Integration of Waste Heat to Decarbonize District Energy

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Sorption Friends III
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LAEC
Laboratory for Alternative Energy Conversion

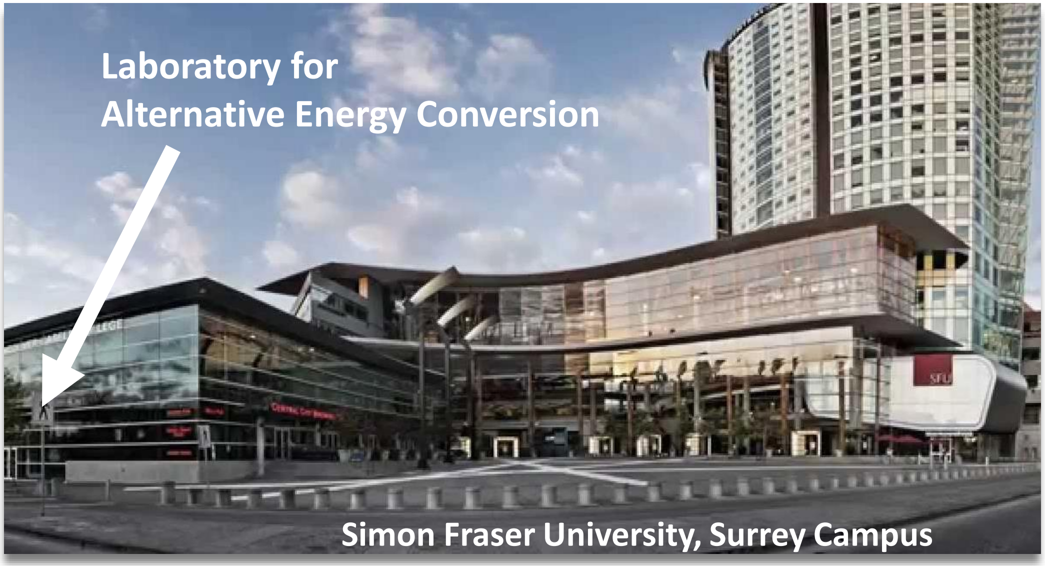
SFU
SIMON FRASER UNIVERSITY
ENGAGING THE WORLD


Burnaby campus


Surrey campus

Laboratory for Alternative Energy Conversion

- Transport phenomena in PEM fuel cells
- Electronic cooling solutions
- Sorption A/C, dehumidification, thermal energy storage
- District energy network modelling
- Energy and water management in greenhouses
- Graphite heat exchangers and heat recovery



How can we decarbonize energy grids?

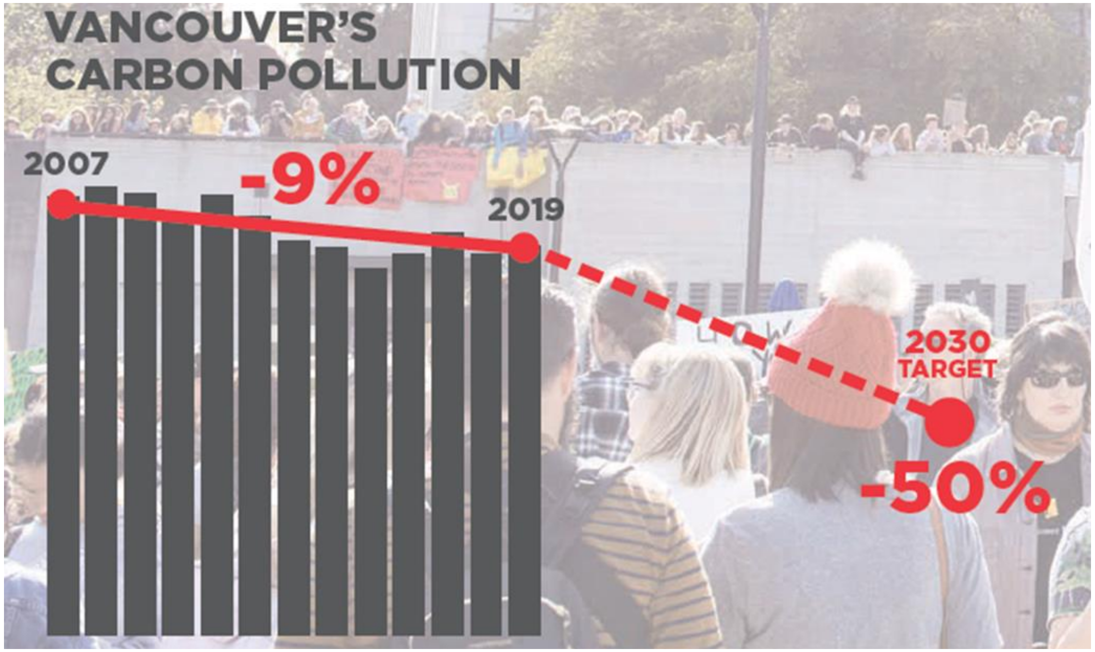
Can “electrification” alone solve our climate/energy crises?

