Nicholas Fette
Update for Phelan lab group meeting

Outline

1. Interesting news from the world
2. Waste heat utilization (AORA Solar)
3. Dissertation outline (most recent)
4. Social ideas

H. J. Cho, J. P. Mizerak and E. N. Wang, "Turning bubbles on and off during boiling using charged surfactants," *Nat Commun,* vol. 6, no. 8599, pp. 1-7, 2015. http://dx.doi.org/10.1038/ncomms9599.

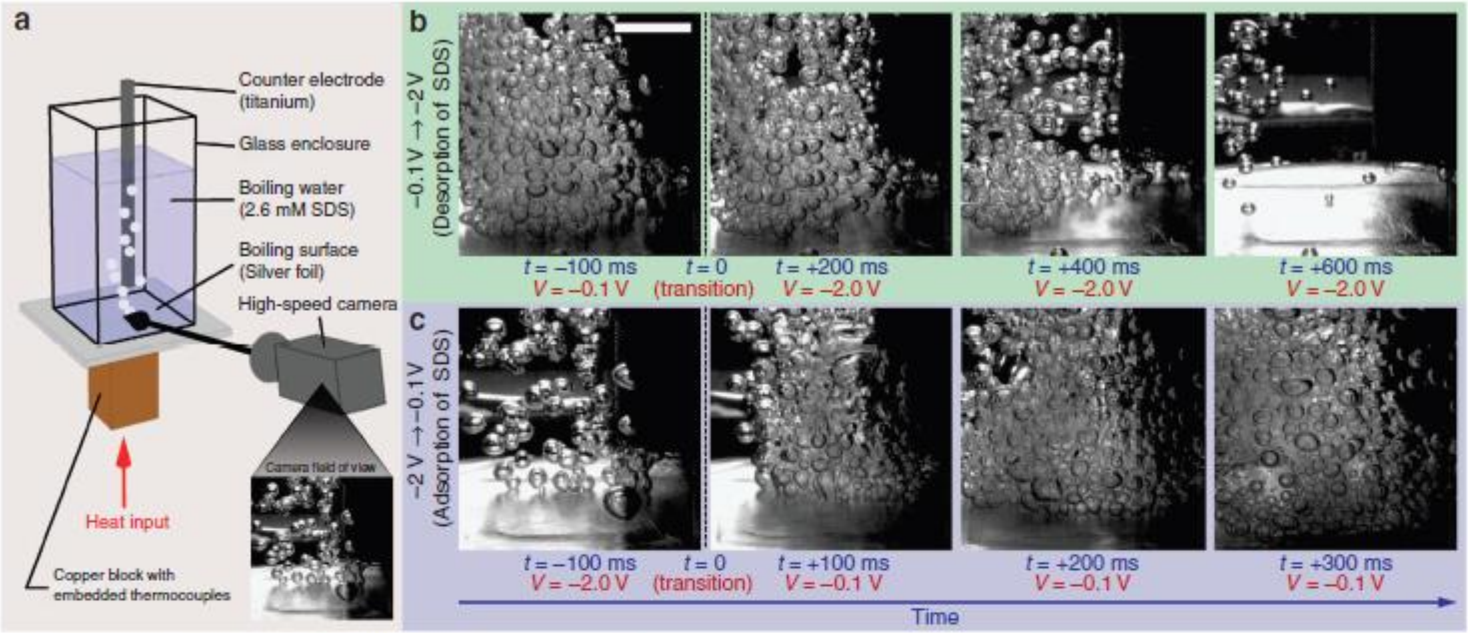


Figure 1 | Turning boiling on and off with a potential switch. (**a**) Pool boiling of a solution of 2.6 mM SDS (negatively charged) in DI water at a constant heater power of 60 W with potential applied between the silver foil boiling surface and an immersed titanium counter electrode. A (**b**) −0.1 to −2.0 V switch decreased bubble nucleation within 600 ms due to electrostatic desorption of SDS from boiling surface. A (**c**) −2.0 to −0.1 V switch increased nucleation within 300 ms due to adsorption of SDS (see Supplementary Movie 1). Scale bar, 1 cm.

H. J. Cho, J. P. Mizerak and E. N. Wang, "Turning bubbles on and off during boiling using charged surfactants," *Nat Commun,* vol. 6, no. 8599, pp. 1-7, 2015. http://dx.doi.org/10.1038/ncomms9599.

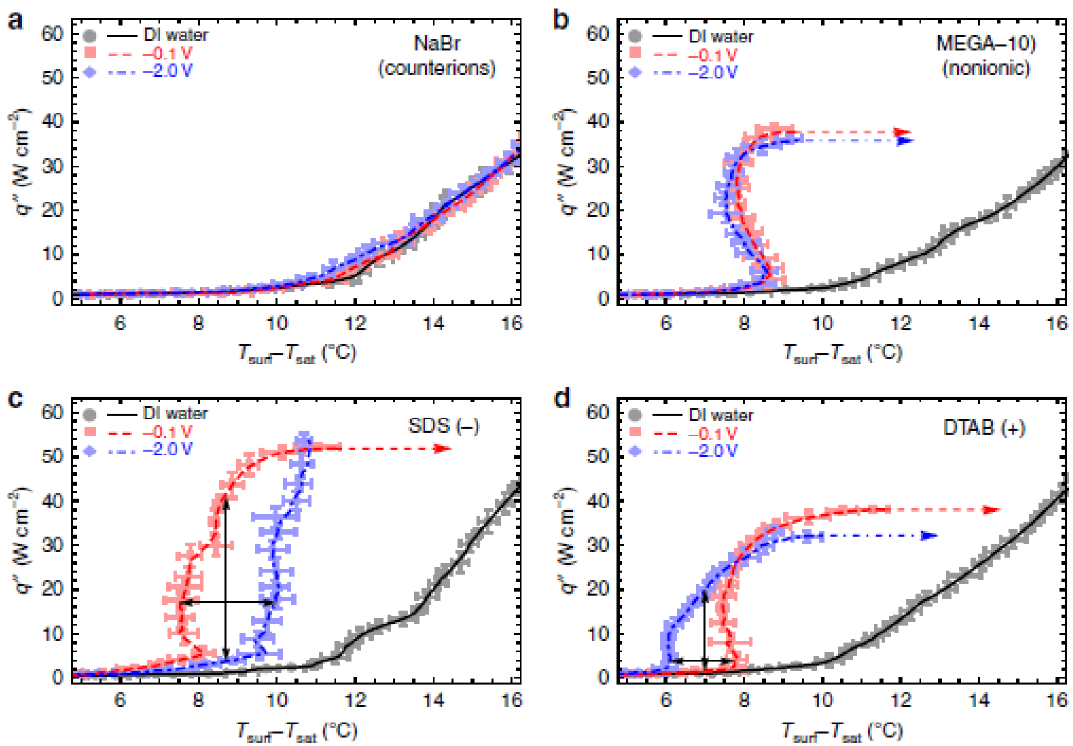
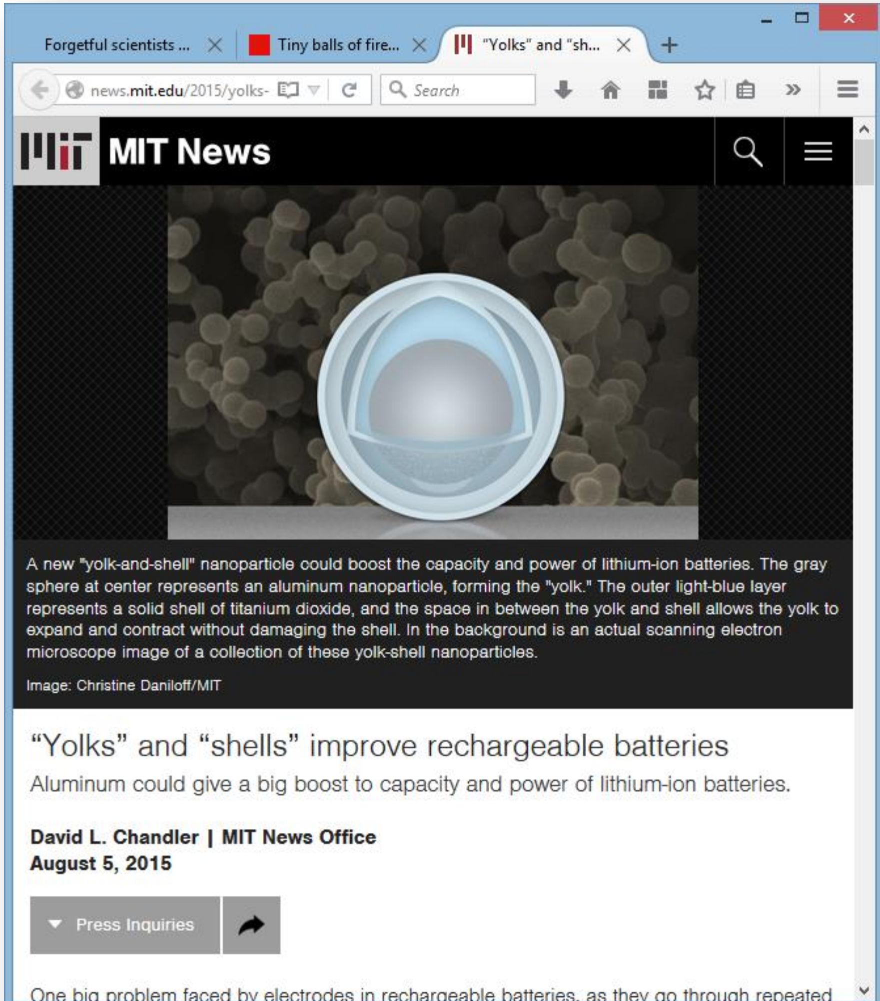


