Using the Open Source SorpSim for Simulation of Sorption Water Heating Applications

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Content

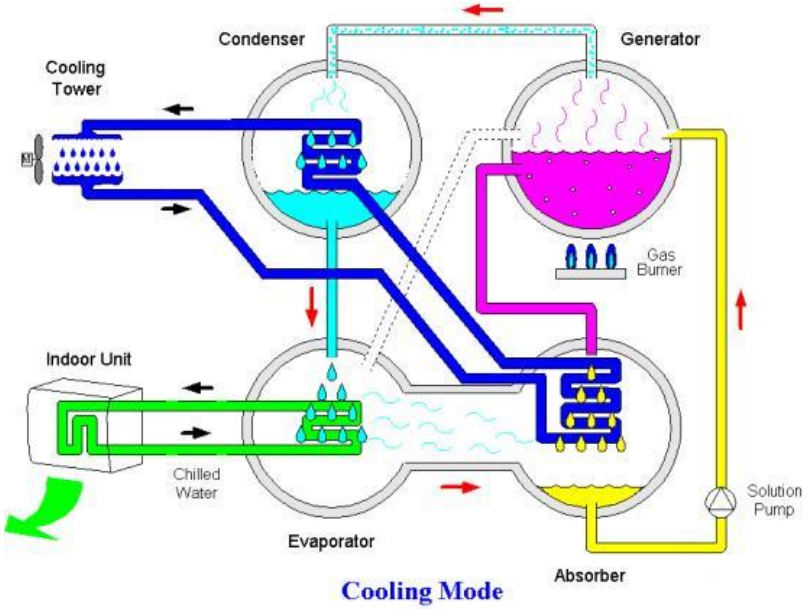
- **Background**
- **Introduction to SorpSim**
- **Example in Hot Water Applications**
- **Conclusion**

Background

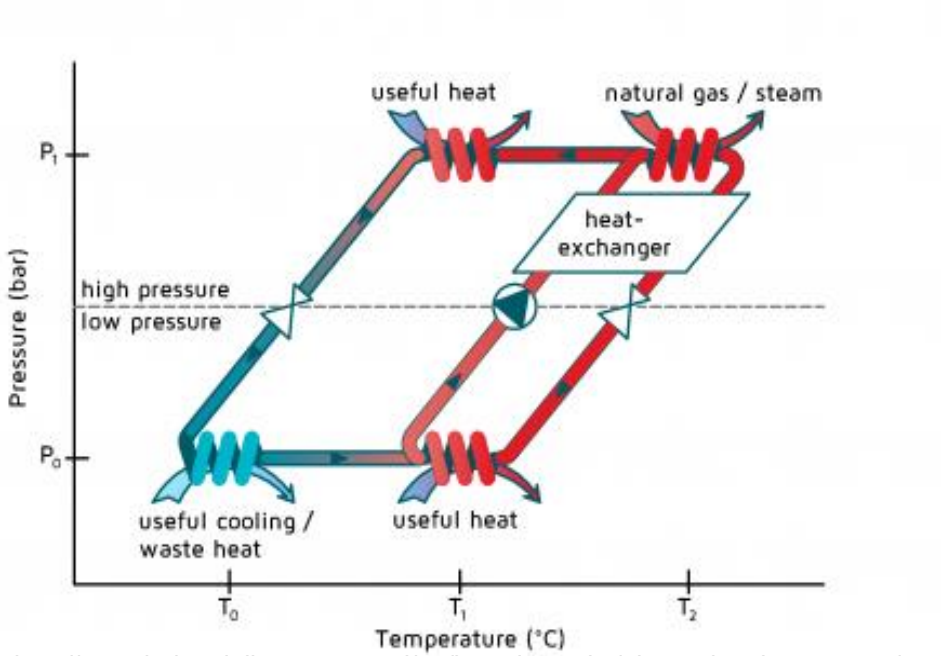
- Sorption systems
  - Heat driven systems using affinity of liquid solution (absorption) or solid material (adsorption) to refrigerants to generate heat pumping effect.
  - Advantage in heating applications:
    - Heat driven, low electricity consumption;
    - Wide source temperature range: waste heat, solar heat, steam, natural gas burner;
    - Higher efficiency than electric resistance;
    - Zero GWP working fluid;
    - No moving parts except pumps: low noise/vibration.

Background

- Absorption water heating systems
  - Various configurations for heat sources at different temperatures.
  - Simulation of complex cycles remains a challenging task.