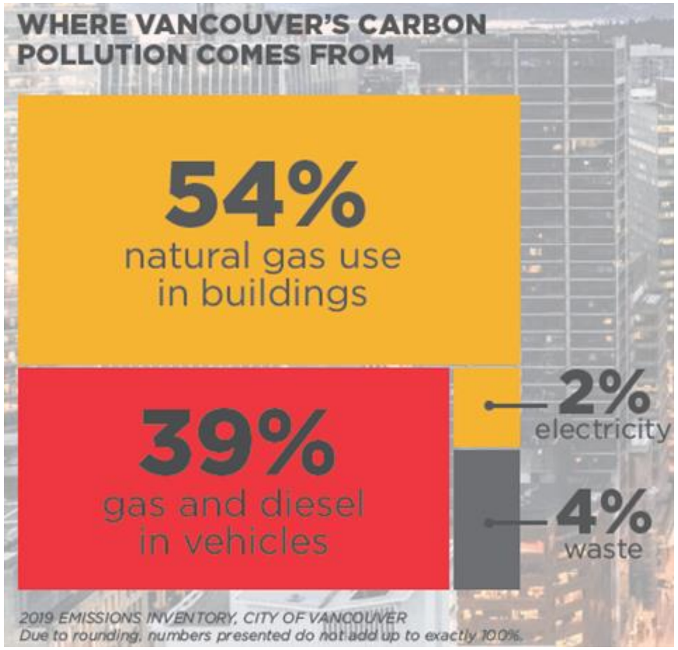
What are the key challenges facing integration of distributed energy resources in energy grids?

What are the transformative (often overlooked) technologies needed to overcome these challenges?

What is the role of waste-heat and thermal storage in meeting climate change targets?

Climate targets in cities



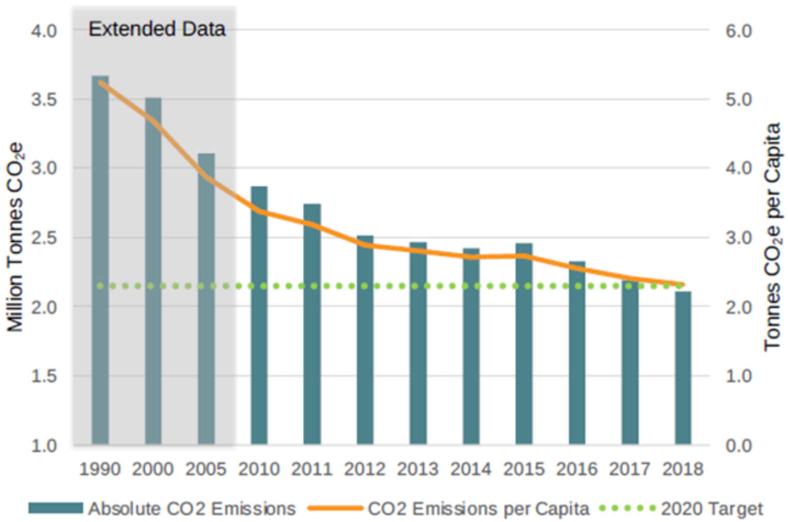


Cities [3]	Climate targets
Vancouver	Achieve 100% of energy needs from renewables sources by 2050
Copenhagen	100% renewable by 2050 (currently 35%)
Frankfurt	100% renewable by 2050

[1] City of Vancouver, Climate Emergency Action Plan Summary 2020-2025.
[2] City of Vancouver, Greenest City 2020 Action Plan Action.
[3] City of Surrey, Low Carbon Strategy, 2021.

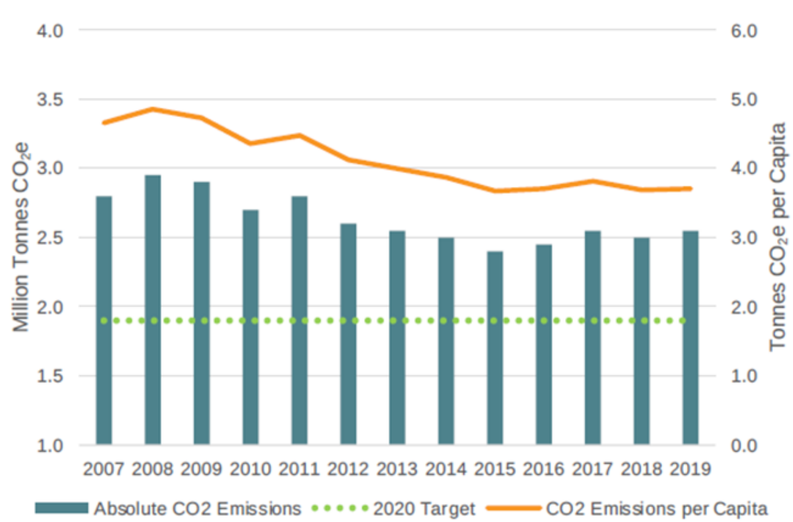
What went wrong in Vancouver?

