Absorption:
Research Challenges, Needs, Opportunities, Outlook

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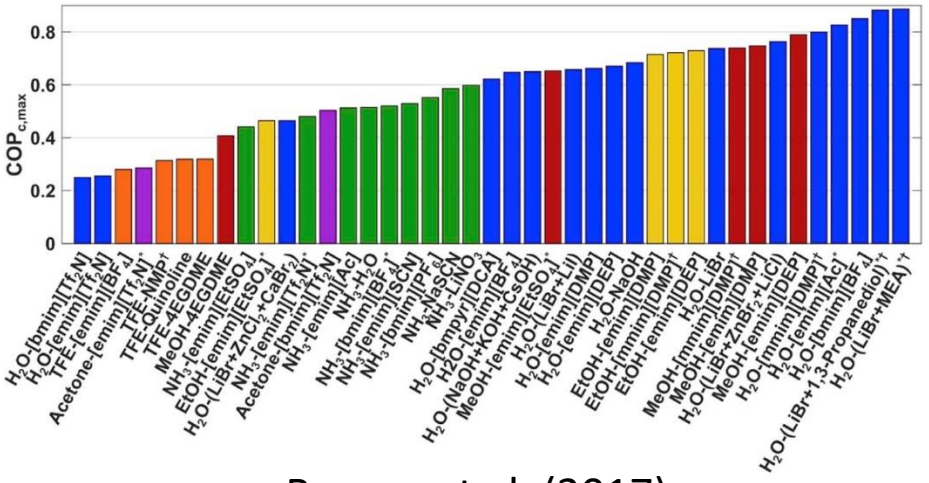
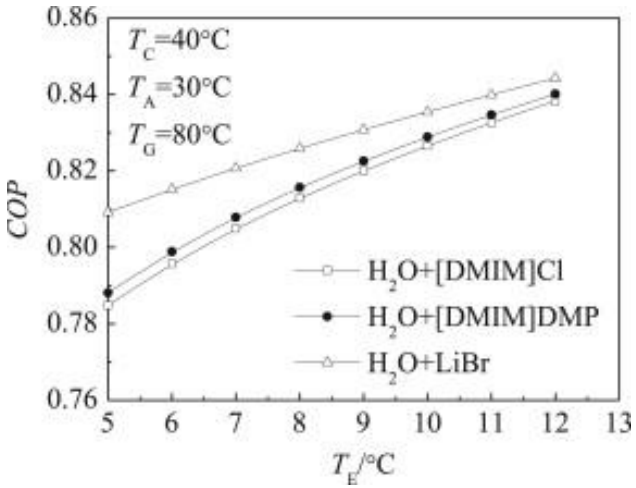
1. Working Pairs

- Conventional working pairs
  - Material compatibility issues
  - Often require rectification
- Working pairs often not suitable for high-temperature heat pumping/transformation
- Novel working fluids like some ionic liquids have very low vapor pressures across wide range of temperatures but
  - Exhibit volatility and stability issues
  - Have poor thermal transport properties



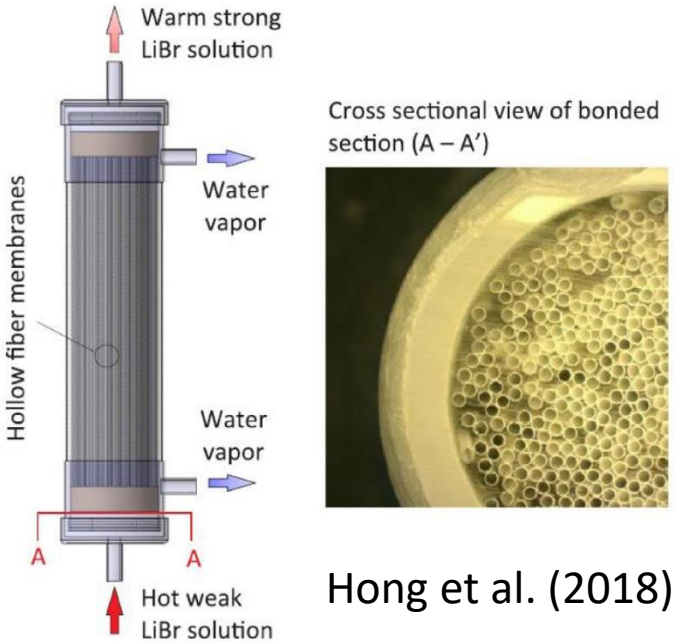
Boman et al. (2017)



