mass integration: A benchmarking case study

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Introduction and Objectives

In large-scale production processes, such as in pulp and paper industries, energy and water usage are interrelated since reuse of water may lead to energy savings.

This work aims at developing an innovative method for simultaneous optimization of water and energy in process plants through a novel Mixed Integer Linear Programming (MILP) for problem formulation.

Methodology

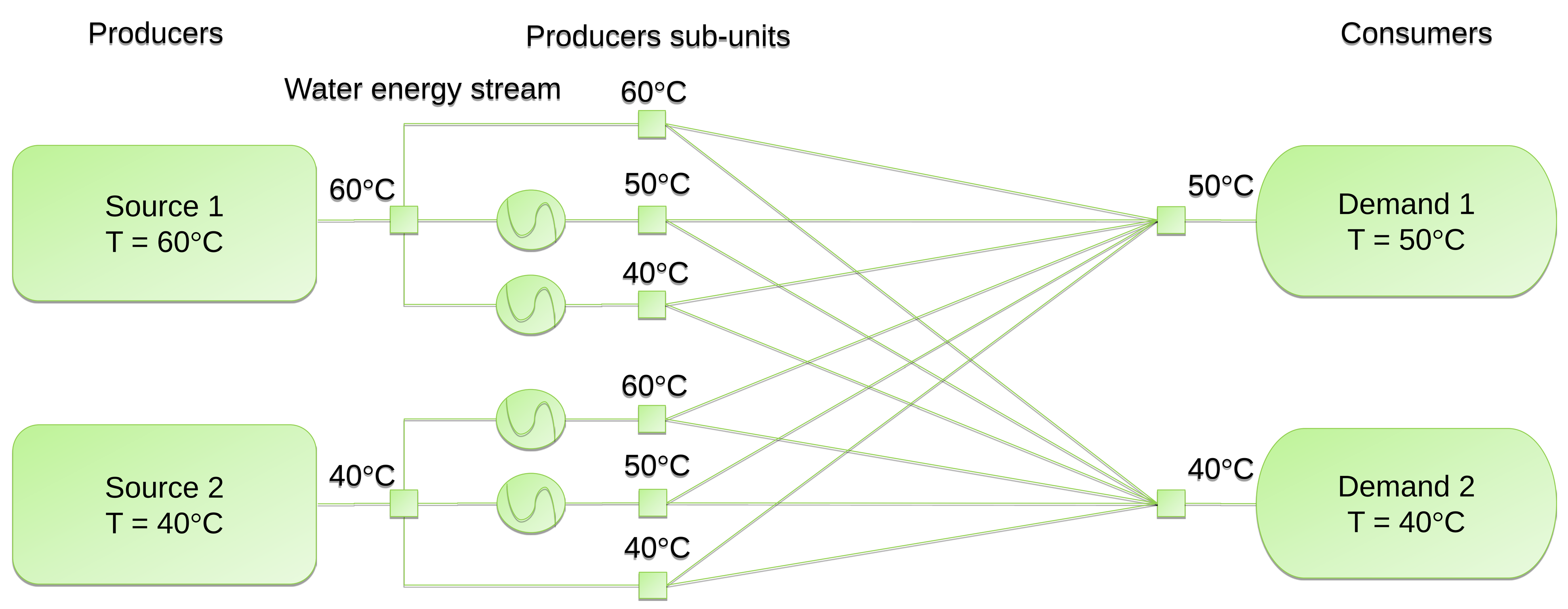

Figure 1. *Superstructure for 2 sources, 2 demands, and 3 levels of temperature (60°C, 50°C and 40°C)*

Superstructure Characteristics

- Heat cascade and source/sink model.
- All possible interconnections are considered
- Each source and demand are characterized by a temperature, a flowrate, and a contaminant temperature.
- All possible temperatures of the water streams are included through demand sub-units (temperature of all sources and demands).
- Isothermal and non-isothermal mixing reduces the number of hot and cold streams considered in the heat recovery heat exchanger network

Optimization Method

The method includes

- Heat cascade model
- Water exchange model
- Utility integration and waste management models

Features of the method

- Simultaneous optimization
- Reduced number of heat exchangers

Expanded for

- Utility system energy conversion (CHP and heat pumping)
- Multi-period problems including storage tanks
- Restricted matches

Case Study

Water Energy Stream (WES): A temperature difference is considered between the source unit and the source sub-unit of the water network.