Figure 4 | Boiling curves showing tunability of charged surfactants. Plain DI water (black), −0.1 V (red) and −2.0 V (blue) boiling curves for 2.6 mM (**a**) NaBr, (**b**) MEGA-10, (**c**) SDS and (**d**) DTAB. Time averaged data points from an individual boiling experiment with error bars (2 standard deviations in data spread from time averaging) and moving averages (lines) are shown. Boiling was not affected by voltage for (**a**) NaBr and (**b**) MEGA-10. For (**c**) negatively charged SDS, the boiling curve at −2.0 V was right-shifted with higher CHF compared with −0.1 V. For (**d**) positively charged DTAB, the boiling curve at −2.0 V was left-shifted with lower CHF compared with −0.1 V. The maximum change in HTC (tunability) at constant q'' (horizontal arrows) and constant superheat (vertical arrows) are shown for SDS and DTAB.

Fun news


Forgetful scientists ... | Tiny balls of fire... | "Yolks" and "sh...

news.mit.edu/2015/yolks-

MIT News

A new "yolk-and-shell" nanoparticle could boost the capacity and power of lithium-ion batteries. The gray sphere at center represents an aluminum nanoparticle, forming the "yolk." The outer light-blue layer represents a solid shell of titanium dioxide, and the space in between the yolk and shell allows the yolk to expand and contract without damaging the shell. In the background is an actual scanning electron microscope image of a collection of these yolk-shell nanoparticles.

Image: Christine Daniloff/MIT

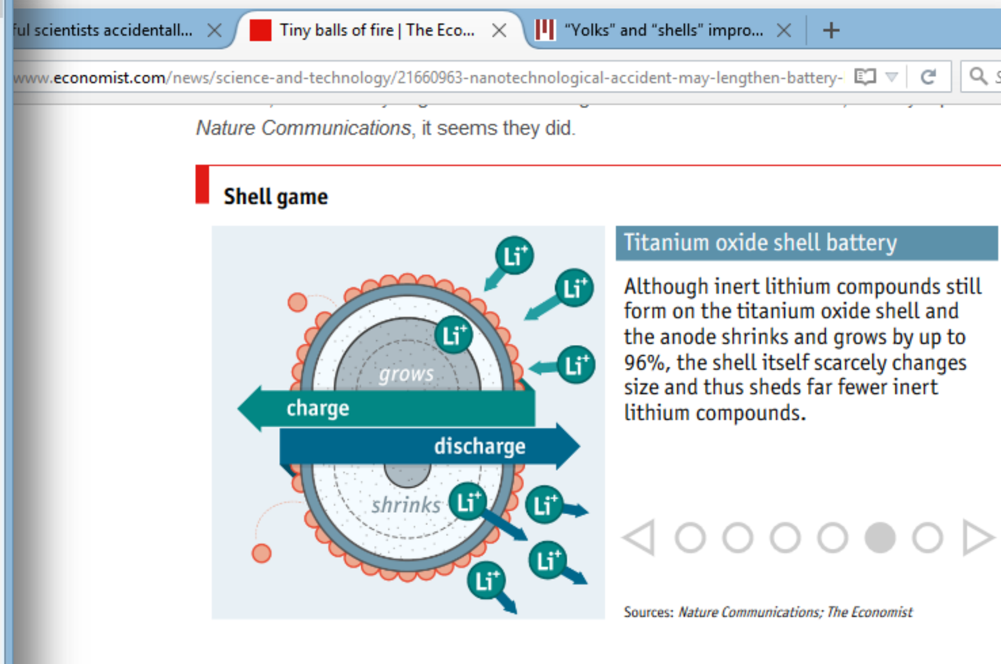
"Yolks" and "shells" improve rechargeable batteries

Aluminum could give a big boost to capacity and power of lithium-ion batteries.

David L. Chandler | MIT News Office
August 5, 2015

Press Inquiries

One big problem faced by electrodes in rechargeable batteries, as they go through repeated


ful scientists accidentall... | Tiny balls of fire | The Eco... | "Yolks" and "shells" impro...

www.economist.com/news/science-and-technology/21660963-nanotechnological-accident-may-lengthen-battery-

Nature Communications, it seems they did.

Shell game

Titanium oxide shell battery

Although inert lithium compounds still form on the titanium oxide shell and the anode shrinks and grows by up to 96%, the shell itself scarcely changes size and thus sheds far fewer inert lithium compounds.

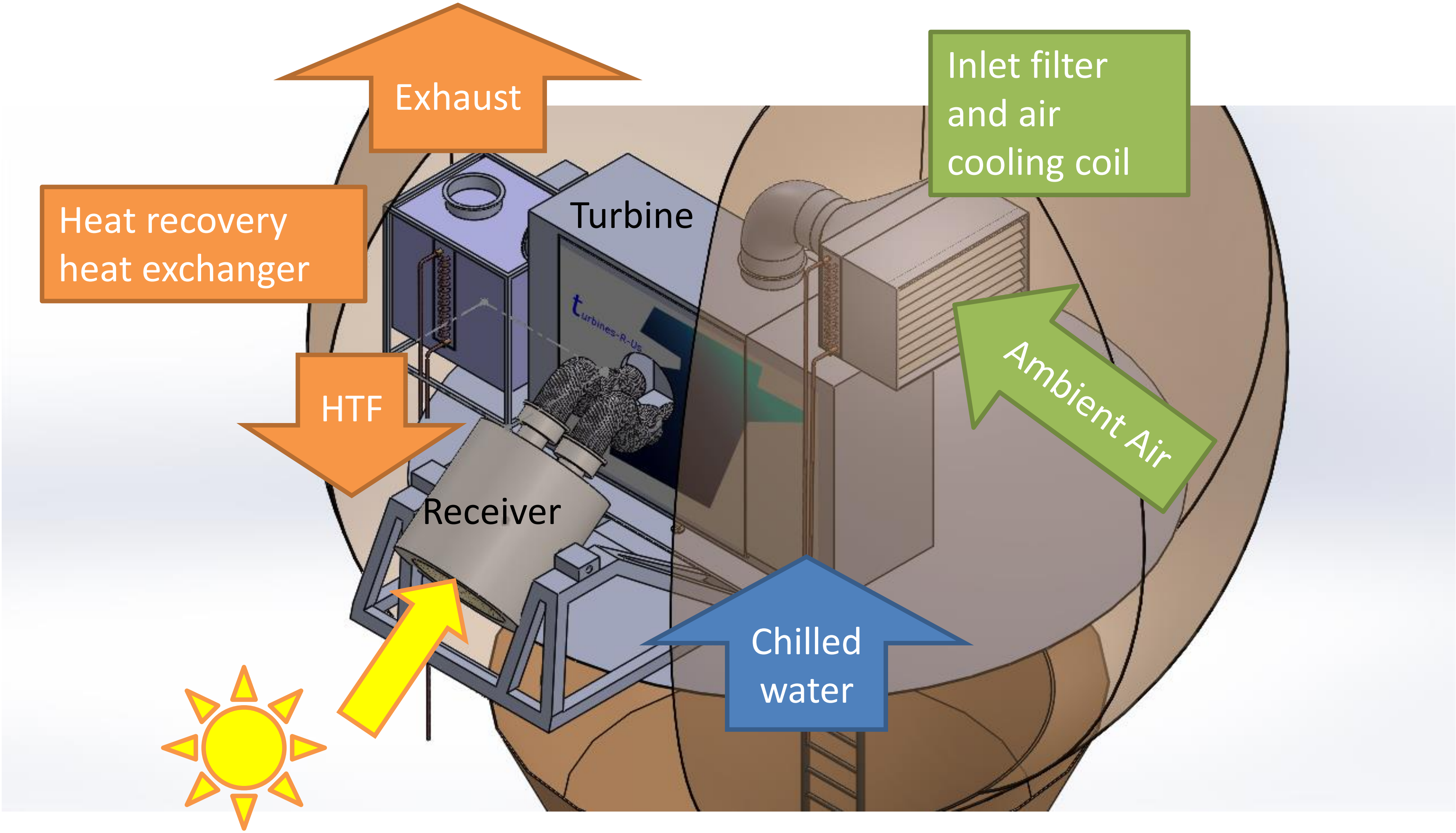
Sources: *Nature Communications; The Economist*