http://www.eurocooling.com/public_html/articleseagroup.htm

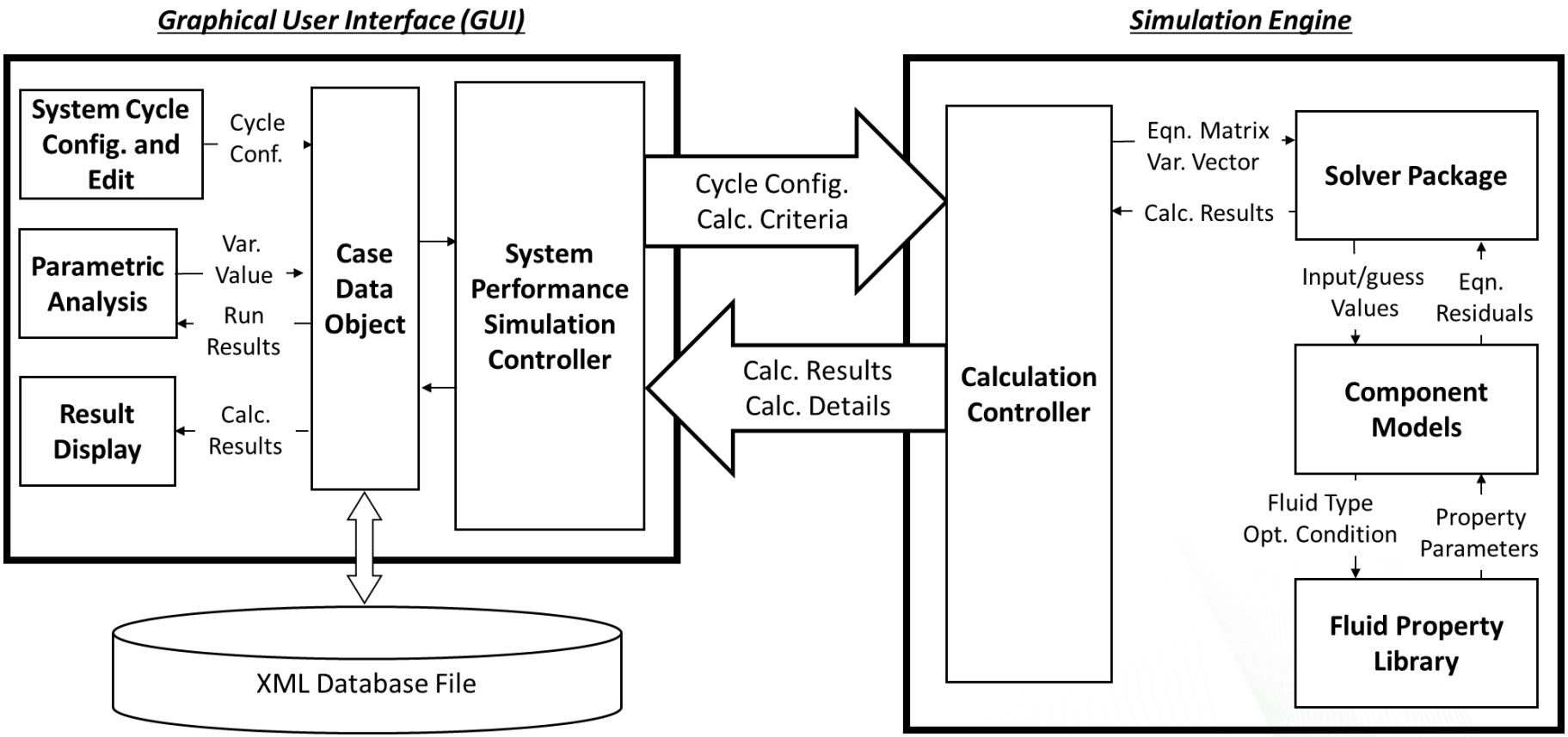


http://www.industrialheatpumps.nl/en/how_it_works/absorption_heat_pump/

SorpSim: Origin

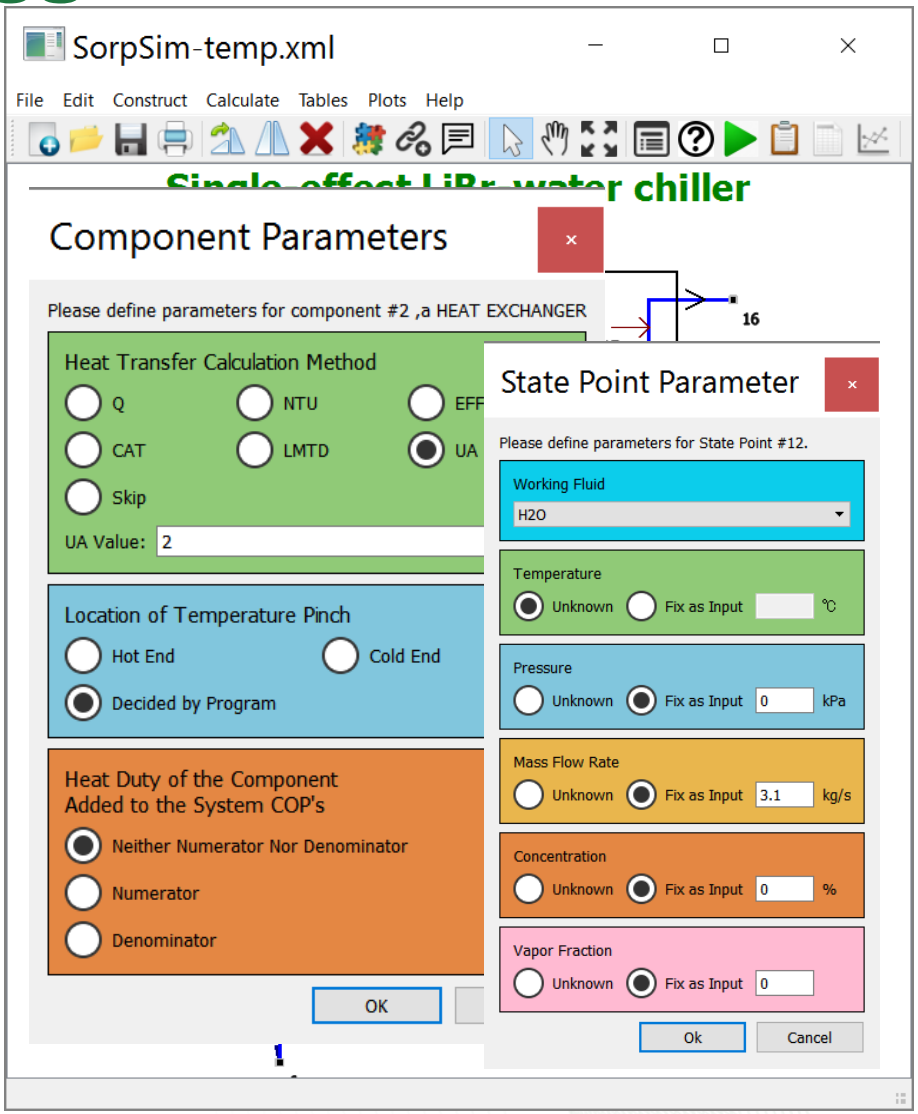
- The Sorption system Simulation program (SorpSim) was developed based on the well-recognized ABsorption SIMulation code (ABSIMW Version 5.0).
- SorpSim combines the built-in component models, fluid properties, and solver subroutines of the legendary code with a versatile graphical interface with enhanced features and functions.
- SorpSim provides a reliable and user-friendly simulation platform that is open-source and compatible across several computer platforms.

SorpSim: Structure



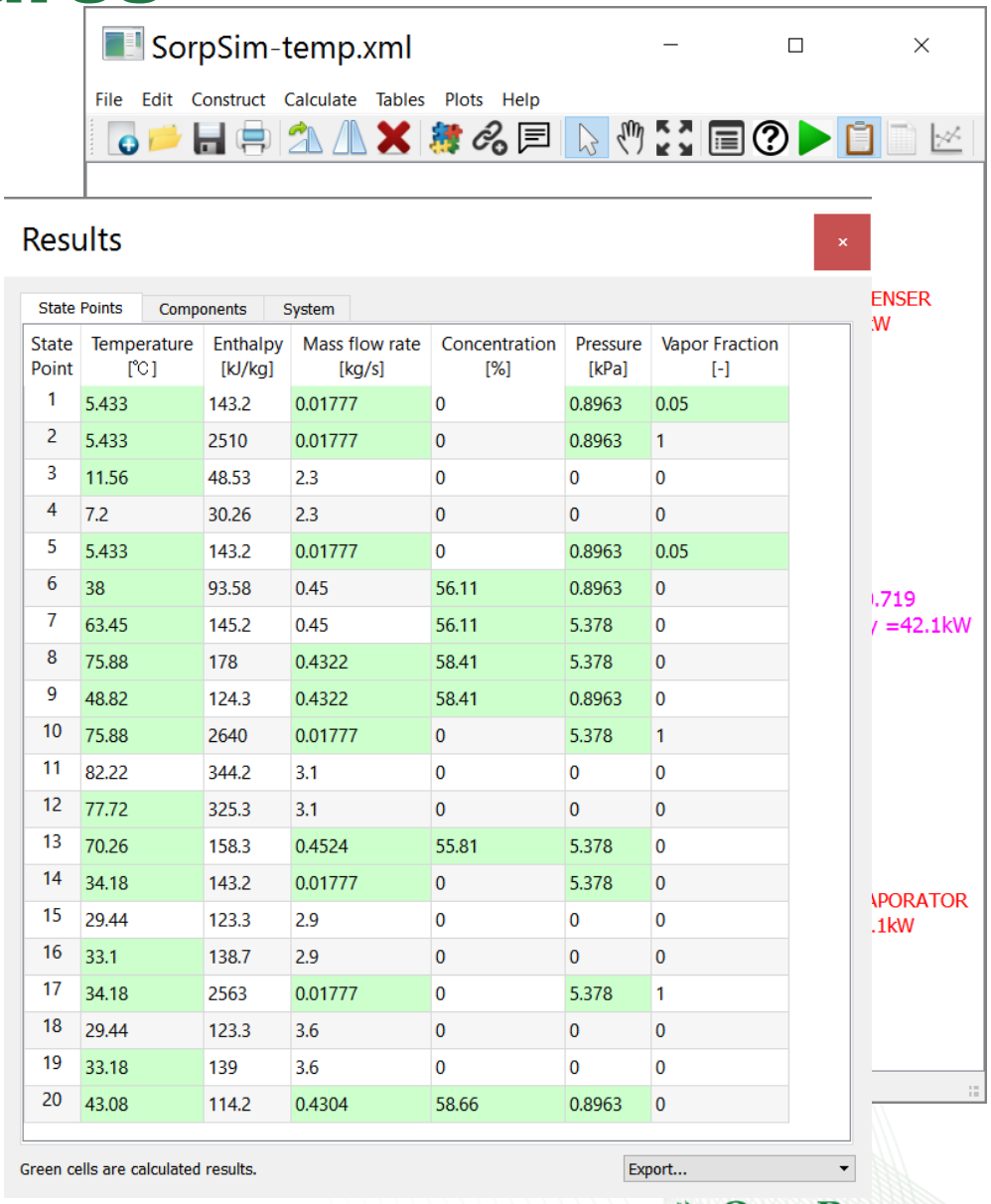
SorpSim: Key Features

- Cycle configuration/edit



SorpSim: Key Features

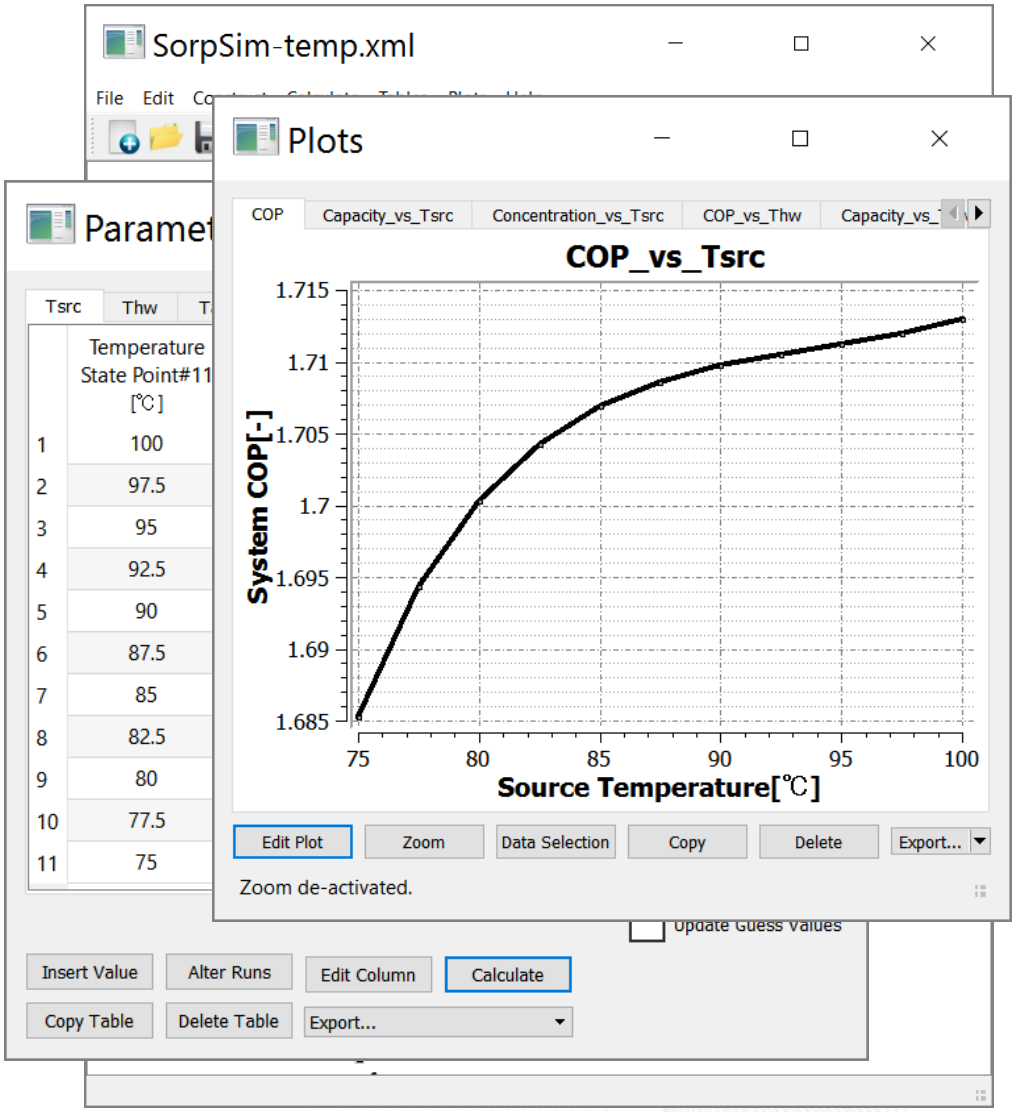
- Cycle configuration/edit
- Result display