Stockholm, Sweden

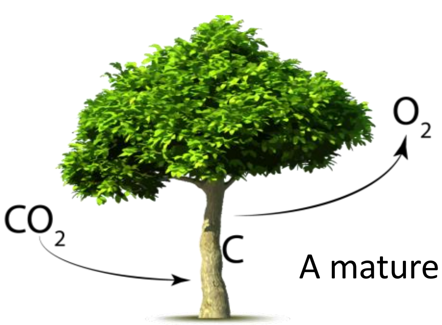


Population		
2007	2020	
705,000	950,000	+35%

Vancouver, BC



Population		
2007	2020	
602,000	697,000	+14%



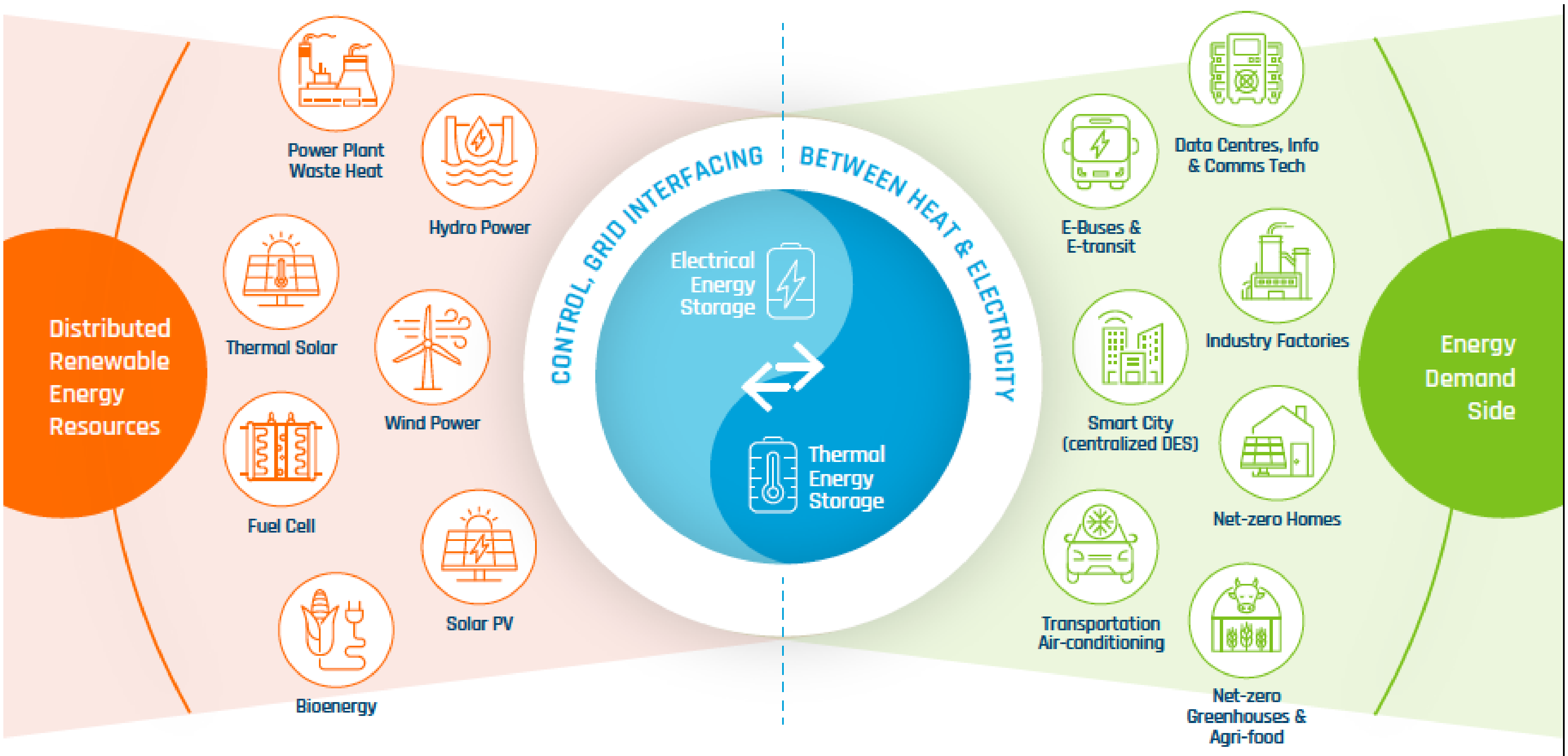
A mature (10 year old) tree absorbs almost 22 kg per year.

SMART CITY SWEDEN

RESHAPE STRATEGIES

[1] Smart City Sweden [2] Reshape Strategies

Hybrid thermal electric microgrid (HyTEM)



Integration, storage, and control of distributed renewable energy sources to meet energy demands and grid resiliency, while reducing emissions and creating sustainable jobs in communities.

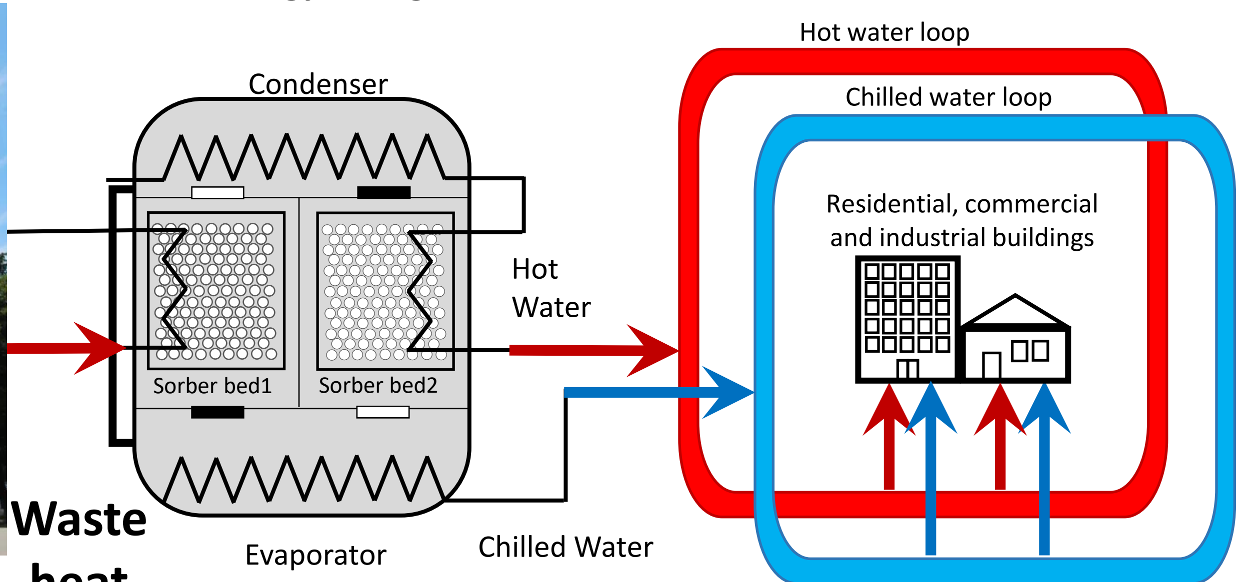
A Sorption Heat Transformer for District Energy

Electricity to Grid

Waste heat

Sorption Heat Transformer and Thermal Energy Storage

City of Burnaby District Energy System

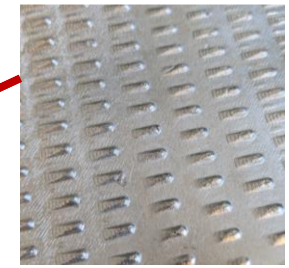


City of Burnaby Waste-to-Energy Facility handles about 260,000 tonnes of garbage per year (a quarter of the region’s garbage). The mass-burn facility generates enough electricity to power 16,000 homes. <u>The waste-heat is currently unused</u>.