AORA Solar collaboration

- Pinchas Doron
  - AORA
- Ellen Stechel
  - Nathan Johnson
  - Marcus Herrman
  - Yulia Peet
  - Clark Miller
  - Perdo Peralta
  - Pat Phelan

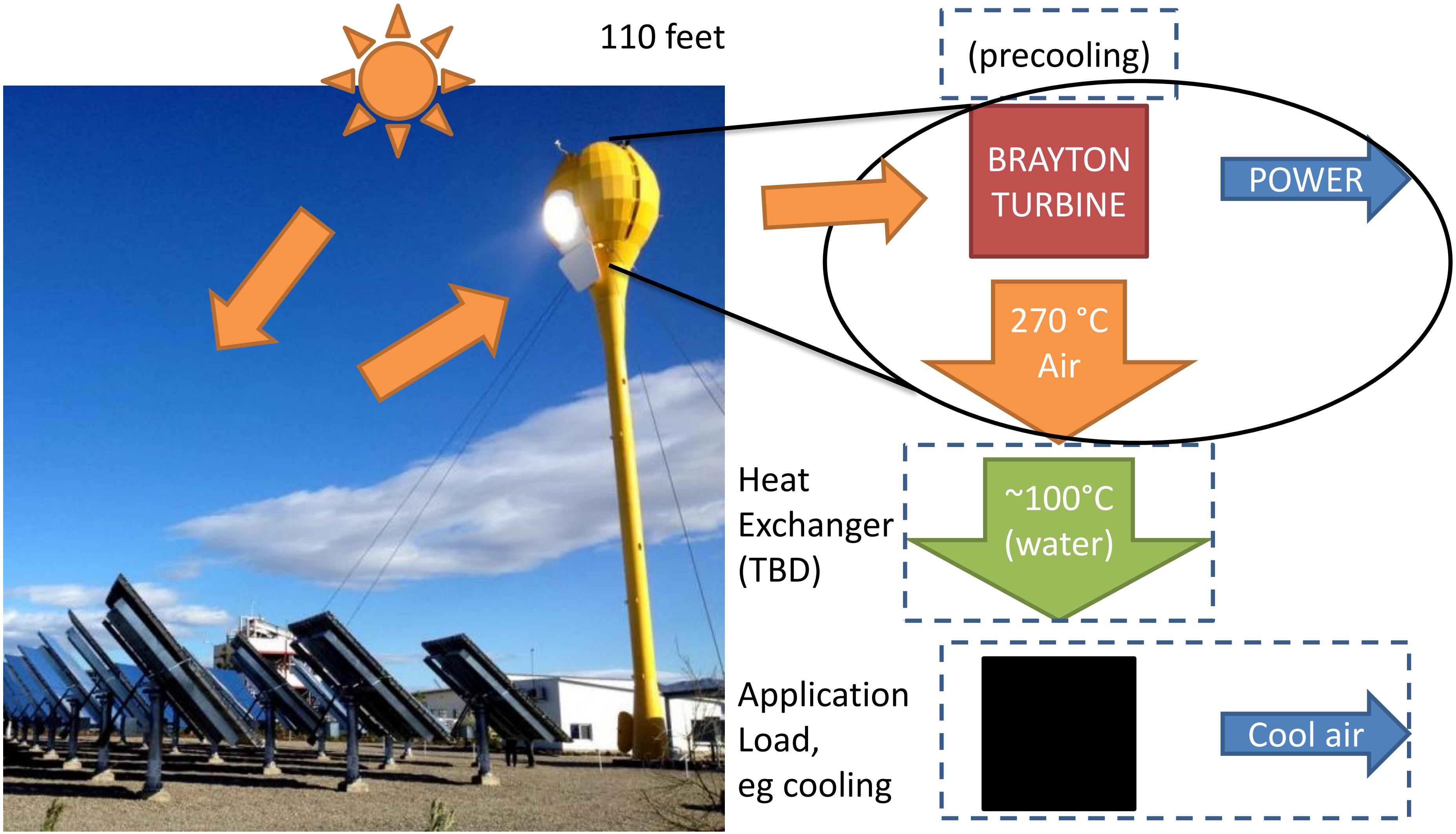
J. M. Duran, "AORA Solar's Tulip System: A hybrid solar thermal solution," 25 11 2013. [Online]. Available: http://www.iitj.ac.in/CSP/material/21dec/aora.pdf. [Accessed 02 11 2015].

Close-up



Exhaust
Heat recovery heat exchanger
Turbine
Inlet filter and air cooling coil
HTF
Ambient Air
Receiver
Chilled water

AORA waste heat utilization



Waste heat utilization team

Jon

Nick

Sami

Weston

Yuqian?