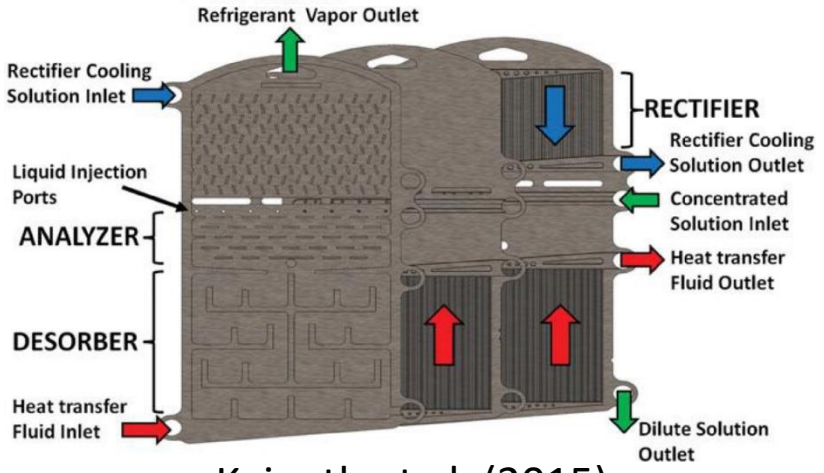
Zheng (2014)

2. Compact Components

- Issues in compact component design
  - Flooding limits
  - Wettability
  - Phase mixing
- Surfactant-enhanced components
  - Improved wetting and interfacial area
  - Long-term stability still in question
- Heat/mass transfer modeling
  - Extrapolated from large capacity systems
  - Difficult to fully predict hydrodynamic instabilities, component performance, and overall system performance



Hong et al. (2018)



Keinath et al. (2015)