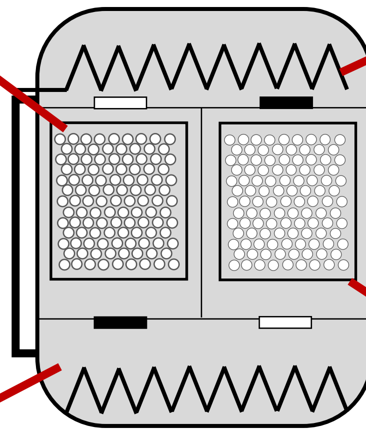
A Heat Transformer for District Energy

Optimized custom-built sorption reactor

Condensing surface with slippery asymmetric bumps



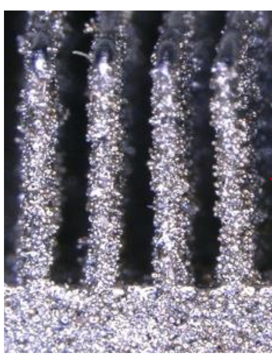
Condenser



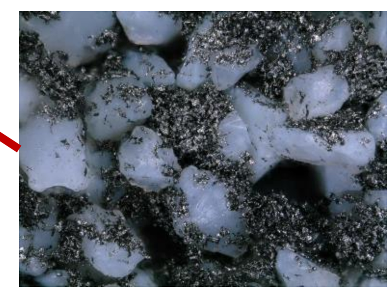
Sorber bed1

Sorber bed2

Evaporator



Capillary assisted low-pressure evaporator

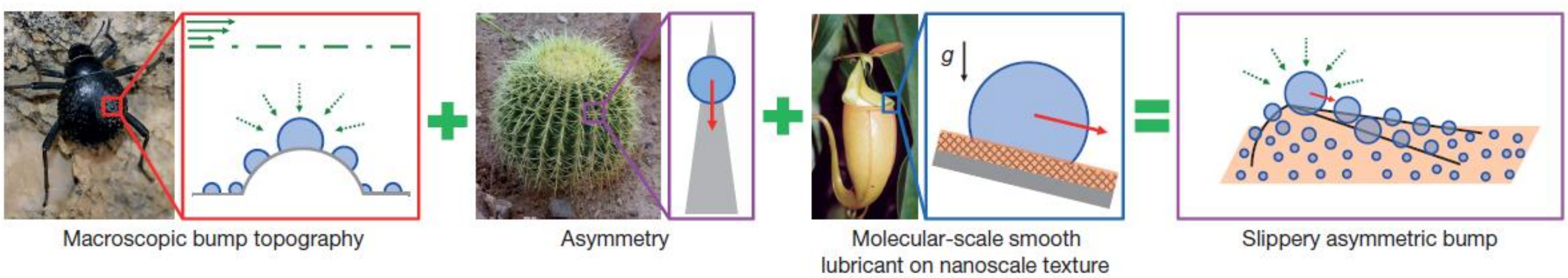


Composite sorbent infused with expanded natural graphite

Nature-Inspired Condensers

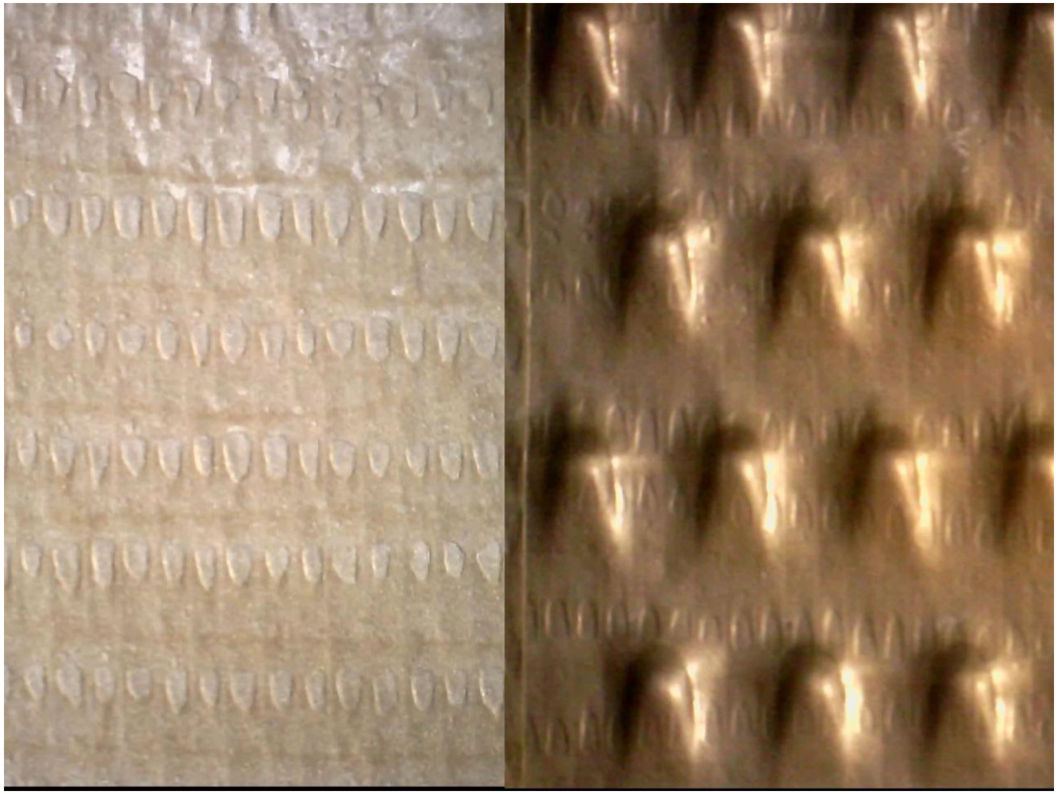
Objective and scope:
Biomimetic water-repellent surfaces, e.g., the lotus leaf inspired a new generation of superhydrophobic structures.