State Point	Temperature [℃]	Enthalpy [kJ/kg]	Mass flow rate [kg/s]	Concentration [%]	Pressure [kPa]	Vapor Fraction [-]
1	5.433	143.2	0.01777	0	0.8963	0.05
2	5.433	2510	0.01777	0	0.8963	1
3	11.56	48.53	2.3	0	0	0
4	7.2	30.26	2.3	0	0	0
5	5.433	143.2	0.01777	0	0.8963	0.05
6	38	93.58	0.45	56.11	0.8963	0
7	63.45	145.2	0.45	56.11	5.378	0
8	75.88	178	0.4322	58.41	5.378	0
9	48.82	124.3	0.4322	58.41	0.8963	0
10	75.88	2640	0.01777	0	5.378	1
11	82.22	344.2	3.1	0	0	0
12	77.72	325.3	3.1	0	0	0
13	70.26	158.3	0.4524	55.81	5.378	0
14	34.18	143.2	0.01777	0	5.378	0
15	29.44	123.3	2.9	0	0	0
16	33.1	138.7	2.9	0	0	0
17	34.18	2563	0.01777	0	5.378	1
18	29.44	123.3	3.6	0	0	0
19	33.18	139	3.6	0	0	0
20	43.08	114.2	0.4304	58.66	0.8963	0

SorpSim: Key Features

- Cycle configuration/edit
- Result display
- Parametric table/plot



SorpSim: Available Components

- Components models
  - Built-in governing equations
  - 12 standard components for absorption systems
  - 7 types of liquid desiccant system components

Index	Component
1	Absorber
2	Desorber
3	Heat Exchanger
4	Condenser
5	Evaporator
6	Valve
7	Mixer
8	Splitter
9	Rectifier
10	Analyser
11	Compressor
12	Pump
13-19	Liquid Desiccant Components

SorpSim: Available Working Fluids

- Fluid property library
  - Built-in property correlations for VLE, enthalpy, density, etc.
  - 11 commonly used fluids for absorption systems

Index	Fluid
1	$LiBr/H_2O$
2	H2O/NH3
3	H2O
4	LiBr/H2O/NH3
5	LiBr/ZnBr2/CH3OH
6	CH3OH
7	LiNO3/KNO3/NaNO3/H2O
8	NaOH/H2O
9	LiCl/H2O
10	Moist Air
11	Flue Gas

SorpSim: Future Expansion

- SorpSim can be used in many application beyond water heating
- Modular structure of program enable convenient expansion of libraries
  - Liquid Desiccant
  - Adsorption
  - More working pair properties
- Open-source guarantees free access and facilitates continuous improvement and development by the sorption research community
  - www.github.com/oabdelaziz/sorpsim

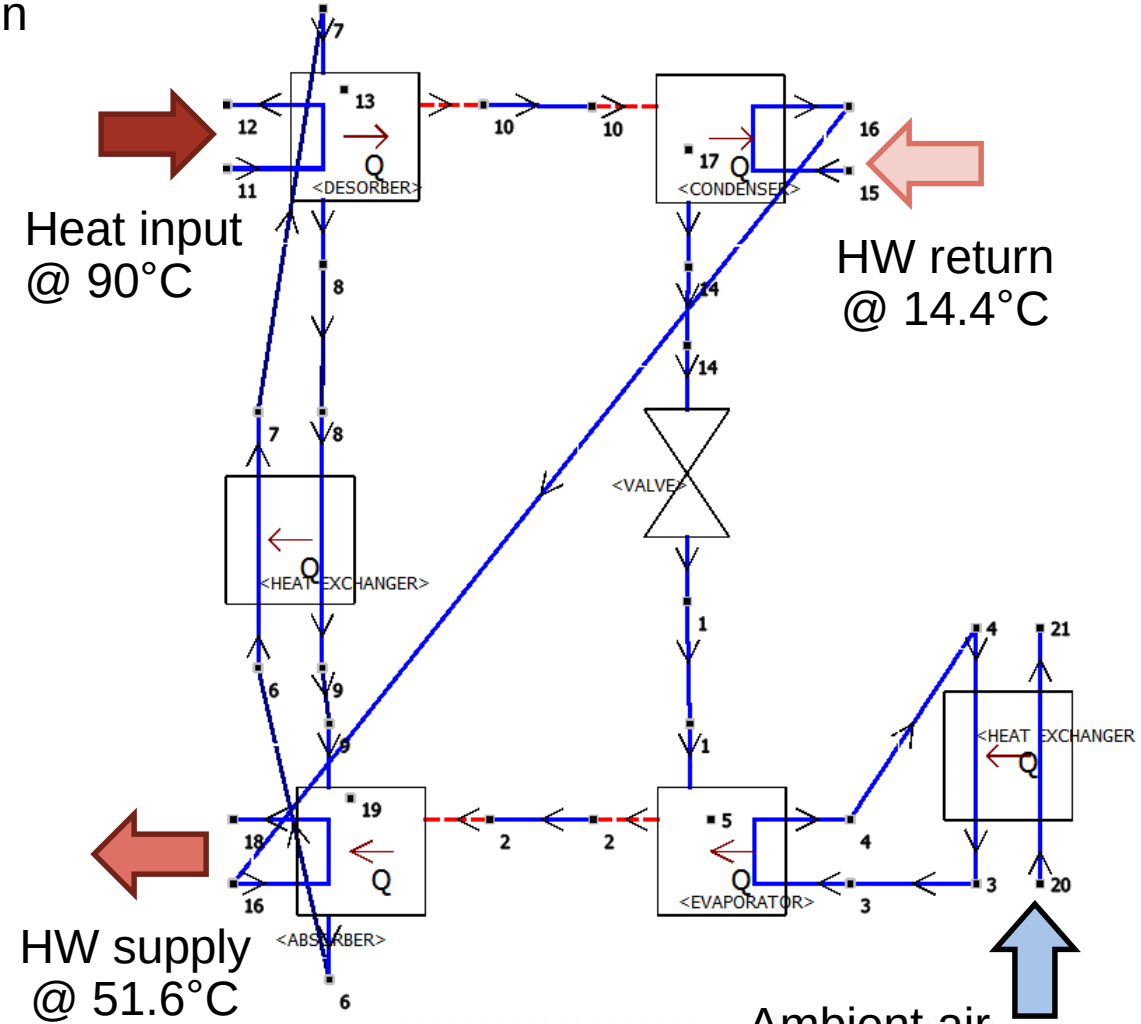
Examples in Hot Water Applications

- Target systems: various absorption cycles using LiBr/H_2O as working fluid
- Operating Conditions
  - DOE energy conservation standard rating condition for consumer water heaters:
    - Hot water supply: 125°F/51.6°C (tank outlet)
    - Hot water return: 58°F/14.4°C
    - Ambient: 67.5°F/19.6°C & 50% rh
- Parametric Analysis
  - T_{amb}, T_{src}, T_{hw}
  - COP, Capacity

Configurations: SEHP

Single-Effect LiBr/H_2O Absorption Heat Pump Water Heater

Component	UA value [kW/°C]
Absorber	6
Desorber	9
Evaporator	12
Condenser	18
Internal HEX	2
Air HEX	5