3a. Flow Distribution: Falling-Film Evaporation

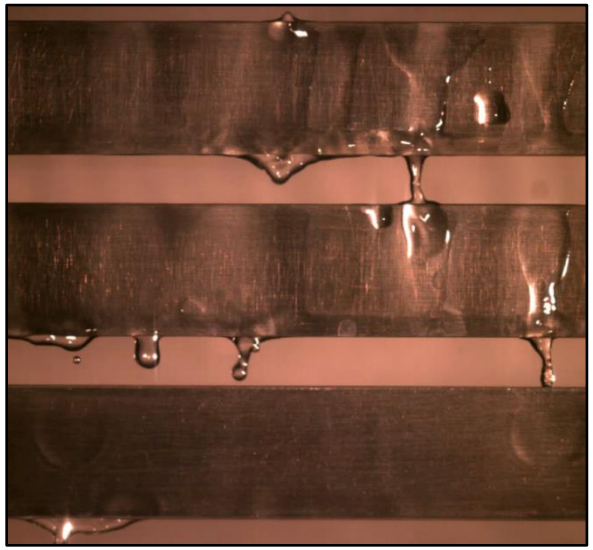
Droplet Mode

Re = 55

s = 10 mm

T_{sat} = 17°C

q'' = 10 kW m^{-2}



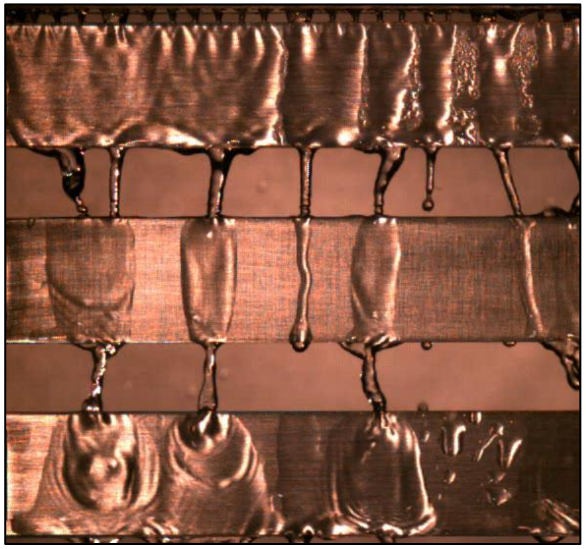
Droplet-Jet Mode

Re = 220

s = 15 mm

T_{sat} = 10°C

q'' = 20 kW m^{-2}



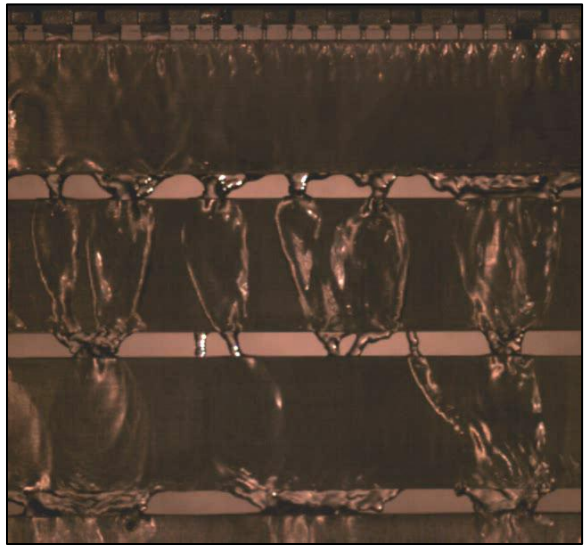
Jet-Sheet Mode

Re = 385

s = 5 mm

T_{sat} = 15°C

q'' = 20 kW m^{-2}

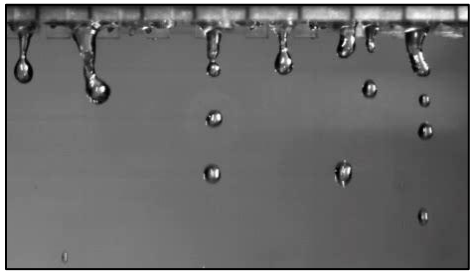


Captured at 500 fps, Shown at 30 fps

3b. Fluid Distributors

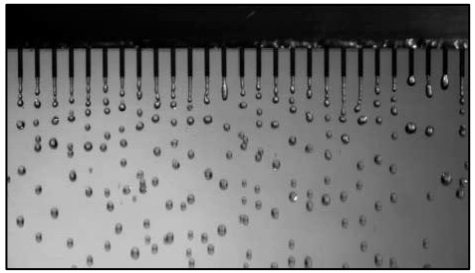
Box-Based Designs

Holes & Feeder Tube

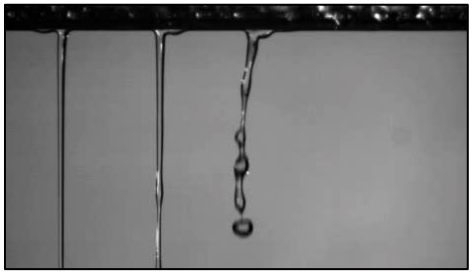