Andrew

Inactive

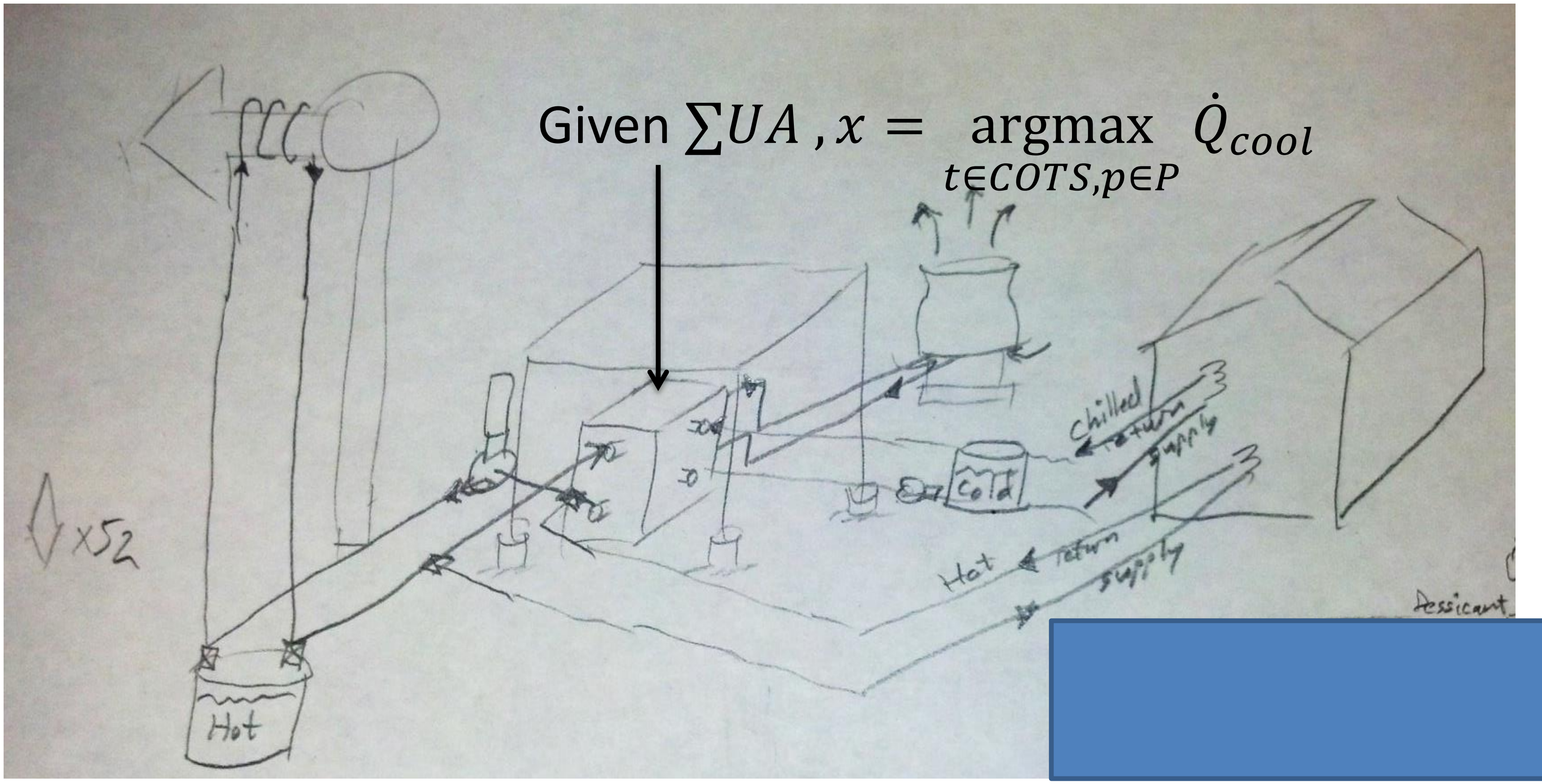
Randi

Turki

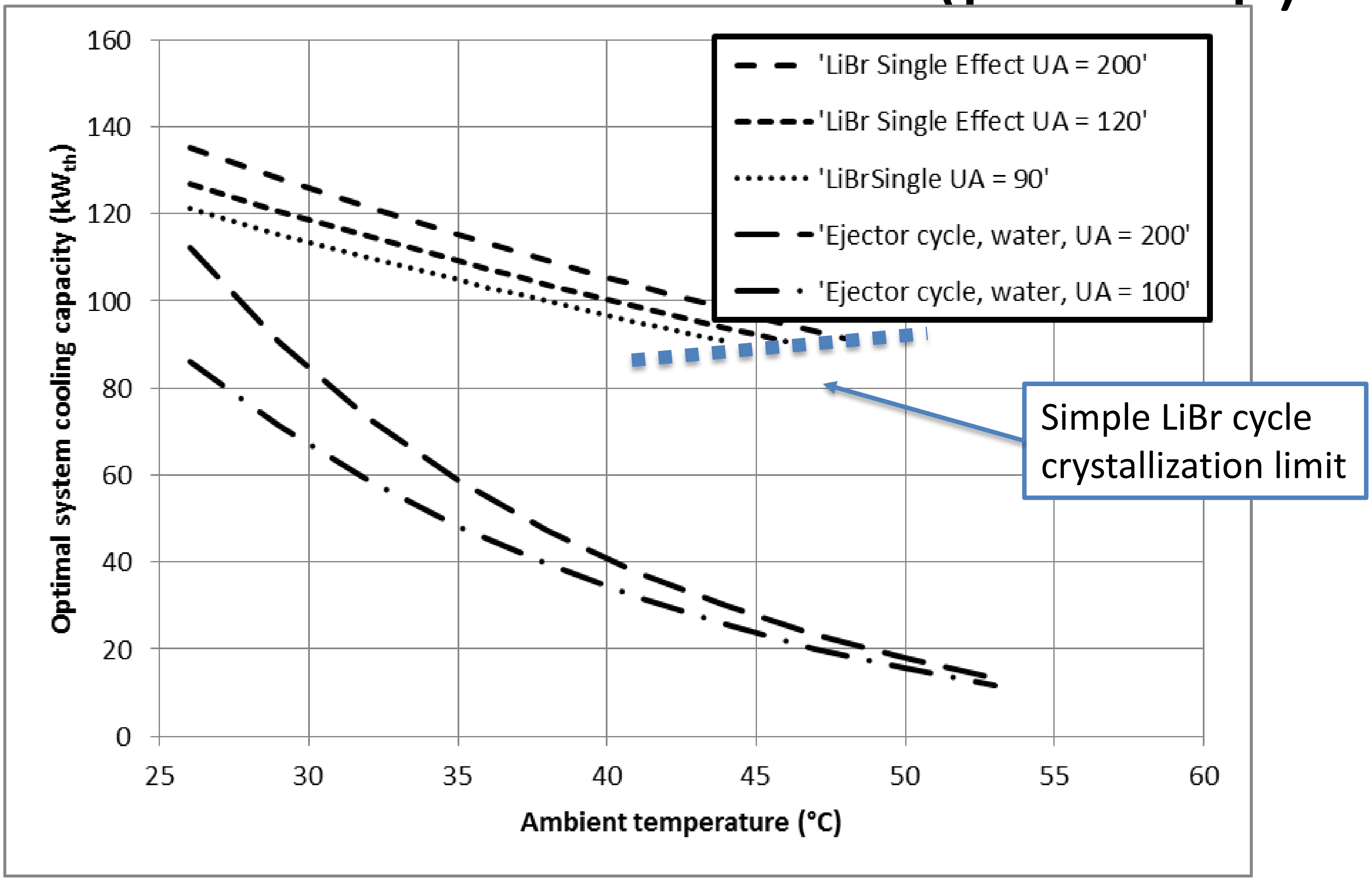
Gaurav

Nick’s dissertation Chapter 1

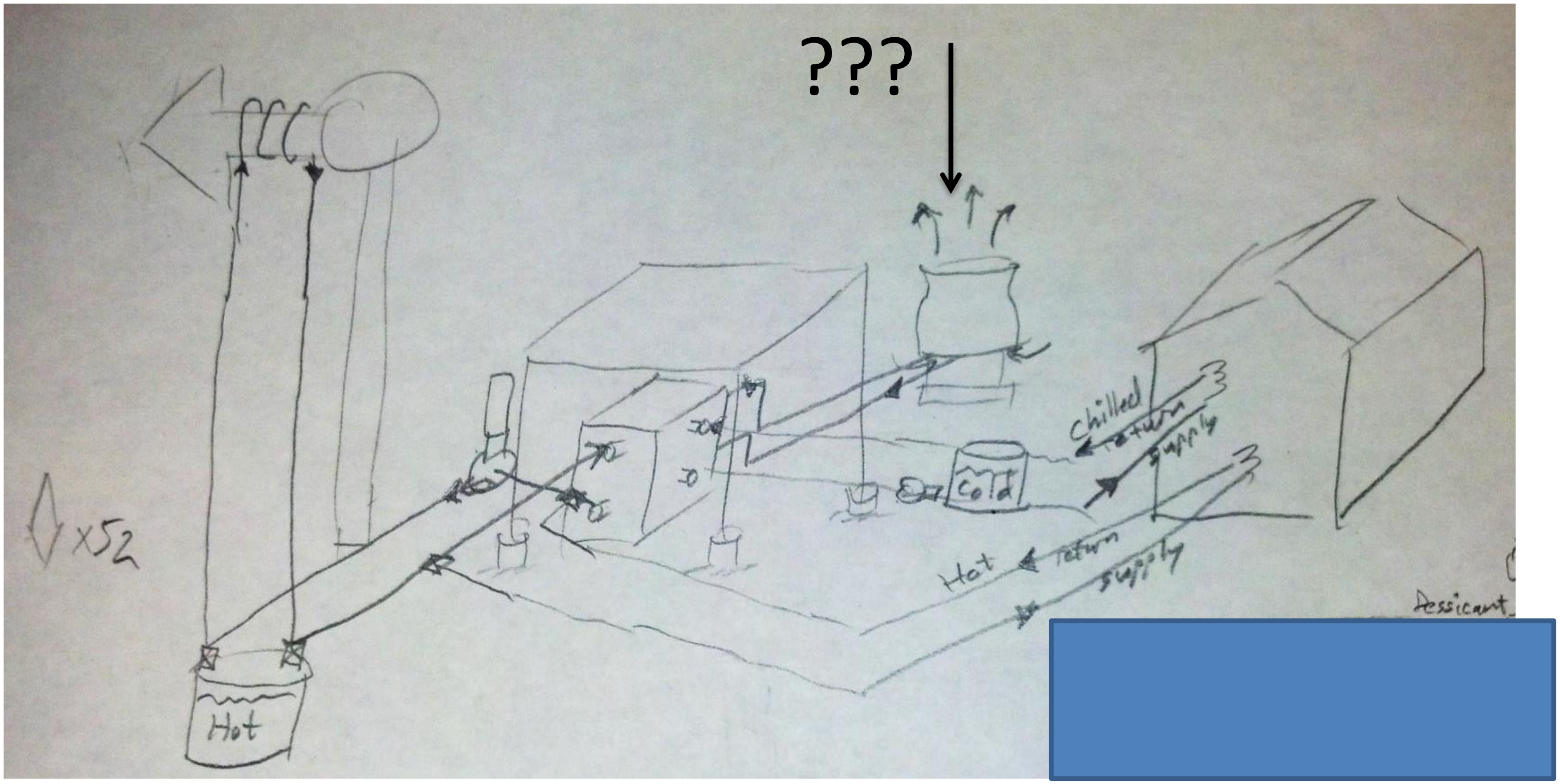
Given $\sum UA$, $x = \underset{t \in COTS, p \in P}{\operatorname{argmax}} \dot{Q}_{cool}$