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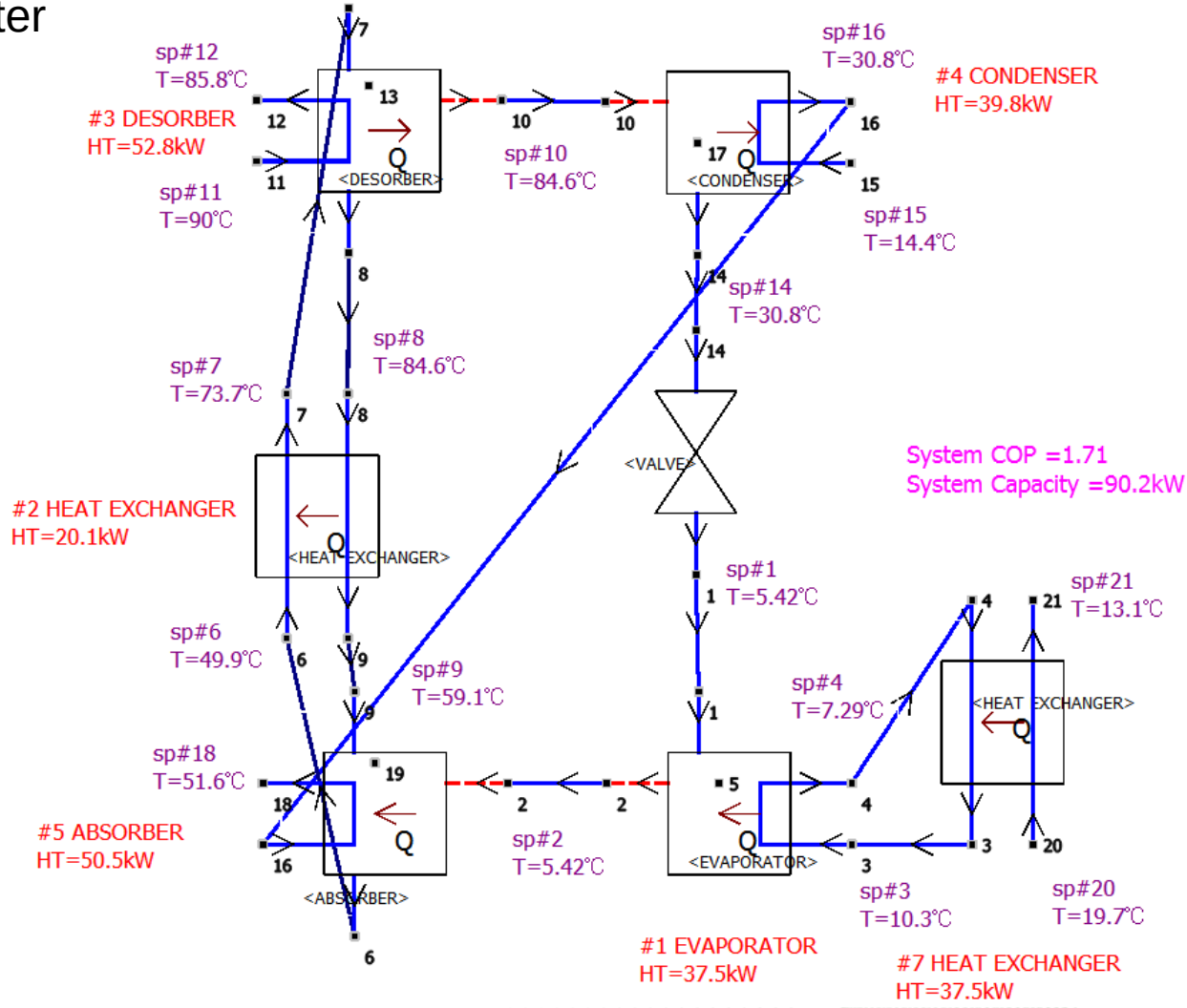
Configurations: SEHP

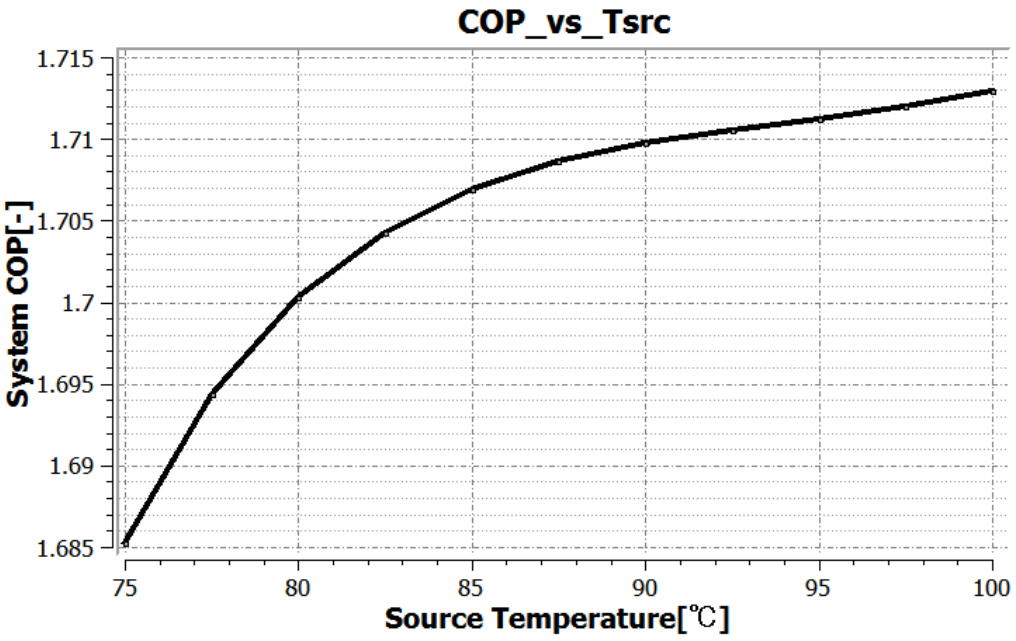
Single-Effect LiBr/H_2O Absorption Heat Pump Water Heater

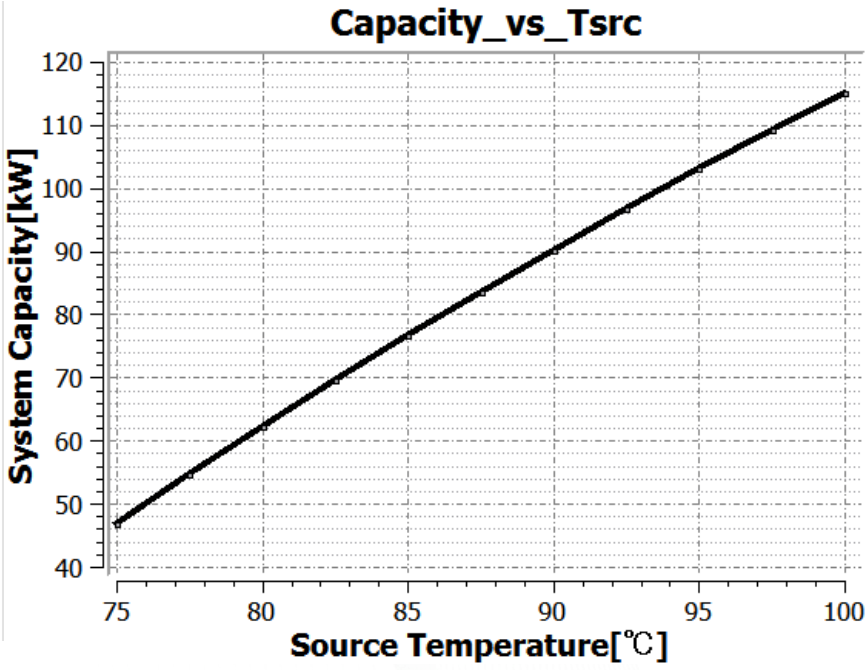
- Baseline results:
  - Capacity: 90.2 kW
  - COP: 1.71
  - Solution: 62.2%/64.4%



Configurations: SEHP

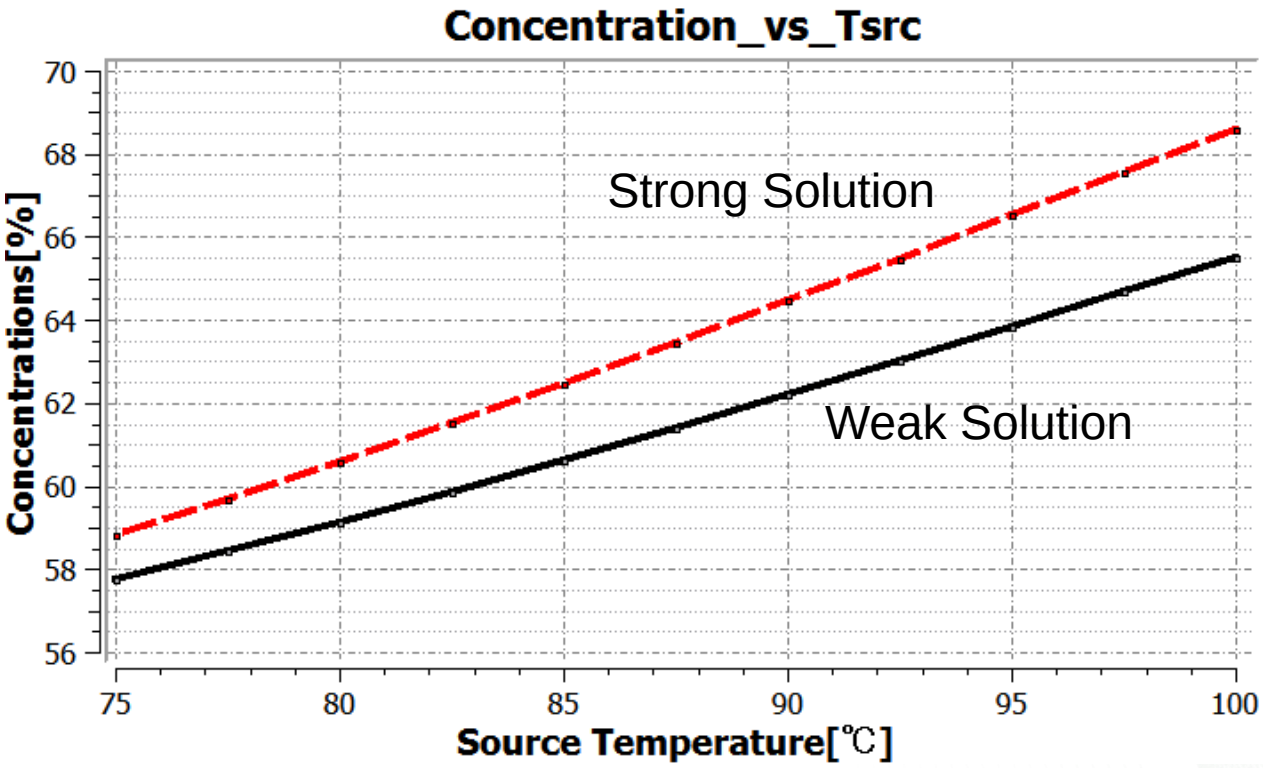
- Parametric Analysis: Source Temperature





