ASTRA: From Expert-Driven to Automated Industrial Heat Pump Design and Integration

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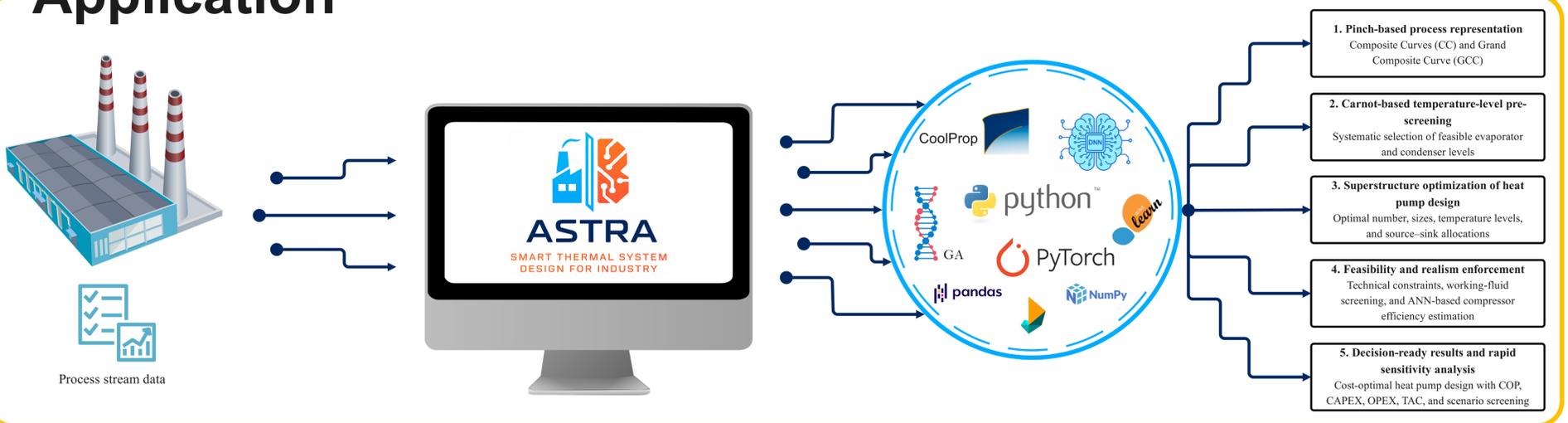
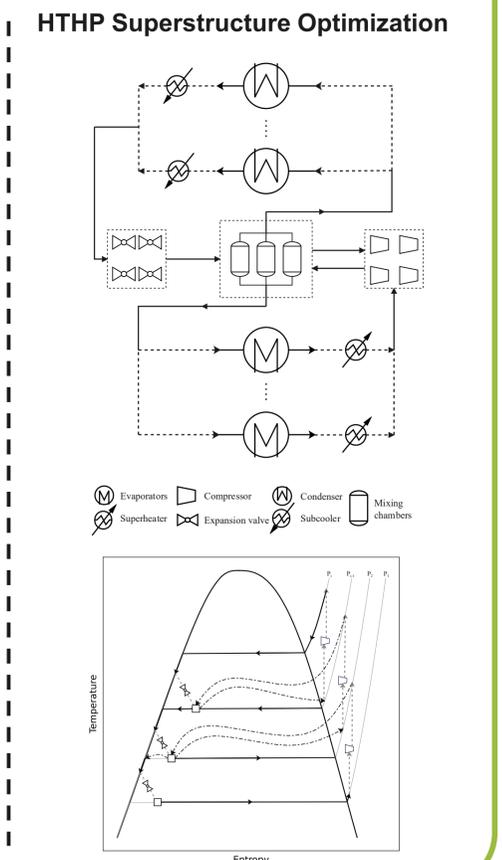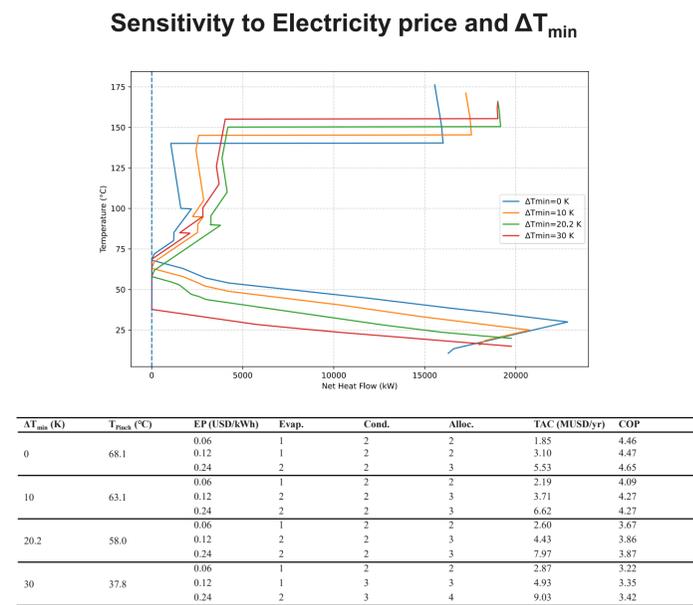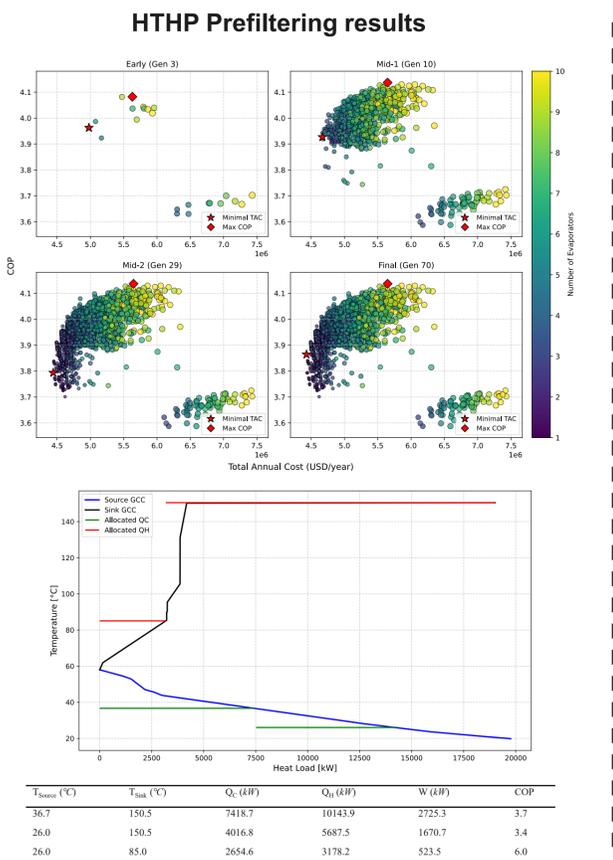✉ Mostafa.Babaei@unige.ch   ✉ Martin.Patel@unige.ch