mm-sized surface structure (slippery asymmetric bumps): 2–10 times higher heat transfer



Park, K. C., Kim, P., Grinthal, A., He, N., Fox, D., Weaver, J. C., & Aizenberg, J. (2016). Condensation on slippery asymmetric bumps. *Nature*.

Condensation on Flat vs "Bumpy" Surfaces



100 x Play

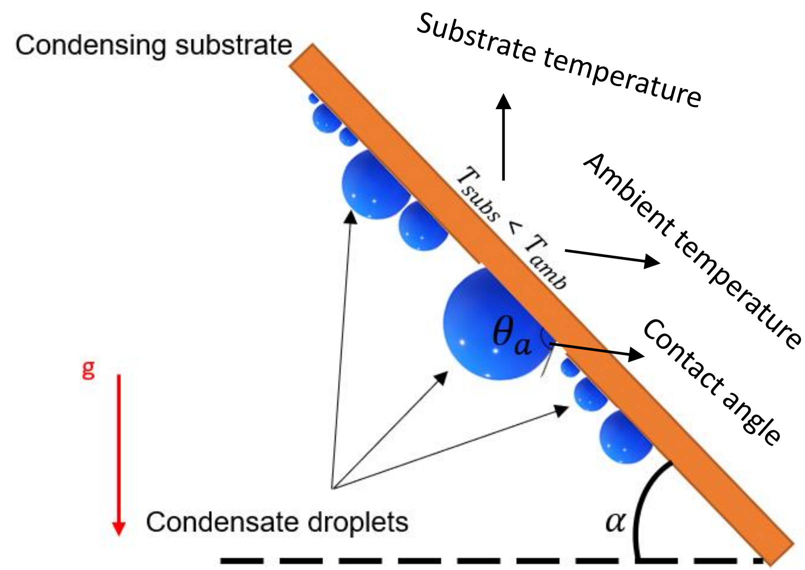
Sample video

(Flat vs. featured surface)
Surface temperature: 0 °C
Ambient temperature: 23 °C
Relative Humidity: 70 %