Cooling technologies compared that deliver 10 °C chilled water (per Tulip)



Nick’s dissertation Chapter 2

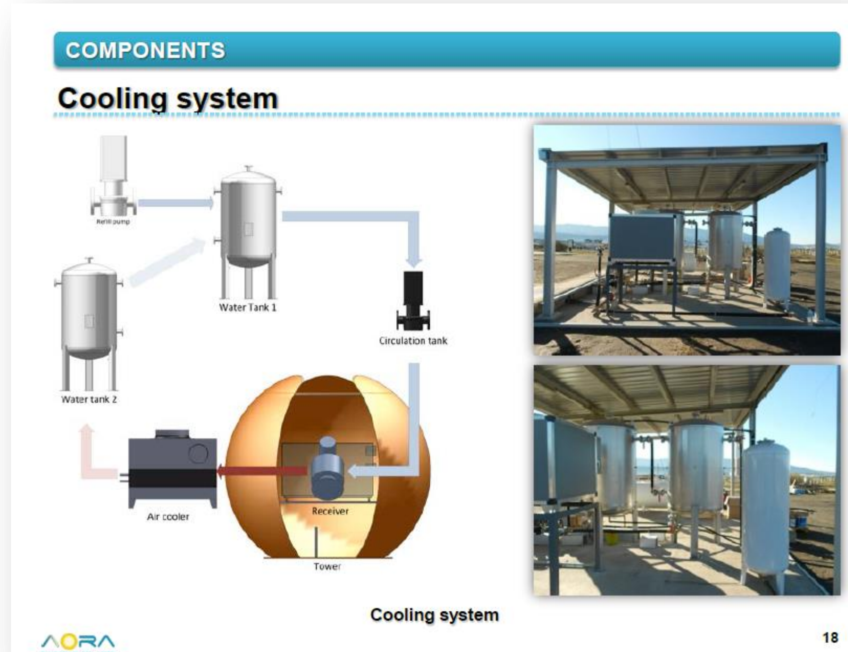


Existing spray cooling system

GREEN ENERGY, LOCAL POWER.

TULIP™ DST UNIT - FEATURES SUMMARY

- Nominal power output:
  - Electrical Power: 100kWe
  - Heat energy: 170kWt
- Powering capability/unit: 60-80 home community
- Assembly configuration: Modular units
- Maximum capacity: (# of units) x 100kW
- Operating mode: Hybrid (Sun only, Sun + fuel, Fuel only)
- Potential operating hours: 24/7 (hybrid mode)
- Footprint: 2,000 m²/unit (less than ½ acre)
- Fuel options: Natural gas, Diesel, Bio gas, Bio diesel, LPG
- Power distribution configurations:
  - Utility grid connection
  - Local grid connection
  - Stand alone plant
- Installation time: 6 months, first electricity produced
- Additional capacity: Easily accommodated, due to modularity
- Power disruption during expansion: None
- Operational water use: **Minimal; 230 l/MWh (when temperature is above 35ºC)**
- Options for use of available heat:
  - Space heating
  - Refrigeration
  - Air conditioning
  - Water desalination
  - Assistance for bio-gas generation



J. M. Duran, "AORA Solar's Tulip System: A hybrid solar thermal solution," 25 11 2013. [Online]. Available: http://www.iitj.ac.in/CSP/material/21dec/aora.pdf. [Accessed 02 11 2015].

AORA Solar Ltd., "Tulip Datasheet," 07 11 2012. [Online]. Available: http://aora-solar.com/wp-content/uploads/2012/01/DatasheetInfographic-MedRes.pdf. [Accessed 02 11 2015].

Heat rejection: evaporative technologies

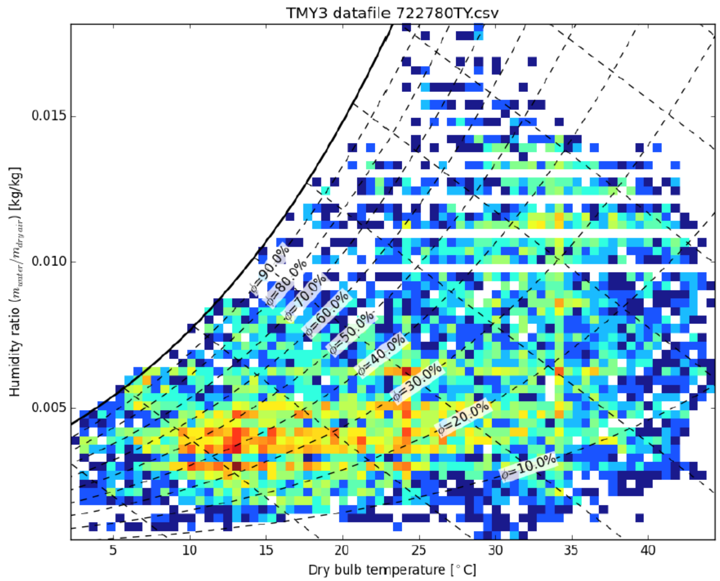


Figure 29. Probability distributions of ambient conditions calculated from TMY3 data for Phoenix [40].

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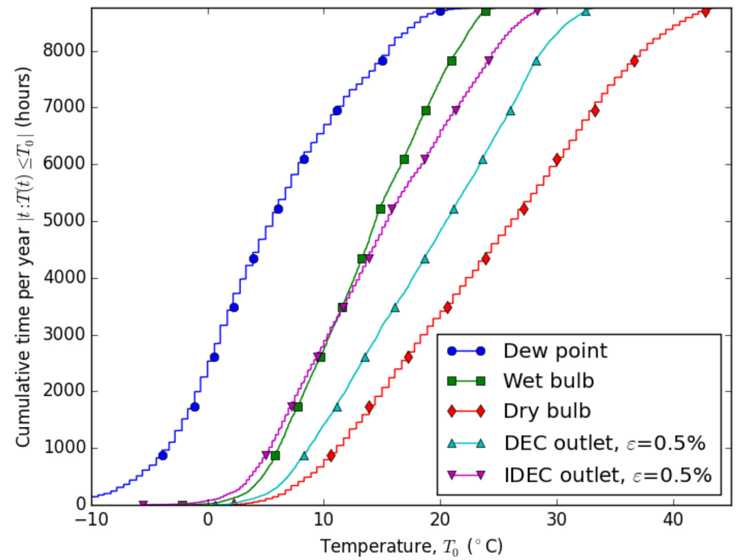

Figure 1. Probability distributions of some effective temperatures calculated from TMY3 data [30] for dry bulb and dew point, including direct evaporative cooler (DEC) and indirect evaporative cooler (IDEC).

Heat rejection: evaporative technologies

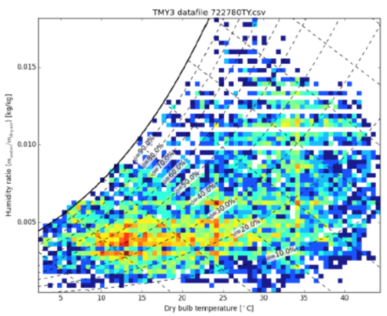

Figure 29. Probability distributions of ambient conditions calculated from TMY3 data for Phoenix [40].

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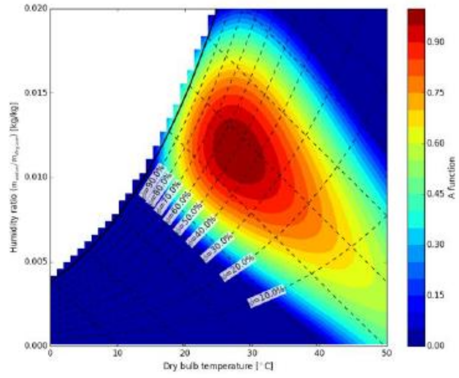

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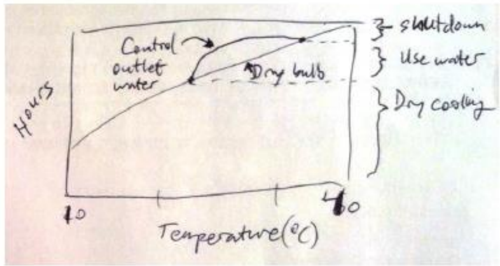

Figure 32. Possible probability distribution for cooled water outlet temperature resulting from control algorithm and simulation with historical data.