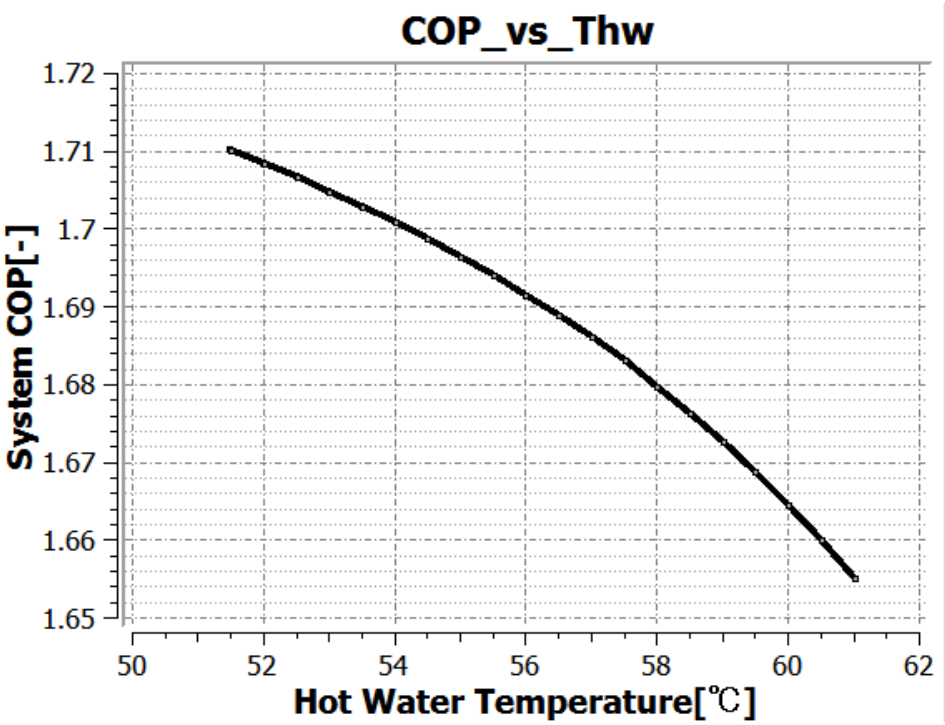
Configurations: SEHP

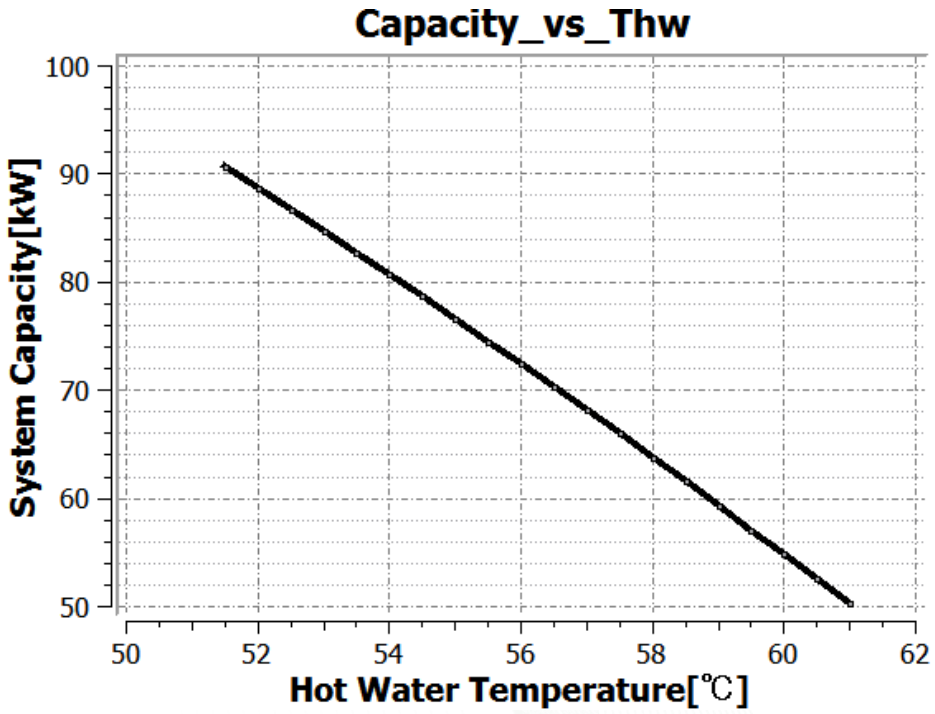
- Parametric Analysis: Source Temperature



Configurations: SEHP

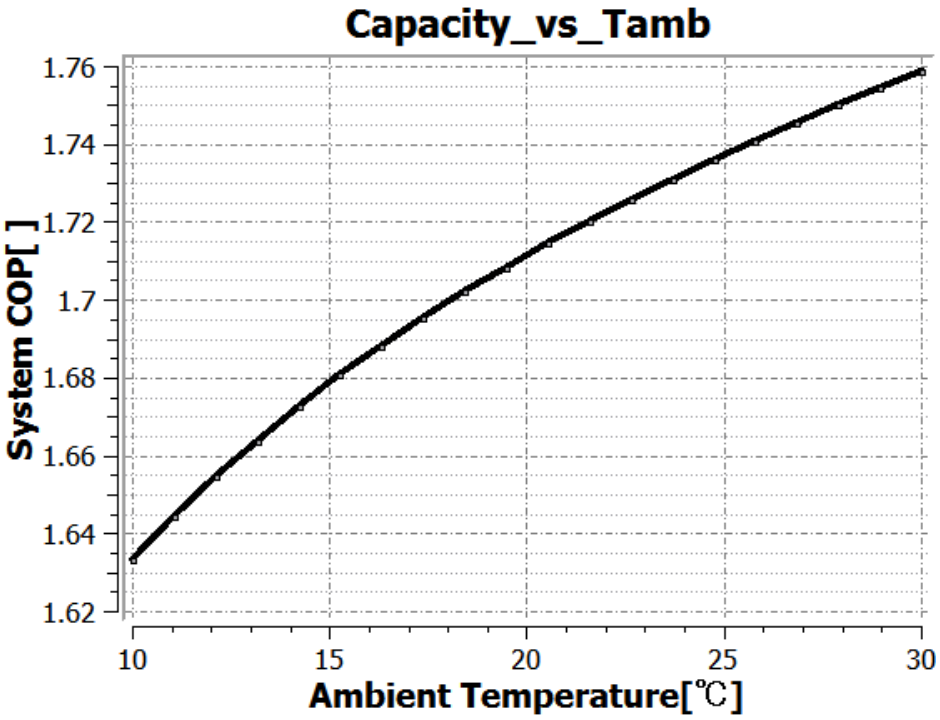
- Parametric Analysis: Hot Water Supply Temperature