Motivation

- Industrial heat pump integration relies heavily on expert-driven heuristics, with limited automation or systematic screening.
- Temperature-level selection and system sizing strongly influence performance and cost yet are often fixed early without quantitative justification.
- The number of possible source–sink combinations and configurations quickly exceeds what can be explored manually.
- As a result, promising integration options may be overlooked, while suboptimal designs remain unchallenged.
- Scalable and transparent decision-support tools are therefore essential for large-scale industrial decarbonization.

ASTRA addresses these challenges by automating early-stage heat pump design decisions using thermodynamically consistent and data-driven methods.

Application

Process stream data

ASTRA — SMART THERMAL SYSTEM DESIGN FOR INDUSTRY

CoolProp · python · GA · PyTorch · pandas · NumPy

1. **Pinch-based process representation**
Composite Curves (CC) and Grand Composite Curve (GCC)

2. **Carnot-based temperature-level pre-screening**
Systematic selection of feasible evaporator and condenser levels

3. **Superstructure optimization of heat pump design**
Optimal number, sizes, temperature levels, and source–sink allocations

4. **Feasibility and realism enforcement**
Technical constraints, working-fluid screening, and ANN-based compressor efficiency estimation

5. **Decision-ready results and rapid sensitivity analysis**
Cost-optimal heat pump design with COP, CAPEX, OPEX, TAC, and scenario screening

Preliminary Results

HTHP Prefiltering results

T_{Source} (°C)	T_{Sink} (°C)	Q_c (kW)	Q_h (kW)	W (kW)	COP
36.7	150.5	7418.7	10143.9	2725.3	3.7
26.0	150.5	4016.8	5687.5	1670.7	3.4
26.0	85.0	2654.6	3178.2	523.5	6.0

Sensitivity to Electricity price and ΔT$_{min}$

ΔTmin=0 K
ΔTmin=10 K
ΔTmin=20.2 K
ΔTmin=30 K

ΔT$_{min}$ (K)	T_{Pinch} (°C)	E.P (USD/kWh)	Evap.	Cond.	Alloc.	TAC (MUSD/yr)	COP
0	68.1	0.06	1	2	2	1.85	4.46
		0.12	1	2	2	3.10	4.47
		0.24	2	2	3	5.53	4.65
10	63.1	0.06	1	2	2	2.19	4.09
		0.12	2	2	3	3.71	4.27
		0.24	2	2	3	6.62	4.27
20.2	58.0	0.06	1	2	2	2.60	3.67
		0.12	2	2	3	4.43	3.86
		0.24	2	2	3	7.97	3.87
30	37.8	0.06	1	2	2	2.87	3.22
		0.12	1	3	3	4.93	3.35
		0.24	2	3	4	9.03	3.42

For more information About this project
Scan this QR Code!
PODCAST

HTHP Superstructure Optimization

Ⓜ Evaporators   ⬜ Compressor   Ⓦ Condenser   ⬜ Mixing chambers
⬒ Superheater   ⧖ Expansion valve   ⬒ Subcooler