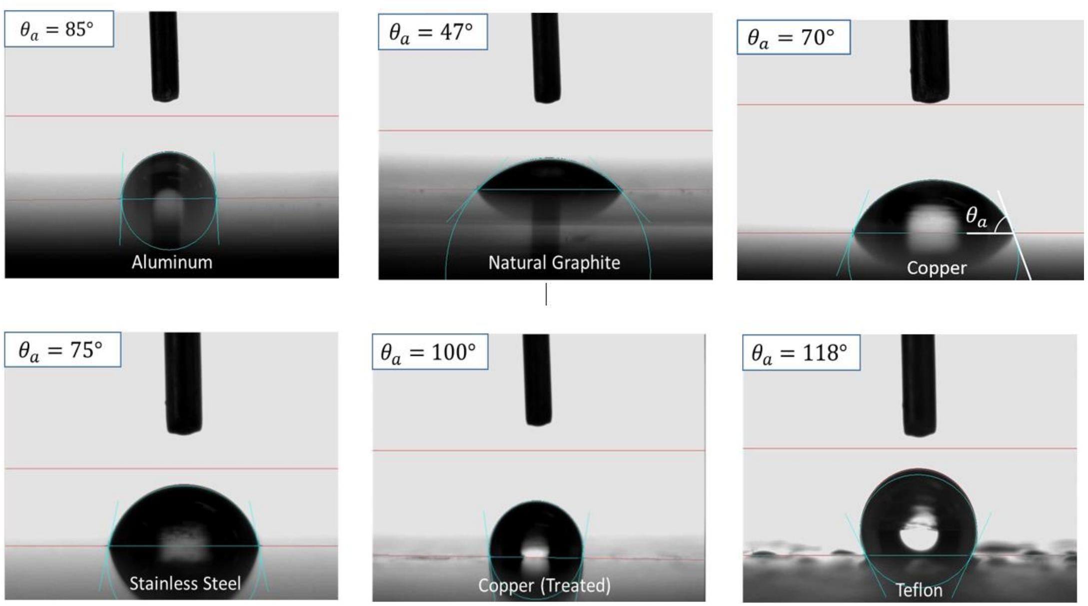
Modeling Dropwise Condensation

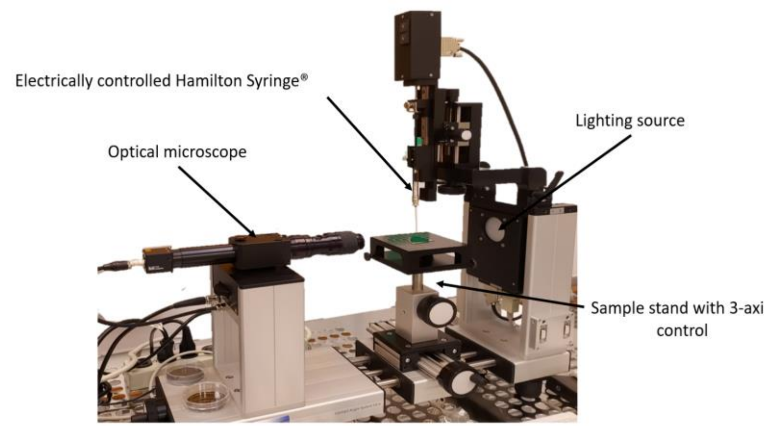
Heat transfer coefficient

$$h = h\,(\underbrace{RH}_{\text{Relative humidity}},\overbrace{[T_{amb} - T_{subs}]}^{\text{Subcooling}},\underbrace{\theta_a}_{\text{Contact angle}},\overbrace{\alpha}^{\text{Inclination}})$$