Holes, Feeder Tube, & Foam

Exit Tubes



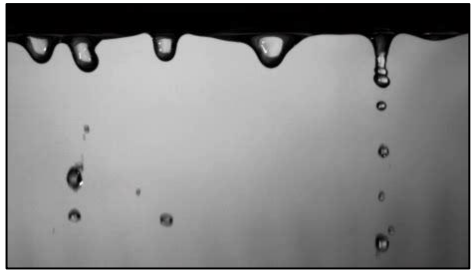
Slot, Curved Plate



Tube-Based Designs

Holes

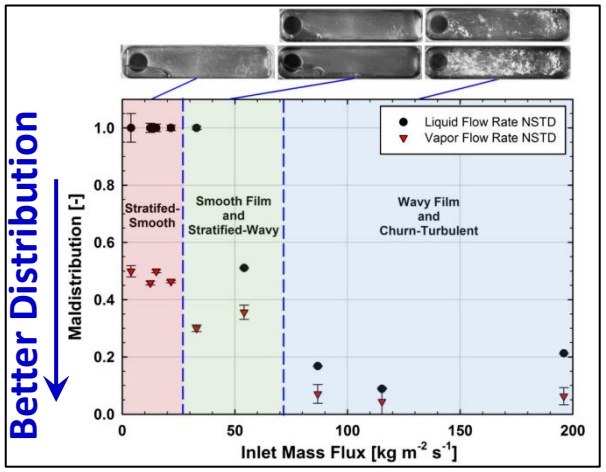
Holes, Adiabatic Tube

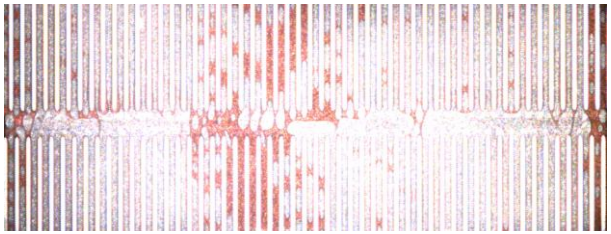


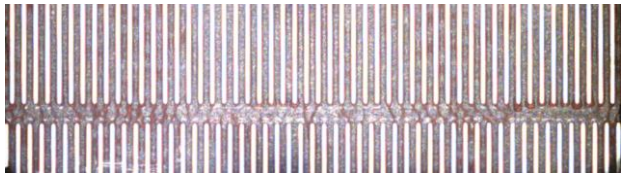
Concentric: Holes, Slot

Concentric: Holes, Half-Tube

3c. Headers and Maldistribution

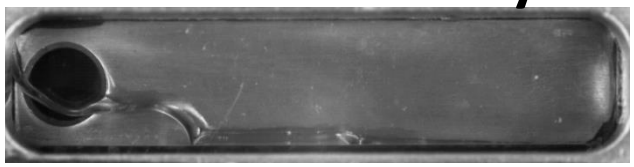






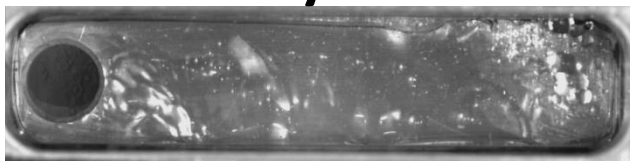
Stratified - Smooth

Stratified - Wavy

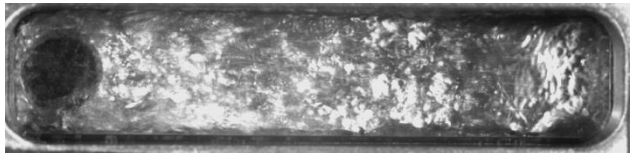


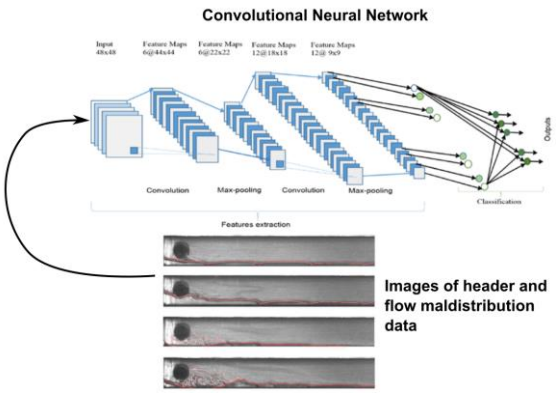
Smooth Film

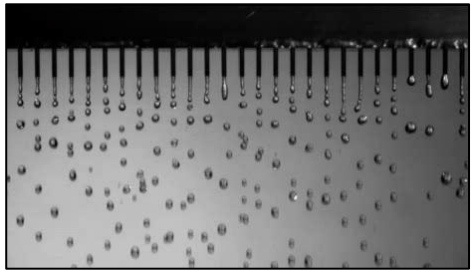
Wavy Film