Heat rejection

Table 1-3
Tradeoffs Among Various Types of Cooling Systems

Tradeoff	**Cooling System Type**				
	Once-Through	**Wet Mechanical Draft**	**Dry Air-Cooled Condenser**	**Hybrid Wet/Dry**	
				Plume Abatement	**Water Conservation**
Water Consumption	Minor	8 to 12 gpm/MWe	~ 0 to <5% of wet tower	~ equal to wet tower	20% to 80% of wet tower depending on design
Capital Cost	<< **BASE**	**BASE**	1.5x to 3x base	1.1x to 1.5x base	3x to 5x base
O&M Cost	**< BASE** Pump maintenance, condenser cooling	Highly site specific; fan/pump power; water treatment; tower fill/ condensate cleaning	Finned surface cleaning; gearbox maintenance; fan power	Similar to **BASE**	Similar to **BASE**
Performance Penalty	< **BASE** Base penalty depends on site	**BASE**	Highly site specific—5% to 20%	~ Equal to base	Highly variable, depending on mode of operations

J. S. Maulbetsch, "Comparison of Alternate Cooling Technologies for California Power Plants: Economic, Environmental and Other Tradeoffs: Consultant Report," EPRI, California Energy Commission PIER, Atherton, CA, 2002.

Heat rejection

6.1. Hybrid ratio

Hybrid ratio is defined as the ratio of the heat that must be removed in dry section to the total cooling load:

$$H.R. = Q_{dry}/Q_{total} \quad (28)$$

Increase of H.R. causes the water loss to be reduced but dictates use of more heat transfer area in the dry section.

Table 11
Parallel arrangement (winter).

Hybrid ratio	0.2	0.4	0.6	0.8	1
Wet cooling load (MW)	147.691	110.768	73.846	36.923	0
Total water loss (m^3/h)	213.8	171	114.1	57	0
Required area (m^2)	22,510.4	45,022.1	67,539.9	89,996.8	112,556

Table 12
Series arrangement (winter).

Hybrid ratio	0.2	0.4	0.6	0.8
Wet cooling load (MW)	147.691	110.768	73.846	36.923
Total water loss (m^3/h)	220.8	176.5	124.5	77
Required area (m^2)	20,464.8	40,905.5	61,394.1	81,848.7

E. Rezaei, S. Shafiei and A. Abdollahnezhad, "Reducing water consumption of an industrial plant cooling unit using hybrid cooling tower," *Energy Conversion and Management,* vol. 51, pp. 311-319, 2010. http://dx.doi.org/10.1016/j.enconman.2009.09.027.

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3) Night-Sky Cooling

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3) Night-Sky Cooling

Explore night-sky cooling as a new HVAC possibility

What it is:
As Greg Allen, sustainable design strategist at HOK, Toronto, explains, night-sky cooling systems are almost the inverse of solar collectors. "Instead of collecting sunshine, they're losing heat back out to the outer atmosphere and beyond."

It's a technology that takes advantage of low night-sky temperatures to cool a building. "It's a nice tie-in between thermal energy storage and a chilled beam system. It's like the perfect marriage of those things," says David Callan, senior vice president, director of sustainable design and high-performance building technology, Syska Hennessy Group, Chicago.
(See *Chilled Beam System* and *Thermal Energy Storage*)

How it works:
As Ted van der Linden, director of sustainability for Redwood City, CA-based DPR Construction Inc., explains, a night-sky cooling system is essentially a rooftop sprinkler system. "Water is sprayed over a flat or sloping metal panel roof at night. Cooled by the night's temperature, the water is funneled through roof gutters and rainwater leaders, and then stored in a thermal storage tank to be used by the building's radiant cooling system, with tubing located in the floor slabs and ceiling panels."

By cooling the roof, you cool the entire structure, explains Erik Ring, director of MEP services at Irvine, CA-based LPA Inc. "It's possible to store that water for use the next day to cool the building. By spraying water on the roof at night, you're able to take advantage of the cold sky and let both the building and the sprayed water cool down in advance of the next day's cooling needs."

"Essentially, the mechanism is pretty simple. You spray the water on the roof, it exchanges energy with the night sky, you store it, and then it's available for use during the day," says Rob Bolin, senior vice president, Syska Hennessy Group, Chicago.

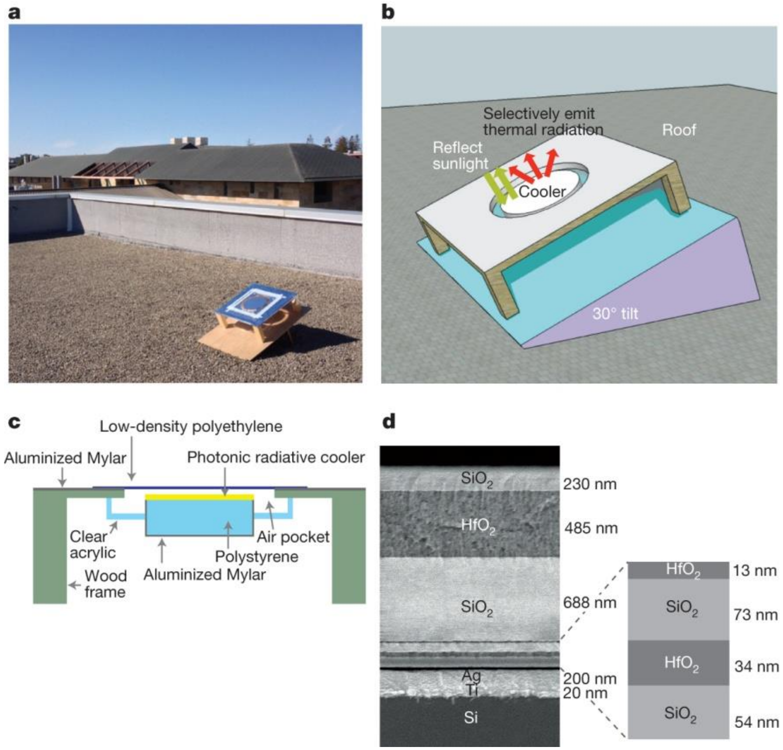
Benefits:

- These systems don't require the substantial infrastructure of larger HVAC systems (ductwork, chillers, etc.).
- Costs are "negligible" when compared to traditional systems, including the necessary radiant tubing or panels, according to van der Linden.
- Virtually no energy is needed to run night-sky cooling systems.

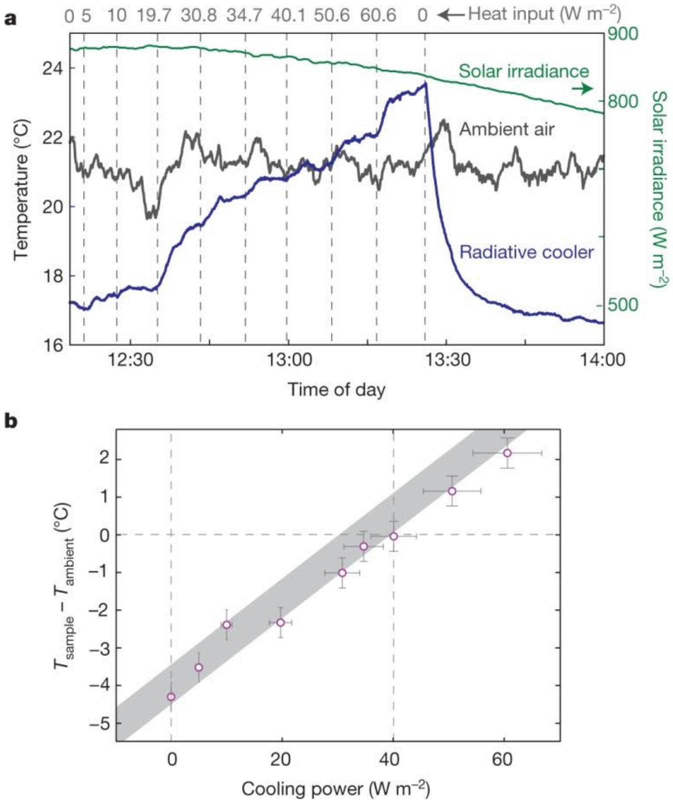
Drawbacks:

- Night-sky cooling relies heavily on the climate. High moisture content in the air, or cloudy weather, decreases system performance and reliability.
- "Water is still, in terms of the cost, competitive with a gallon of gasoline," says Bolin. Translation: Water conservation is an issue (although the sprayed water can be harvested and reused).
- Water quality can pose setbacks. "Building owners have a difficult enough time keeping scaling and calcium deposits out of their cooling towers.