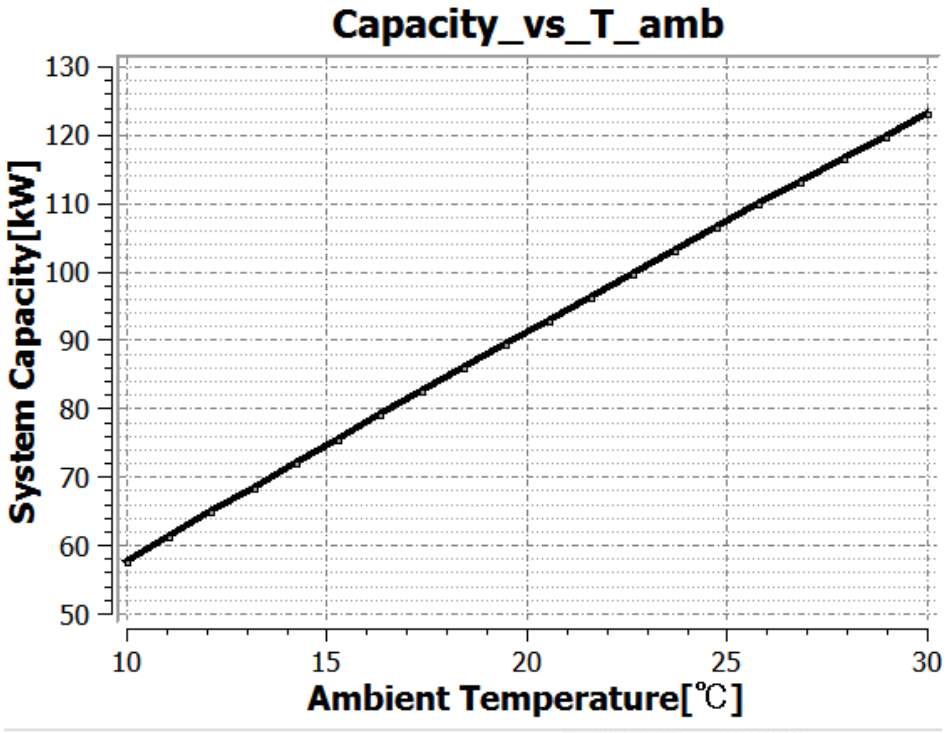




Configurations: SEHP

- Parametric Analysis: Ambient Temperature

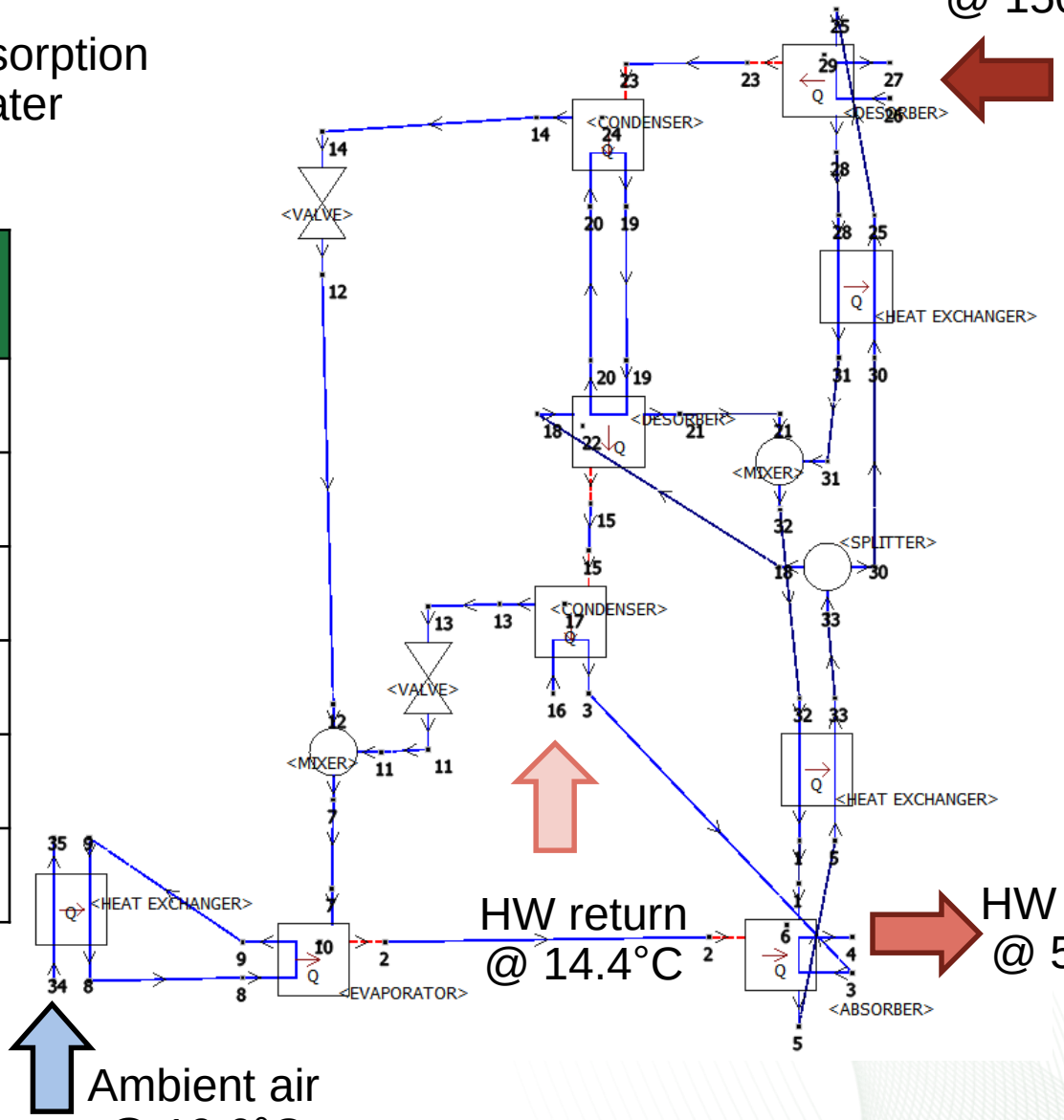




Configurations: DEHP

Double-Effect LiBr/H_2O Absorption
Heat Pump Water Heater

Component	UA value [kW/°C]
Absorber	6
Desorber	9
Evaporator	12
Condenser	18
Internal HEX	2
Air HEX	5



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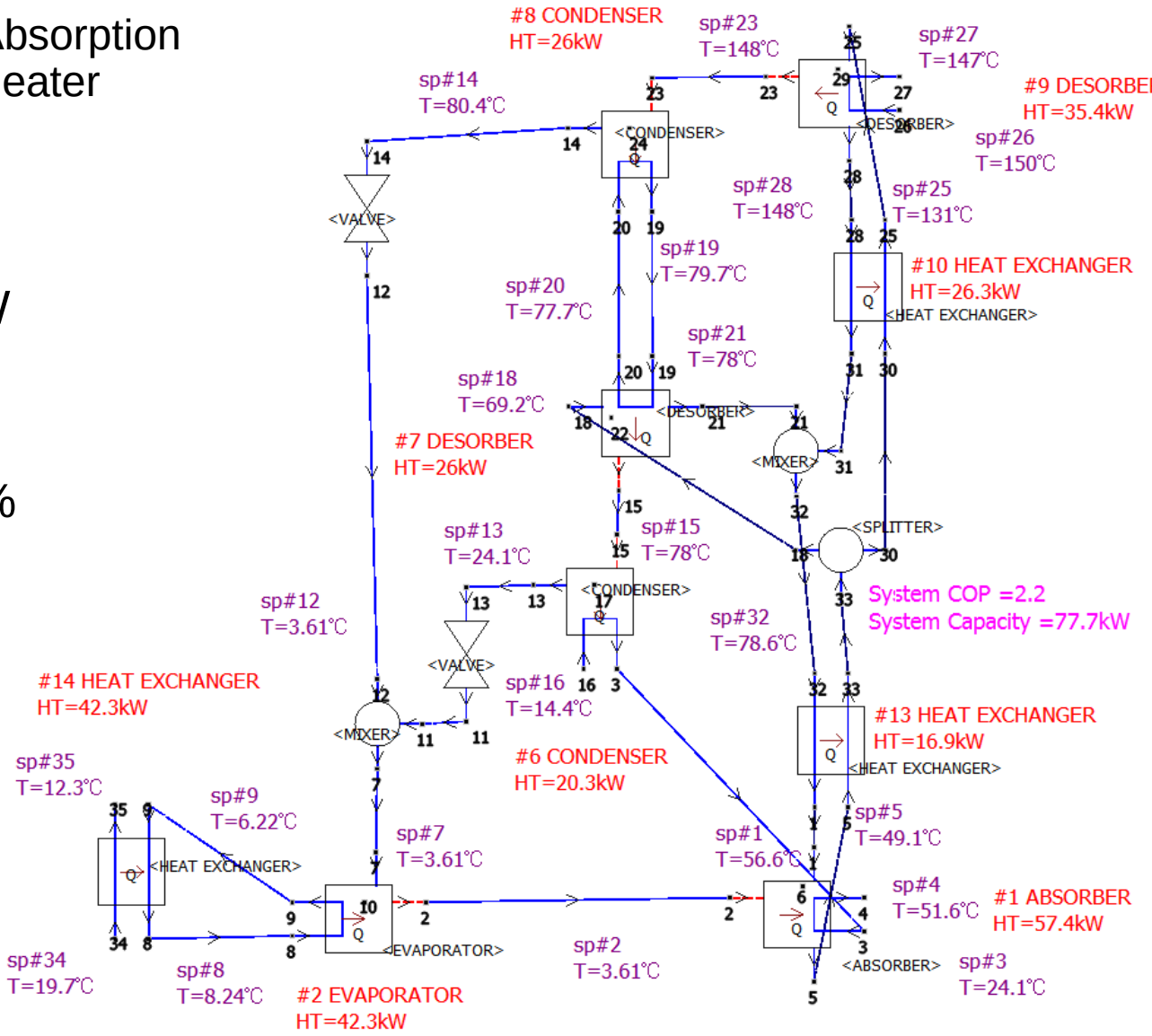
Configurations: DEHP

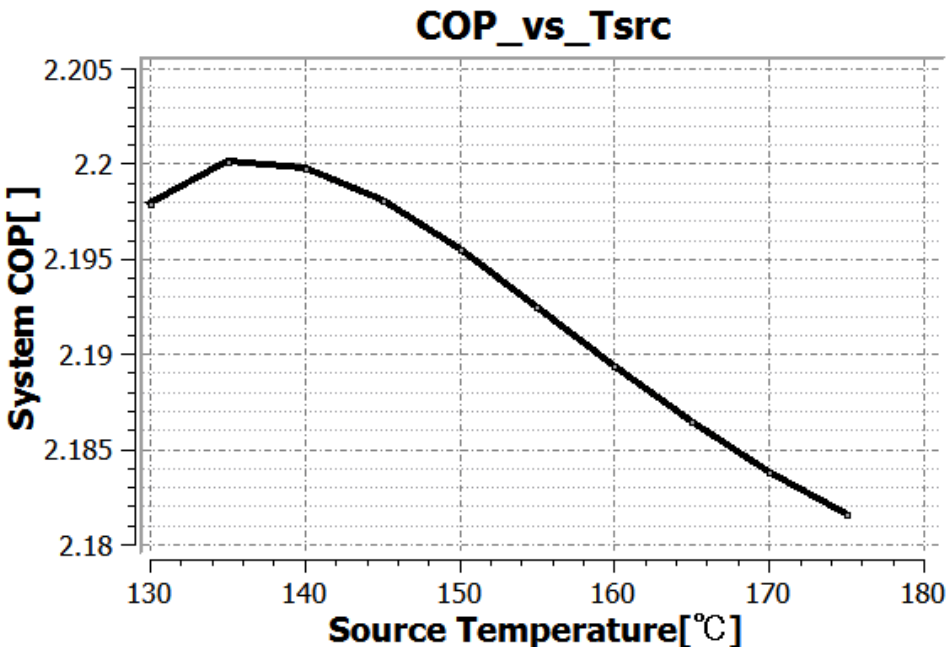
Double-Effect LiBr/H_2O Absorption Heat Pump Water Heater