Churn-Turbulent







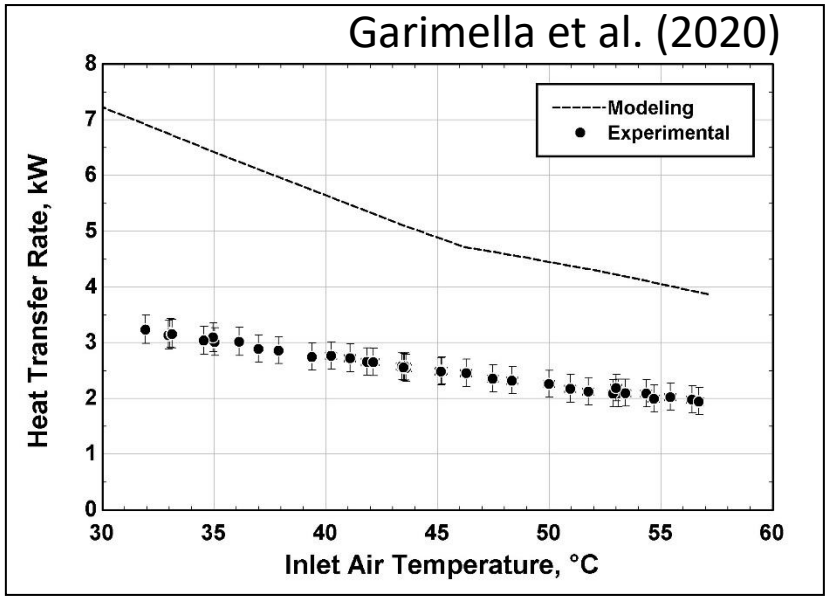
AI/ML could help with:

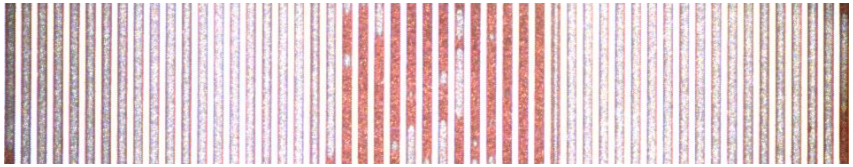
- Header design
- Identification or mitigation of flow maldistribution

3d. Performance Degradation

Components often underperform due to flow maldistribution - Pettersen (2004), Bobbili *et al.* (2006), Garimella et al. (2020), Pacio and Dorao (2010), Zhang (2009), Kærn et al. (2011), etc.

Mahvi and Garimella (2018)





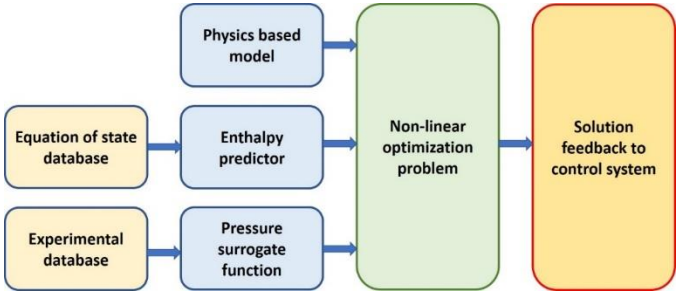
4. System Control and Optimization

Motivation

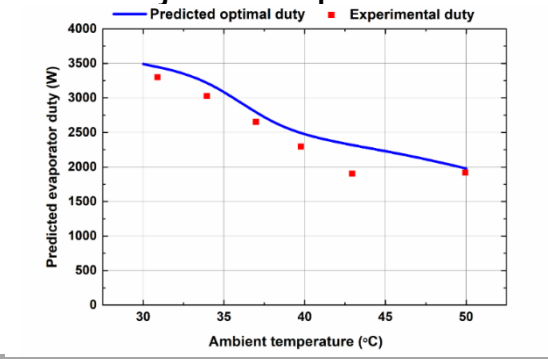
- Develop simple, scalable control systems