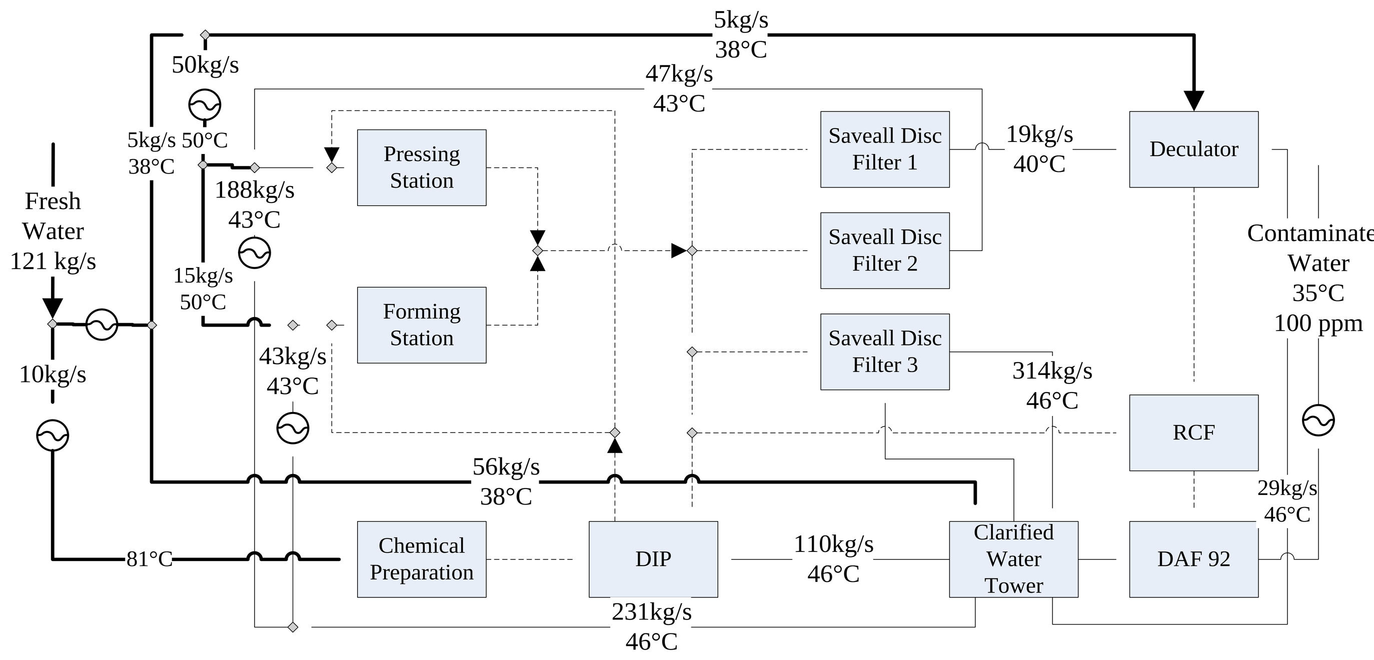

Figure 2. *Existing water distribution network (Manan et al. (2009)*

Process Energy Stream (PES): Standard process hot or cold streams are integrated as process demands

Table 1. *Process energy streams (PES)*

	Tin (°C)	Tout (°C)	ΔHk (kW)	Type
Cold streams				
Air preheating	20	120	500	Process demand
Chemicals preheating	20	60	1400	Process demand
Hot streams				
Humid air Segment 1	80	65	3740	Waste heat
Humid air Segment 2	65	52	1600	Waste heat
Humid air Segment 3	52	39	860	Waste heat
Humid air Segment 4	39	25	530	Waste heat
Steam vented	110	110	100	Waste heat

Results and Discussion

Water network heat and mass optimization

Table 2. *Performance, complexity and economic indicators*

	Scenarios	Reference case	Manan et al	Simultaneous Method
Performance	Steam (kW)	6466	5154 (-20%)	4181 (-35%)
	Cooling water (kW)	0	0	0
	Clean water (kg/s)	121	105 (-13%)	94 (-22%)
	Contaminated water (kg/s)	121	105 (-13%)	94 (-22%)
Complexity	Nb. of thermal streams (-)	6	8 (+33%)	4 (-40%)
	Nb. of heat exchangers (-)	5	7 (+40%)	3 (-40%)
	Total heat exchange area(m^2)	237	240 (1%)	140 (-41%)
Economics	Operating cost (M$/y)	1.506	1.238	1.044
	Investment cost (M$/y)	0.0757	0.0984	0.0452
	Total cost (M$/y)	1.581	1.336 (-15%)	1.090 (-31%)

Energy recovery opportunity between water network and process plant

Table 3. *Heat recovery between WES and PES*

Scenario	Water network only	Water network and process plant
Steam (kW)	4181	610 (-85%)
Cooling water (kW)	0	0
Clean water (kg/s)	94	94
Contaminated water (kg/s)	94	94
Nb. of thermal streams (-)	4	10
Nb. of heat exchangers (-)	3	12
Total heat exchange area (m^2)	140	252 (+44%)
Operating cost (M$/y)	1.044	0.515
Investment cost (M$/y)	0.0452	0.152
Total cost (M$/y)	1.090	0.667 (-39%)

Conclusion

The innovative component of the method is simultaneous integration of water and energy streams of the water network as well as process energy streams, waste heat streams and utilities. The proposed method allows a total cost reduction by 31% compared to the current operating conditions of the case study.

References

Z.A., Manan, S.Y. Tea & S. R. W. Alwi, 2009, A new technique for simultaneous water and energy minimization in process plant. ChERD, 87(11), 1509-1519.

Z.A., Manan, Y. L., Tan, D. C. Y., Foo & S.Y. Tea, 2007, Application of the water cascade analysis technique for water minimization in a paper mill plant. IJEP, 29(1), 90–103.

Further Information

More information regarding this project is available following this QR code or by email to francois.marechal@epfl.ch

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