Rooftop apparatus and photonic radiative cooler.



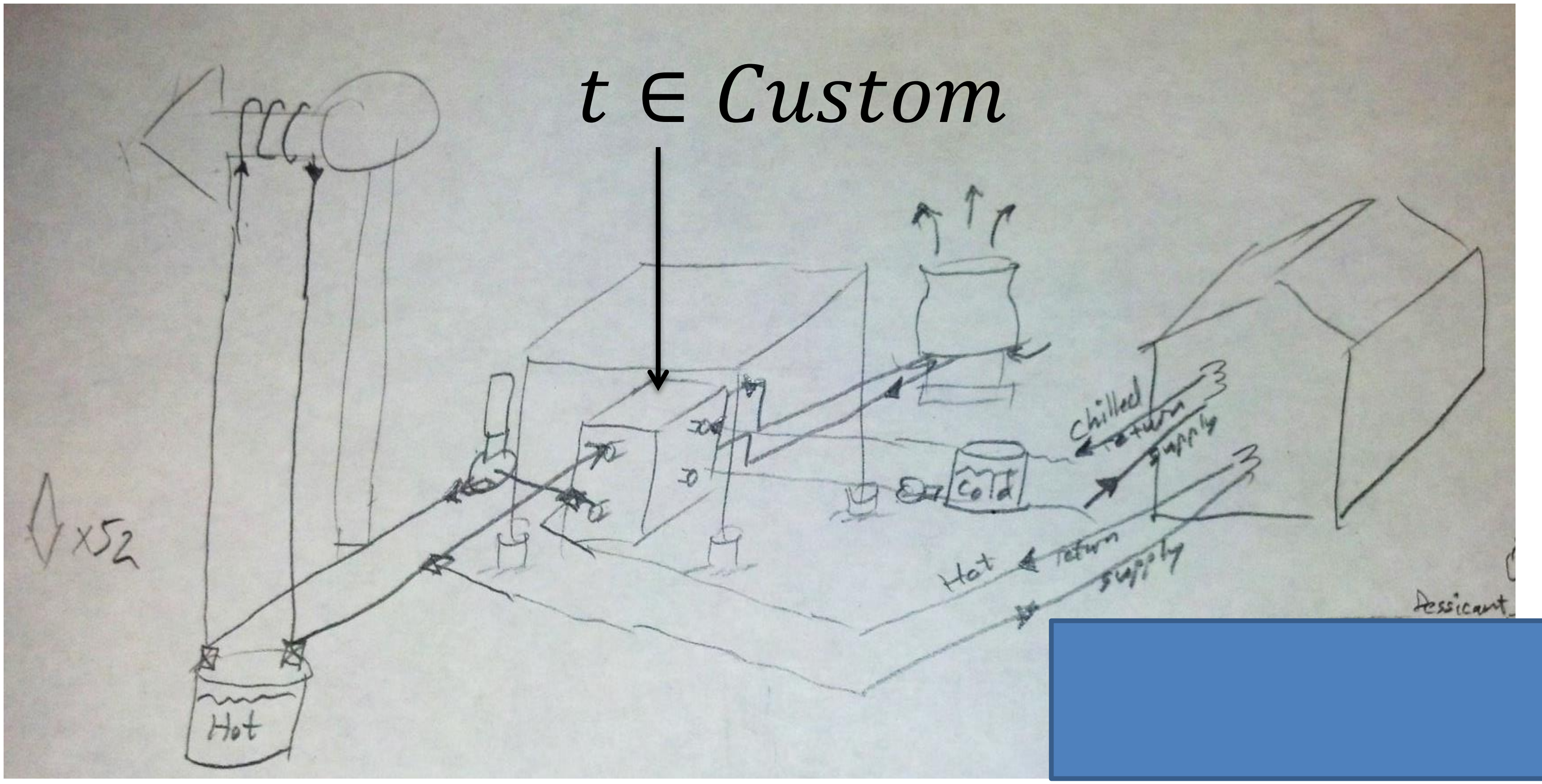
Cooling power of photonic radiative cooler.



AP Raman *et al.* *Nature* **515**, 540-544 (2014) doi:10.1038/nature13883

nature

Nick’s dissertation Chapter 1



Multiple chillers

Assume: exergetic efficiency of chiller = 37 %
(calculated based on Thermax LiBr single & double effect)

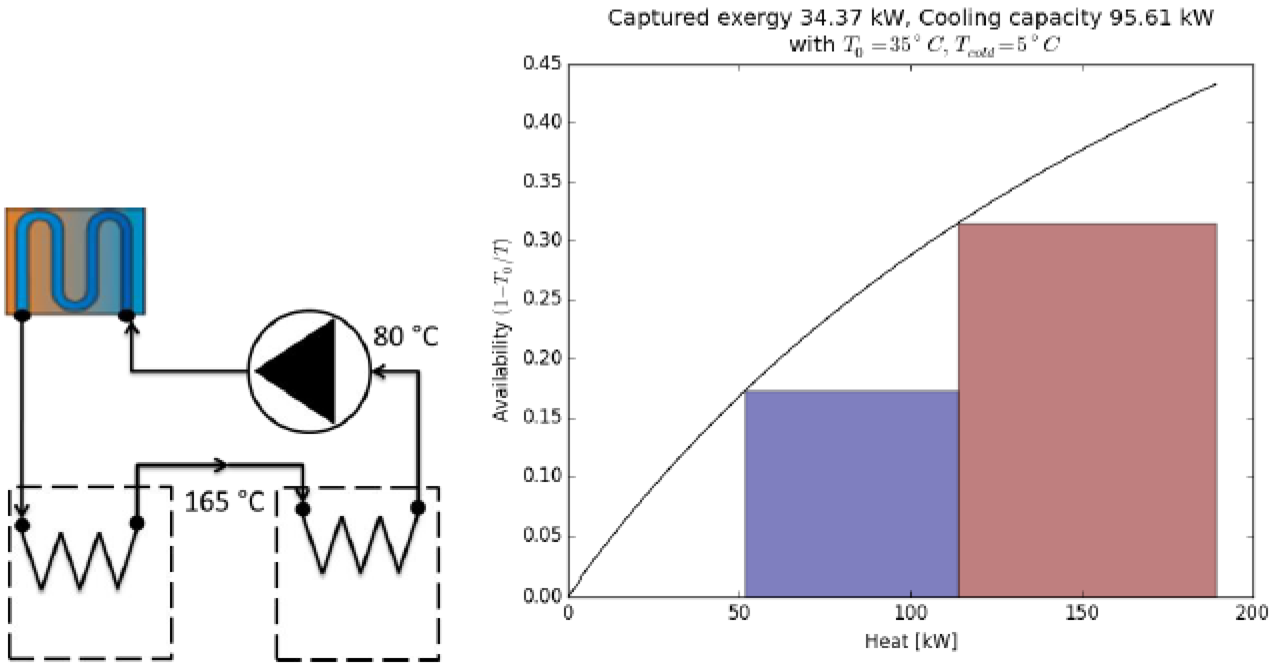


Figure 34. Multiple chillers drawing heat from heat source in series: conceptual schematic (left, not actual temperatures) and rescaled heat exchange diagram (right). Box areas show exergy supplied to the high effect chiller (red) and low effect (blue).