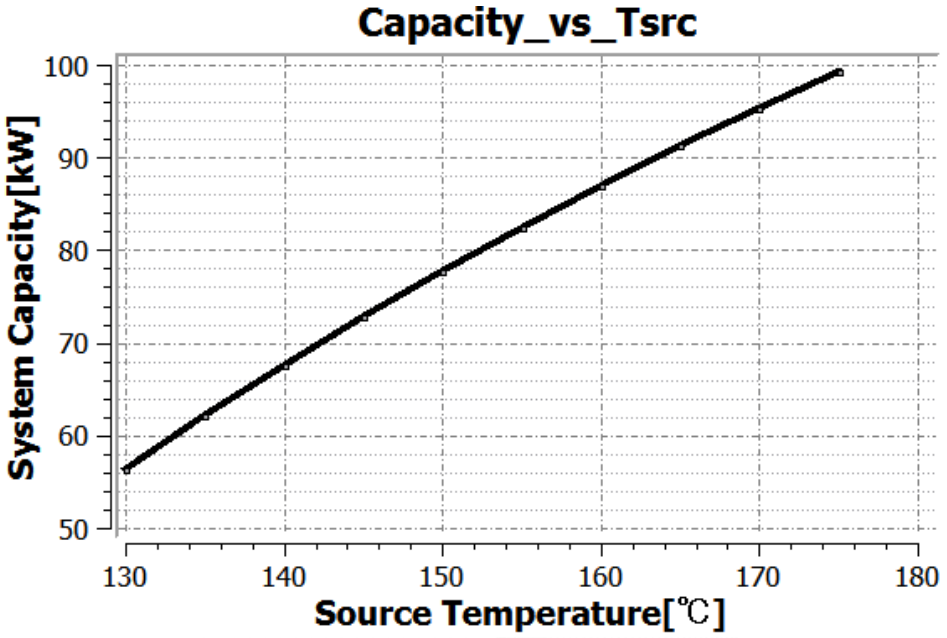
- Baseline results:
  - Capacity: 77.7 kW
  - COP: 2.2
  - Solution: 62.9%/65.2%/66%



Configurations: DEHP

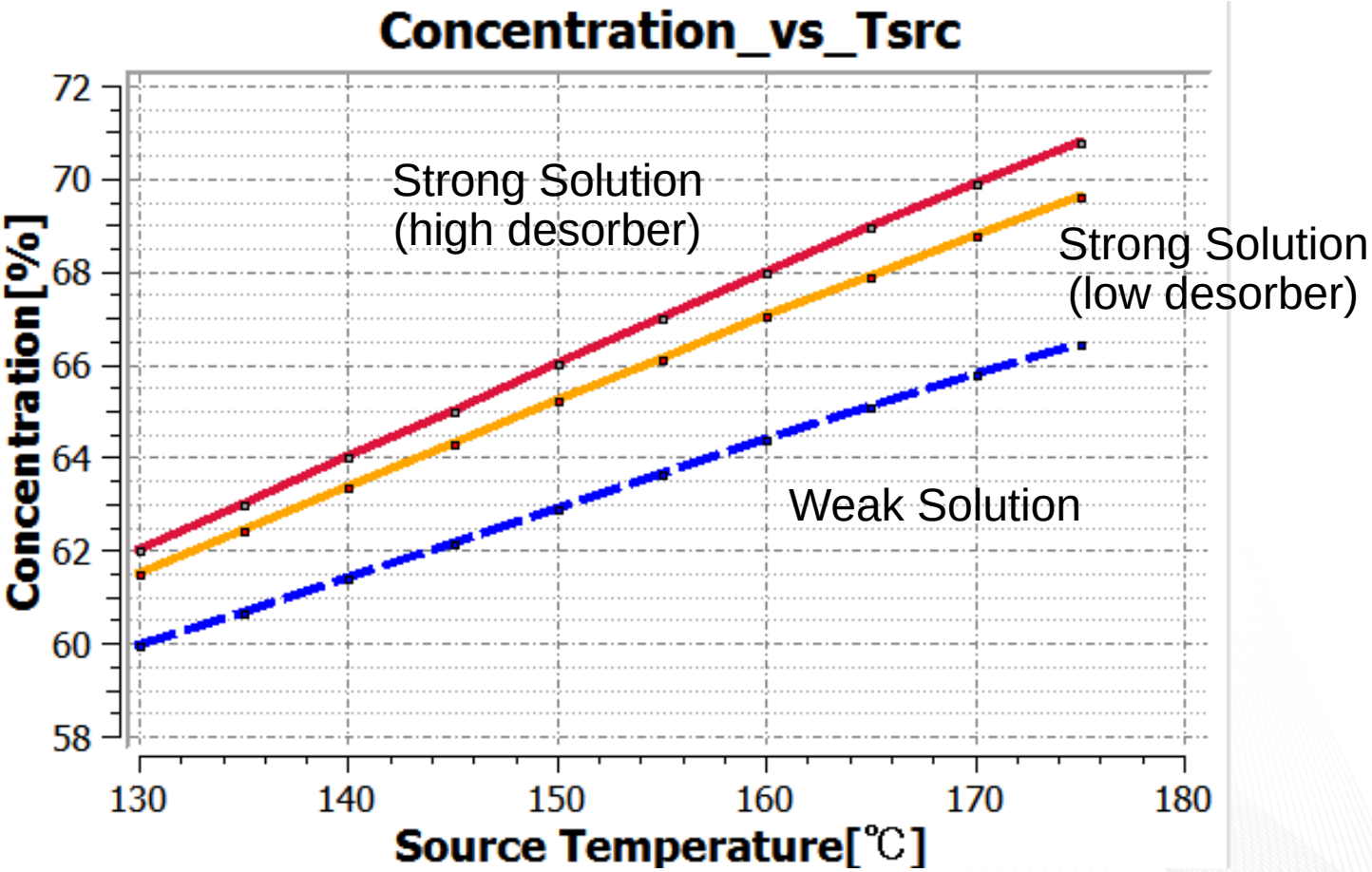
- Parametric Analysis: Source Temperature





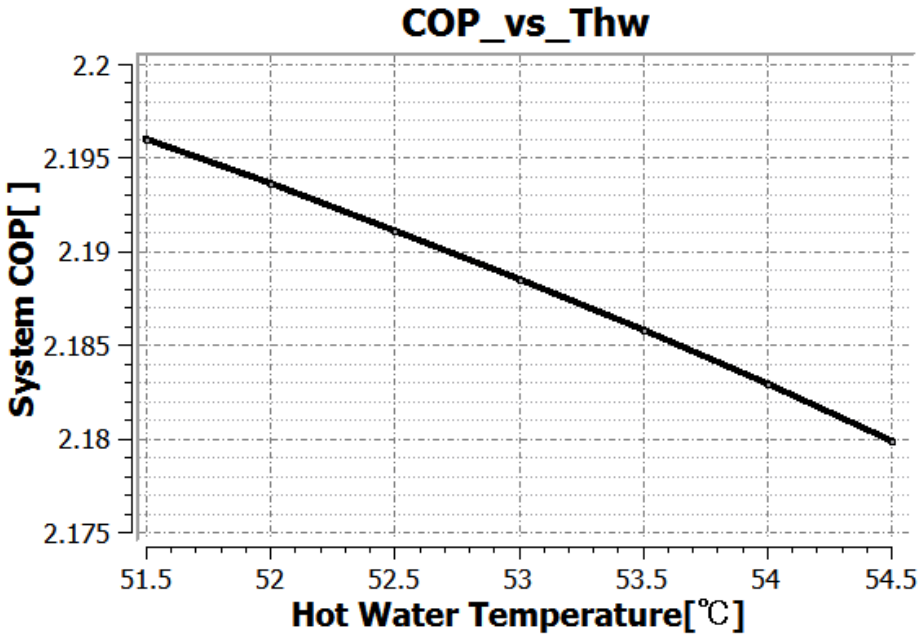
Configurations: DEHP

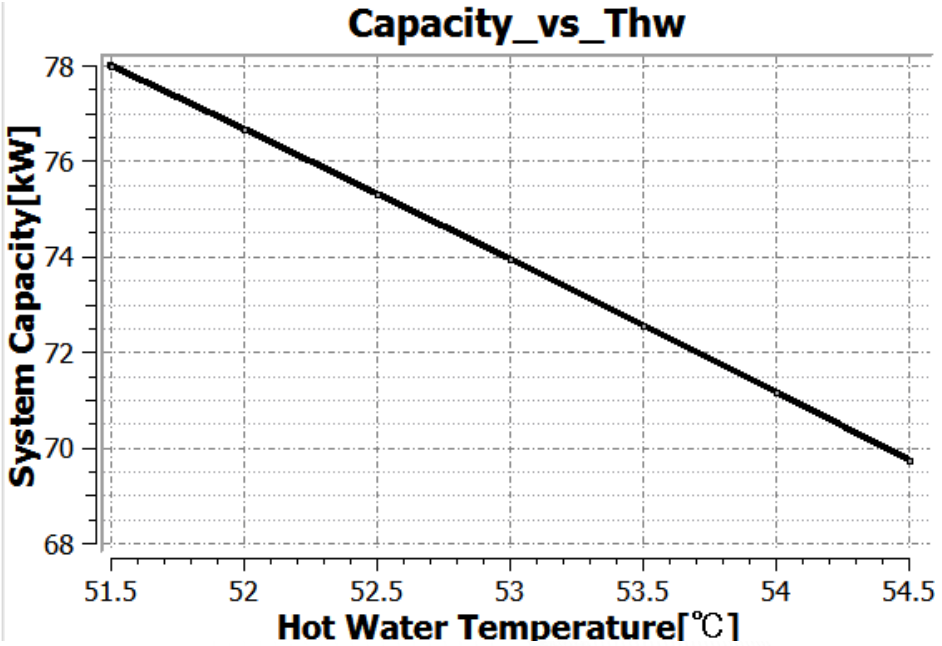
- Parametric Analysis: Source Temperature