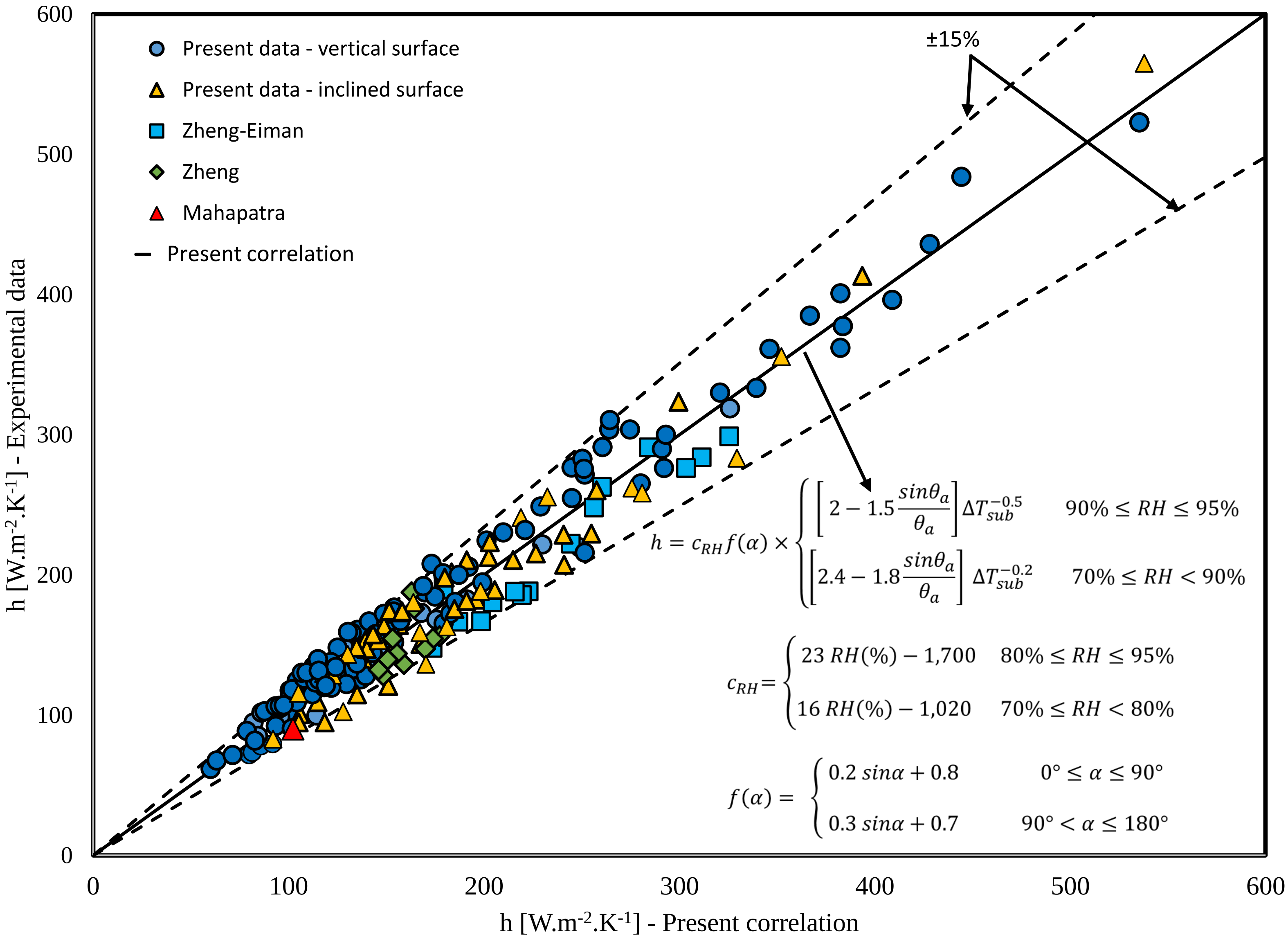
Contact angle measurement





Goniometer®

Correlation for Dropwise Condensation



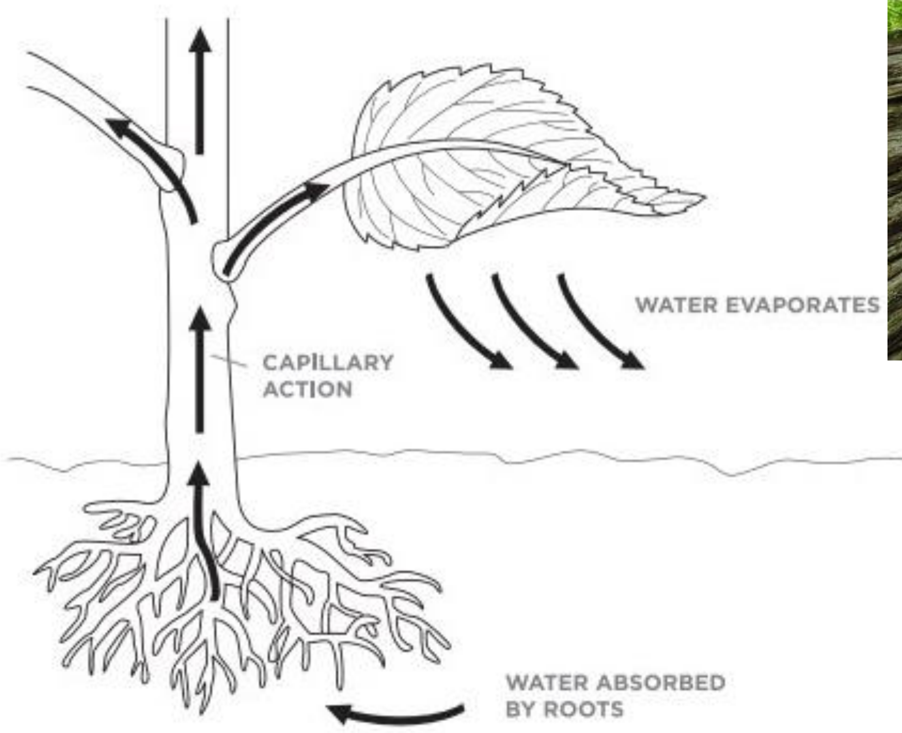
$$h = c_{RH} f(\alpha) \times \begin{cases} \left[2 - 1.5\frac{\sin\theta_a}{\theta_a}\right] \Delta T_{sub}^{-0.5} & 90\% \le RH \le 95\% \\ \left[2.4 - 1.8\frac{\sin\theta_a}{\theta_a}\right] \Delta T_{sub}^{-0.2} & 70\% \le RH < 90\% \end{cases}$$

$$c_{RH} = \begin{cases} 23\, RH(\%) - 1{,}700 & 80\% \le RH \le 95\% \\ 16\, RH(\%) - 1{,}020 & 70\% \le RH < 80\% \end{cases}$$

$$f(\alpha) = \begin{cases} 0.2 \sin\alpha + 0.8 & 0° \le \alpha \le 90° \\ 0.3 \sin\alpha + 0.7 & 90° < \alpha \le 180° \end{cases}$$

Nature-Inspired Capillary-Assisted Evaporation

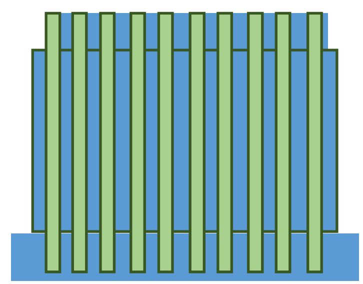
Inspiration: Plants use capillary action to draw water from the ground



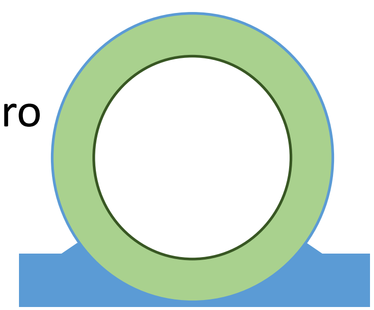
Douglas-fir trees (100 m)
Uses capillary pumping

Passive pumping

Capillary water rise

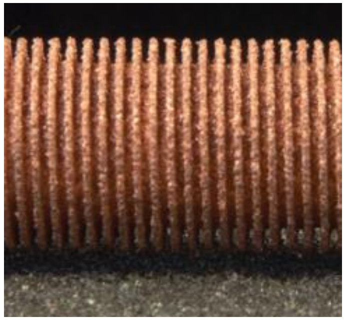


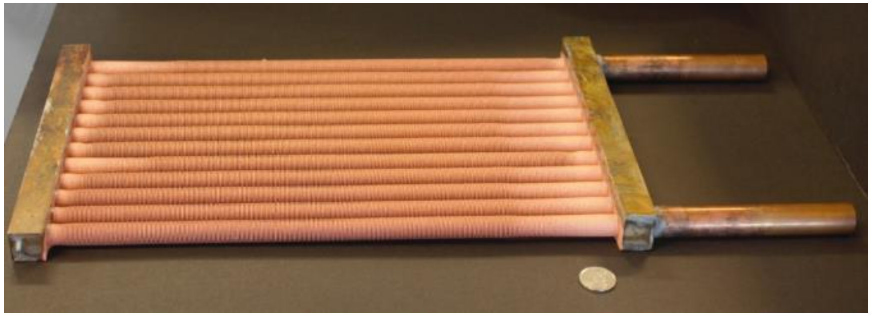
Fins/micro grooves



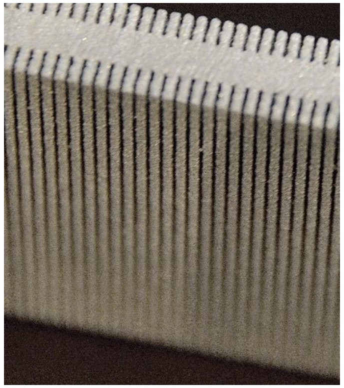
Pooled water

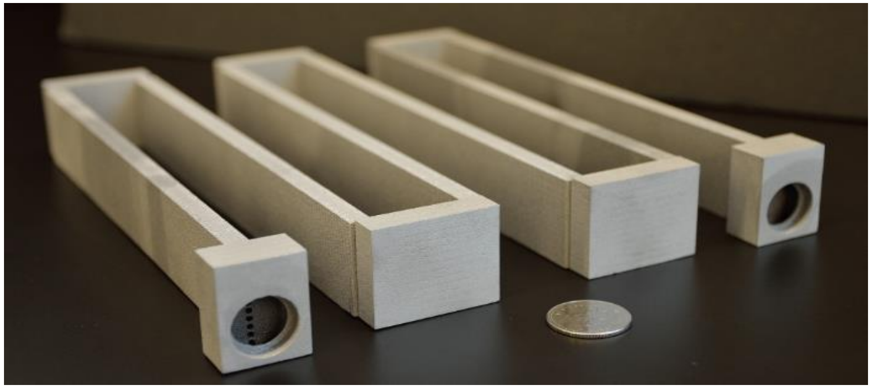
Micro Capillary-Assisted Low-Pressure Evaporator