Multiple chillers: analytic result

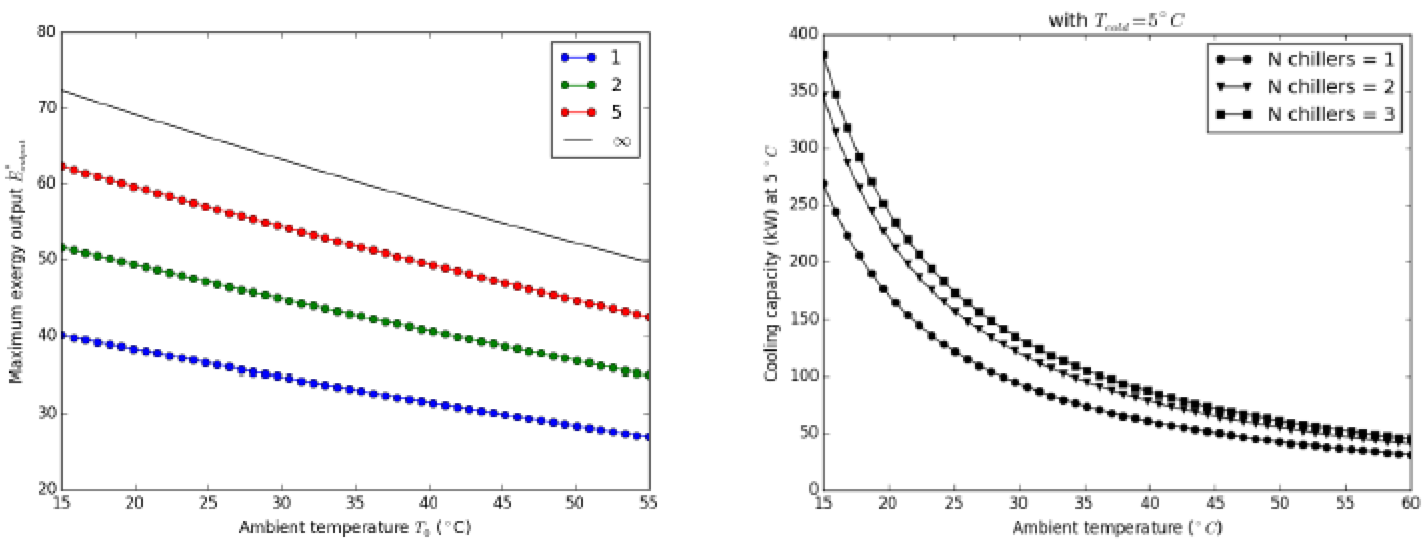


Figure 35. Multiple chillers: naïve model trends for optimal configurations.

High ambient temperature

Figure 1 Schematic diagram of the hybrid GAX-E absorption refrigeration system (see online version for colours)

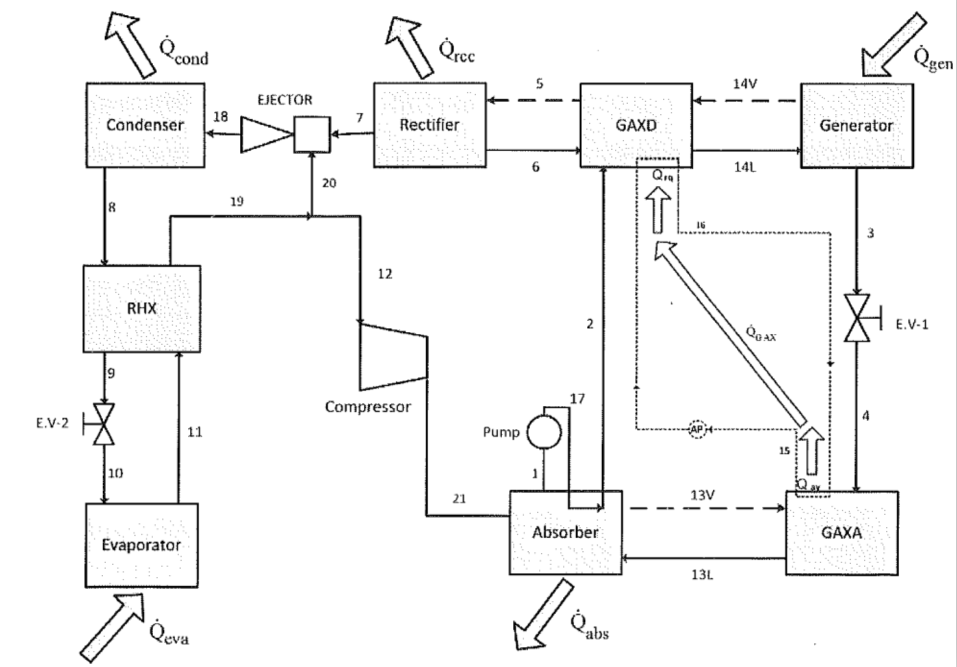


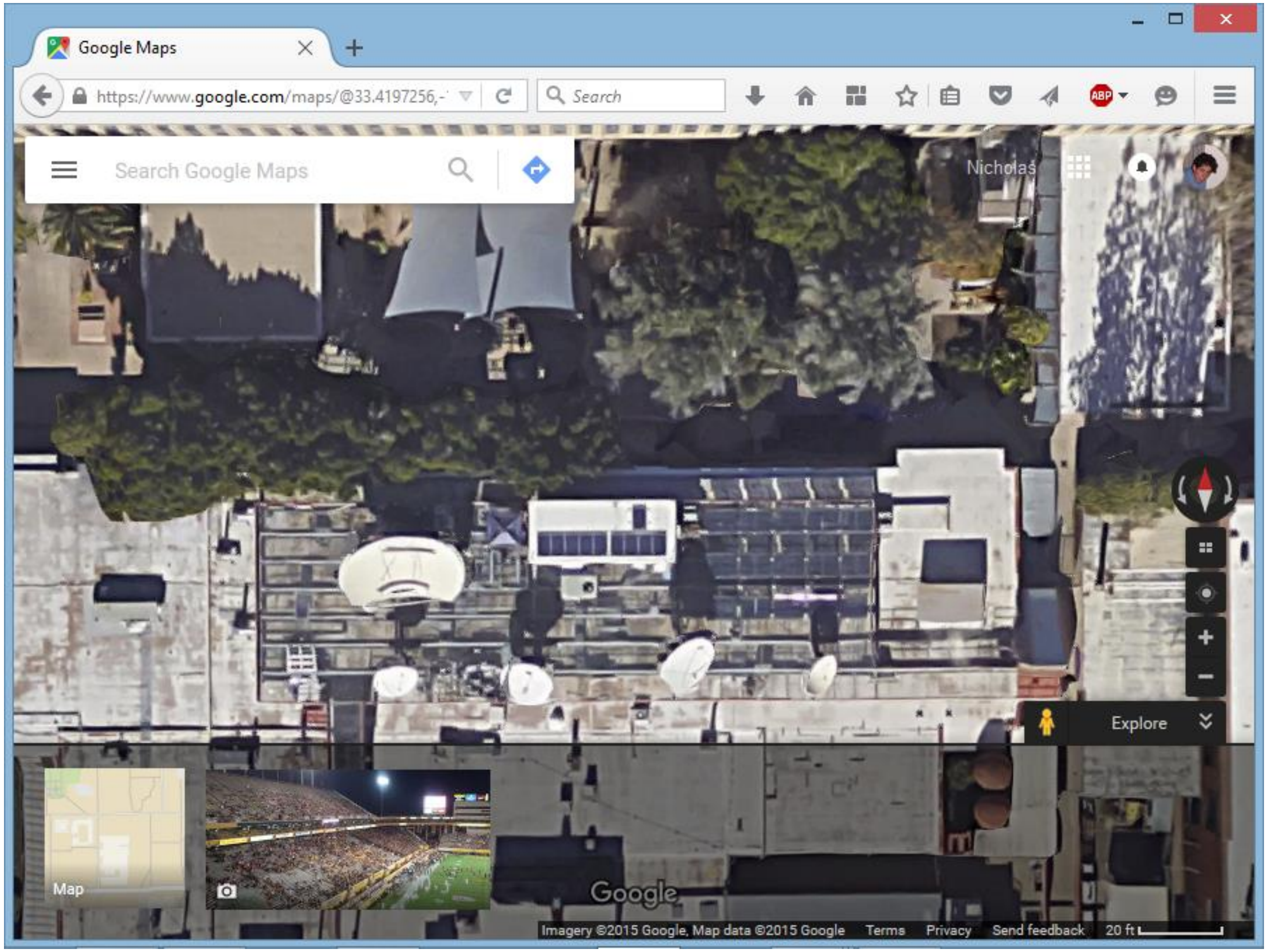
Figure 1. A cycle modified to recover energy from refrigerant expansion, from [40].

[40] A. Mehr, S. Mahmoudi, M. Yari and A. Soroureddin, "A novel hybrid GAX-ejector refrigeration cycle with an air-cooled absorber," *International Journal of Exergy,* vol. 13, no. 4, pp. 447-471, 2013.

Dynamic modelling users group?

- Modelica: a dynamic modelling language
- My application
  - Open source model (eventually dynamic) for absorption chiller
  - Requires: Open source library for properties (based on work from Spring, openACHP …)
- Other applications
  - Building controls optimization

Solar tea?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