Configurations: DEHP

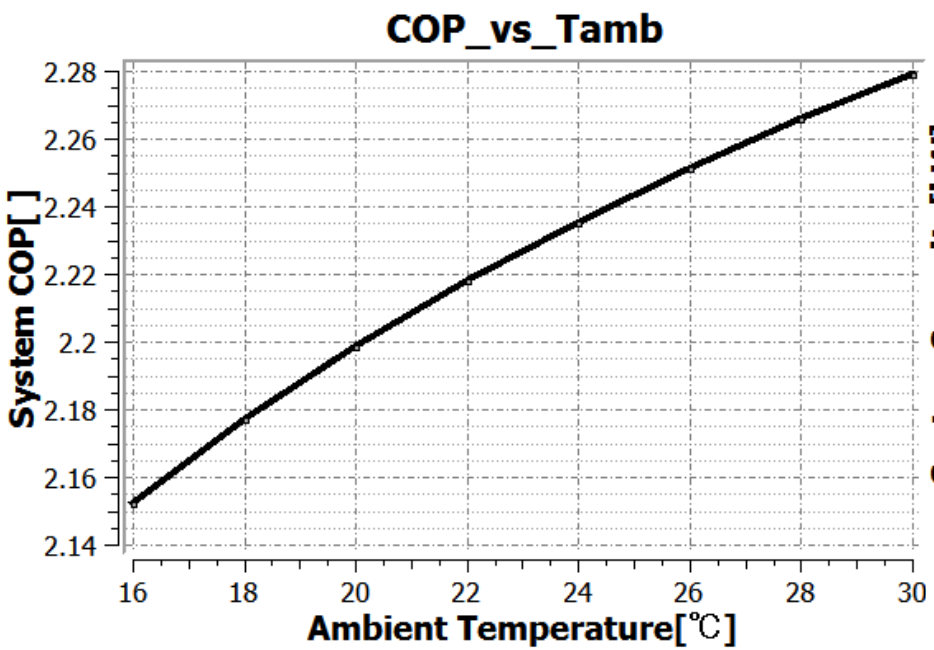
- Parametric Analysis: Hot Water Supply Temperature

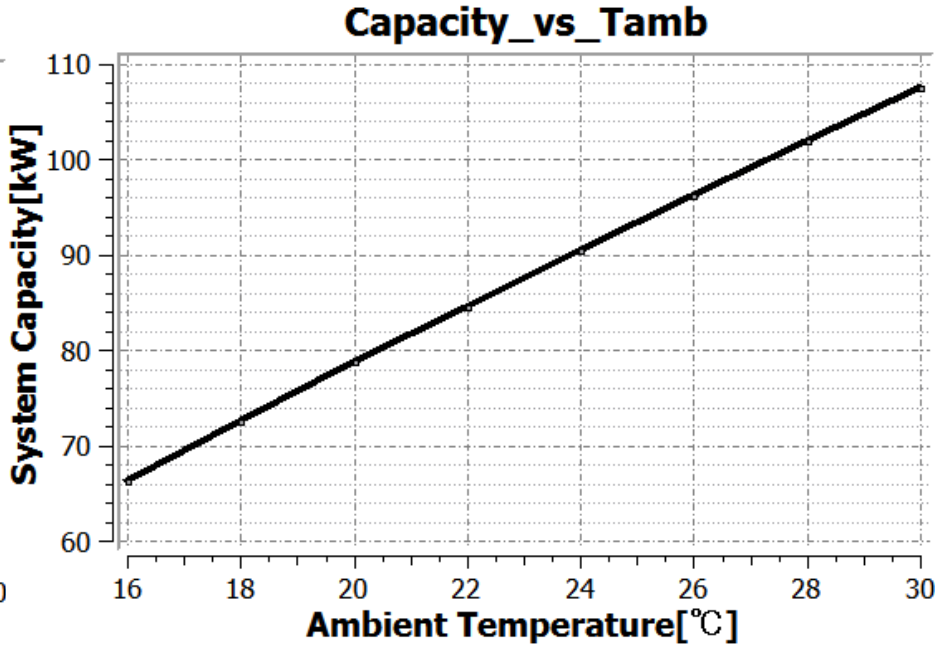




Configurations: DEHP

- Parametric Analysis: Ambient Temperature

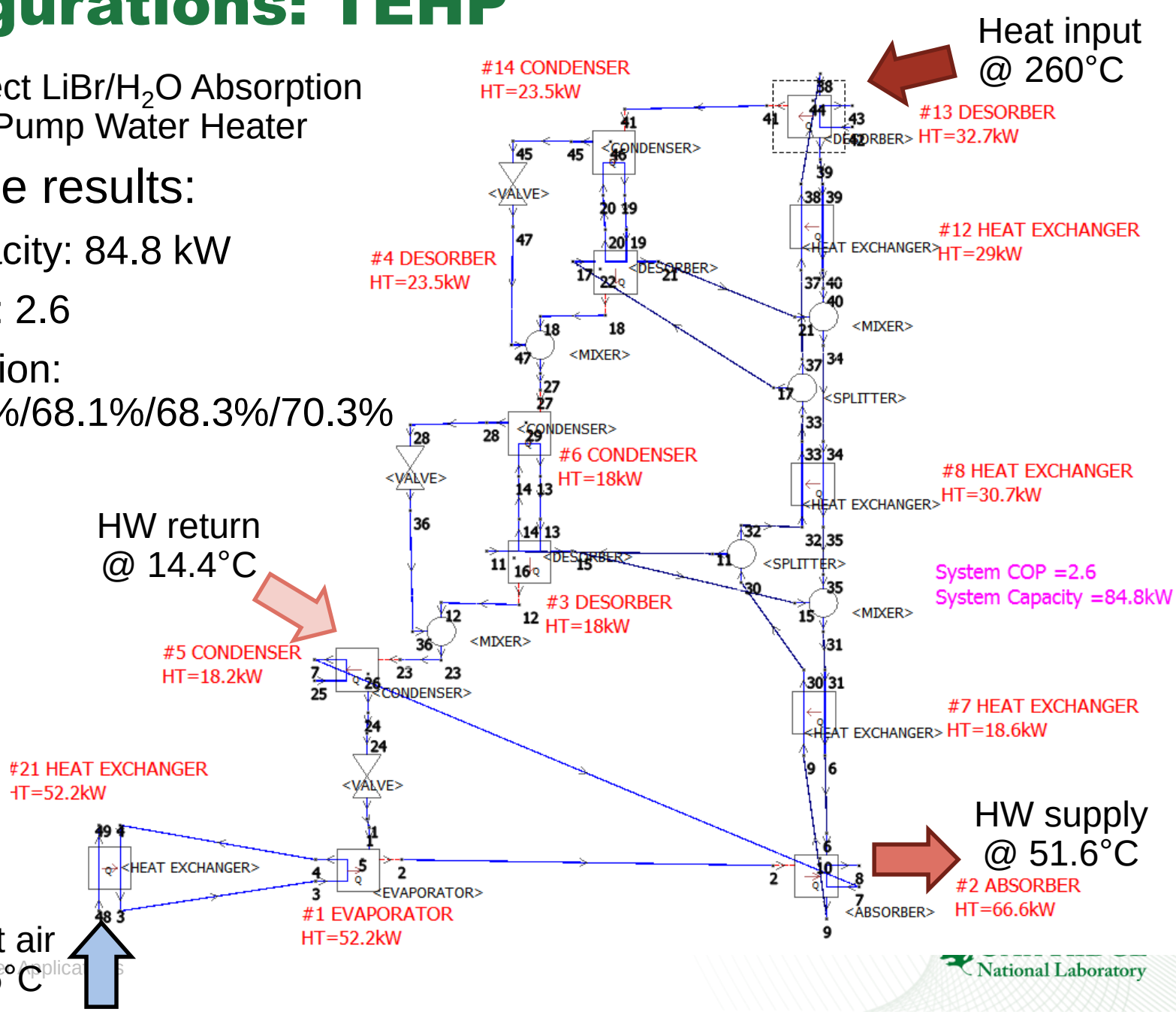




Configurations: TEHP

Triple-Effect LiBr/H_2O Absorption Heat Pump Water Heater

- Baseline results:
  - Capacity: 84.8 kW
  - COP: 2.6
  - Solution: 65.6%/68.1%/68.3%/70.3%



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Conclusion

- Sorption technologies hold unique advantages in water heating applications.
- The open-source SorpSim program provides a reliable and convenient platform to facilitate research and development of absorption systems for HW applications.
- SorpSim has been continuously updated, and it will include more ready-to-use template cases, new working pairs, and simulation capability for adsorption systems.
- Examples of absorption water heating cycles in SorpSim demonstrated its capability to conveniently simulate and analyze complex sorption system under various operating conditions.

Acknowledgement

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Questions?

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