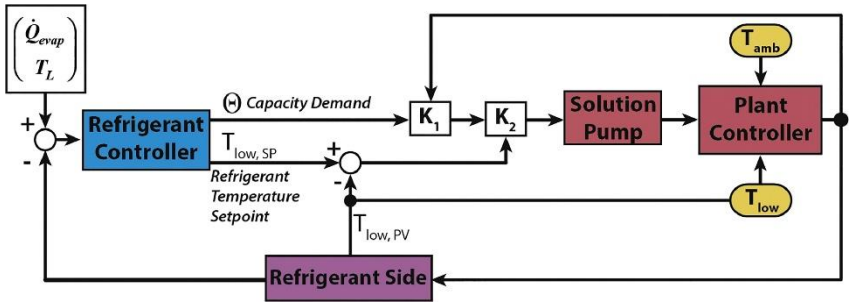
Opportunities

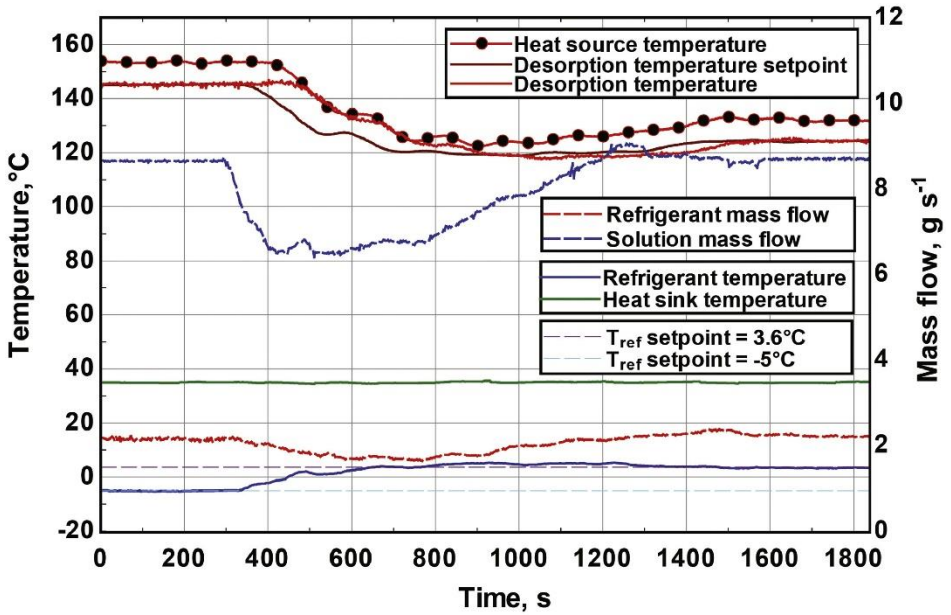
- Use dimensionality reduction algorithms on experimental data