Thermal spray porous copper coating on finned tube heat exchanger



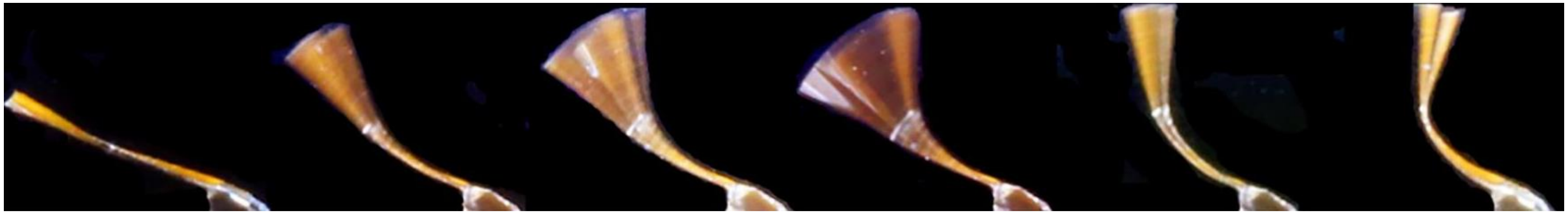


Direct metal sintering of finned aluminum microtube heat exchanger

	Cooling Power
• Porous copper evaporator:	0.3 kW/kg
• Sintered aluminum evaporator:	1.2 kW/kg

Vortex Generators

Critical flow velocity: Velocity at which transition to fluttering mode occurs



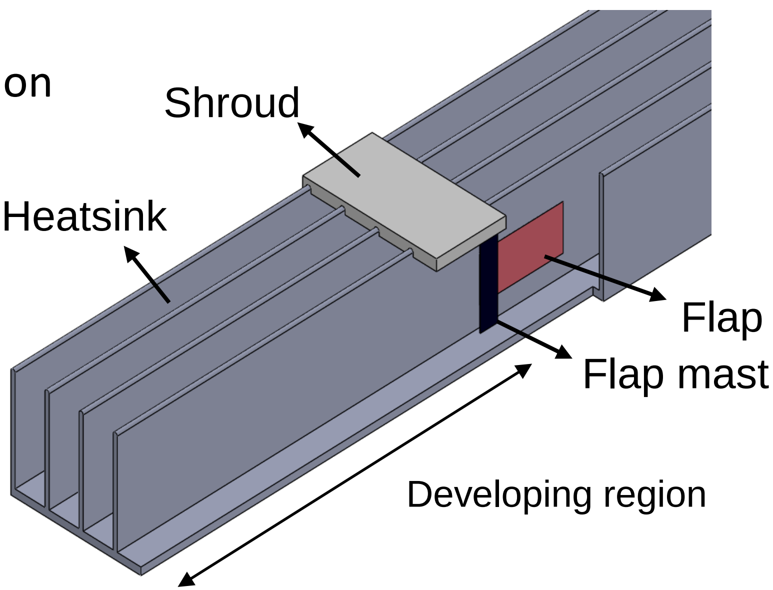
Stretched mode Flapping mode Deflected mode

Increasing flow velocity

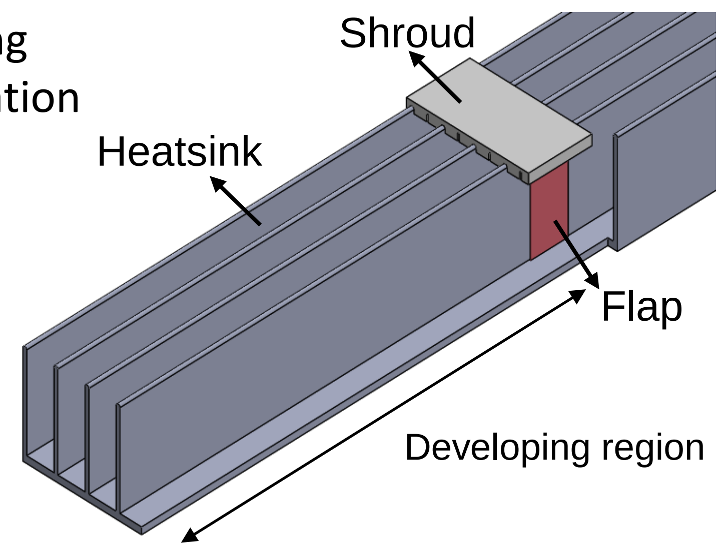
Li, Zheng, et al. "Bio-inspired self-agitator for convective heat transfer enhancement." *Applied Physics Letters* (2018)
K. Li, et al. "A novel caudal-fin-inspired hourglass-shaped self-agitator for air-side heat transfer enhancement in plate-fin heat exchanger," Energy Convers. Manag. (2019)

Flap Orientation: Reducing Critical Flow Velocity

Vertical Configuration



Hanging Configuration



Comparison of Thermal-Hydraulic Performance