- Number of control variables can be reduced to just 2-3 parameters



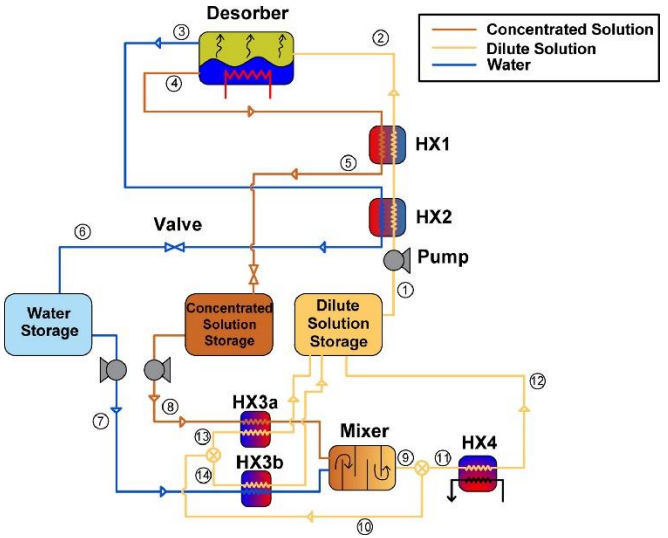




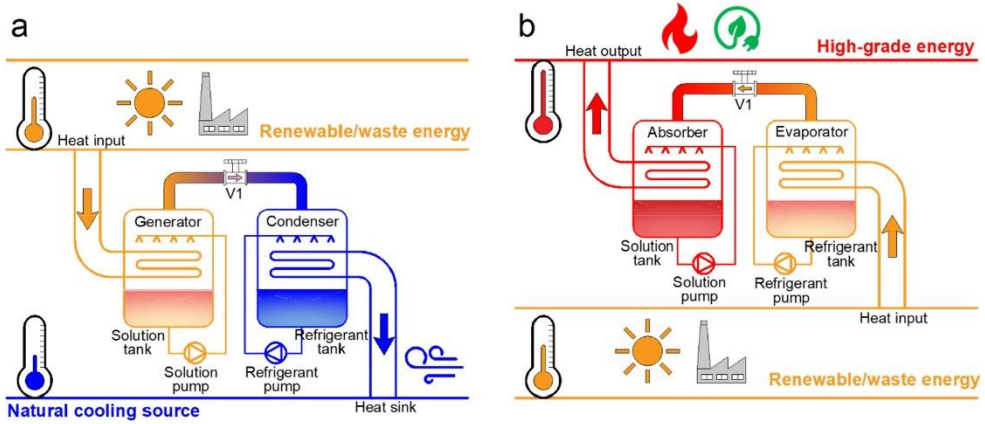
Staedter and Garimella (2019)

5. Thermal Storage and Heat Pumping

- **High temperature heat pumping**
  - With increasing electrification, less low-grade thermal energy is available
  - What role can absorption play in decarbonizing industrial heat?
- **Absorption heat pump thermal storage**
  - Easily stores energy intermittently
  - Cannot easily store low-grade heat
- **Absorption heat transformer thermal storage**
  - Can upgrade low-grade heat to useful temperature
  - Requires constant waste energy source for charging and discharging



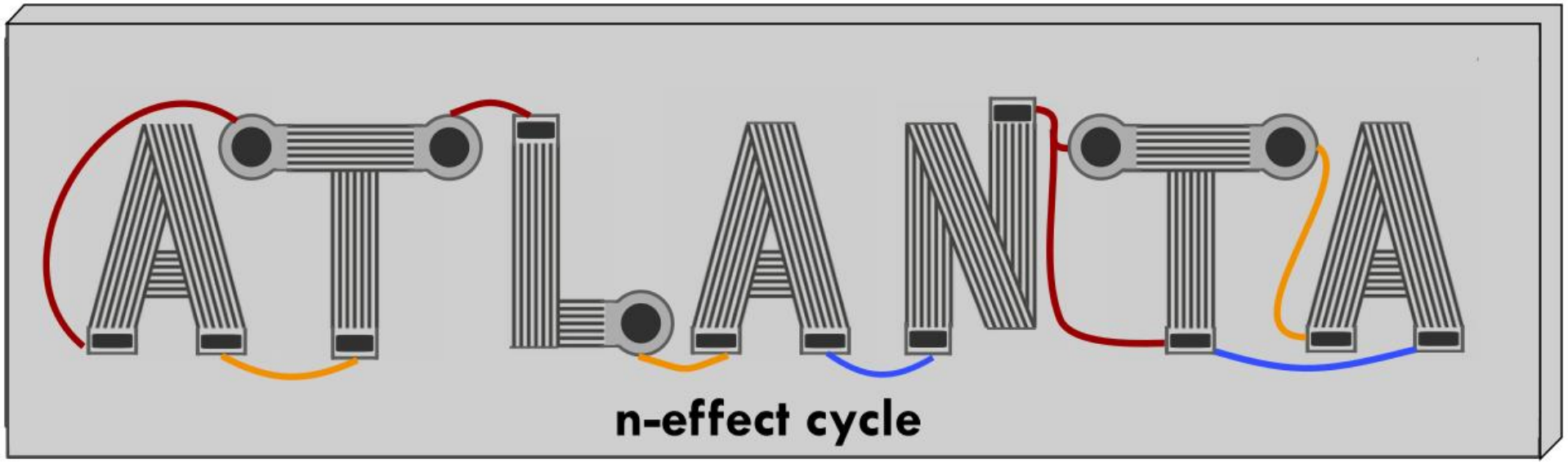
Garimella et al. (2021)



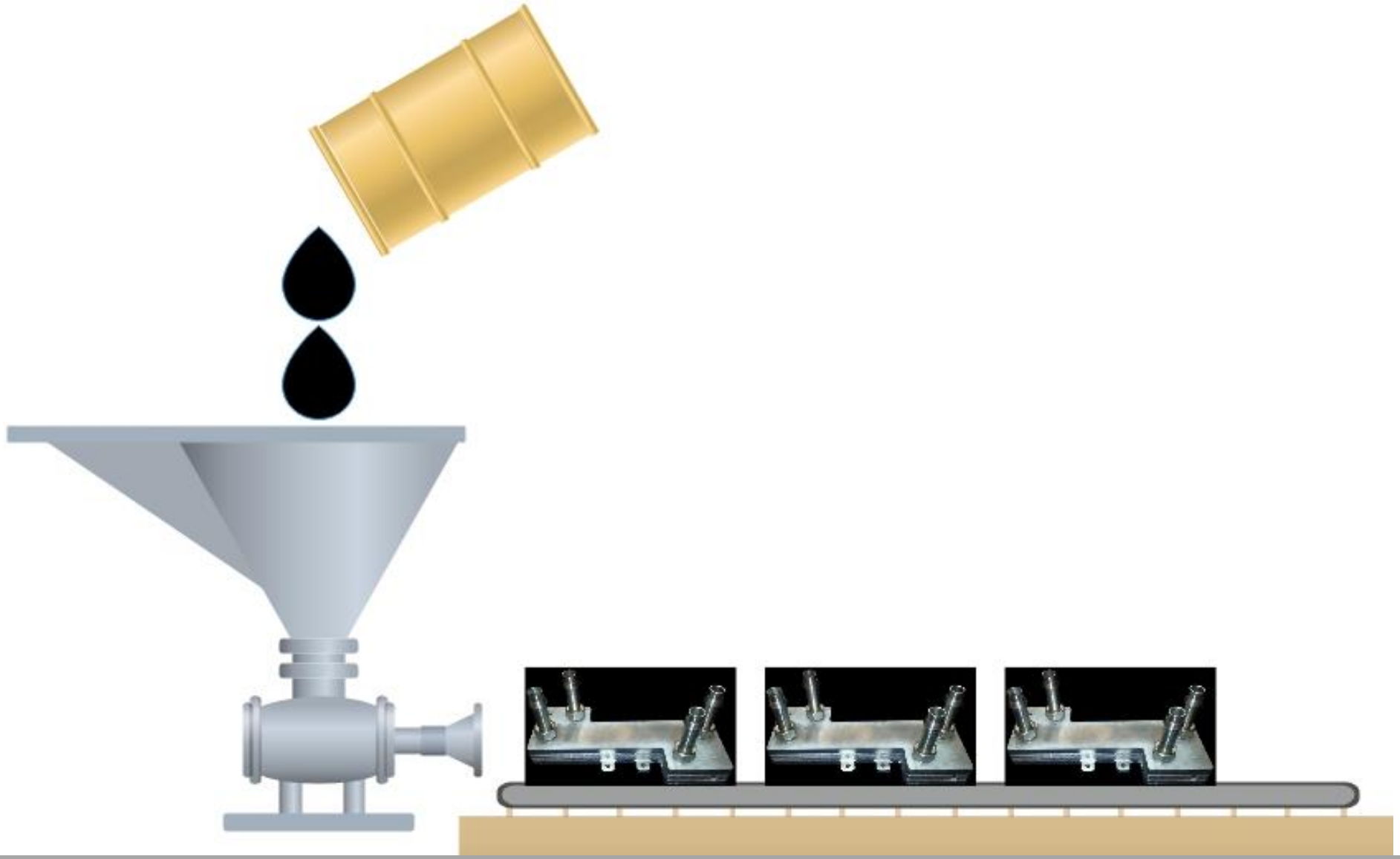
Ding and Wu (2022)

6a. Additive Manufacturing, 3D Printing

- "Print" whatever cycle you want



6b. Pour in Raw Materials, Churn out Heat Pumps



The ultimate solution: Just ask ChatGPT

There one was a fridge with no compressor

It used heat and a pair of fluids lesser

It absorbed the vapor

With no noise or labor

And kept the food cold with no pressure