Design guide for solar cooling with multi-effect absorption chillers – Draft Proposal for Discussion

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ENERGY TECHNOLOGY
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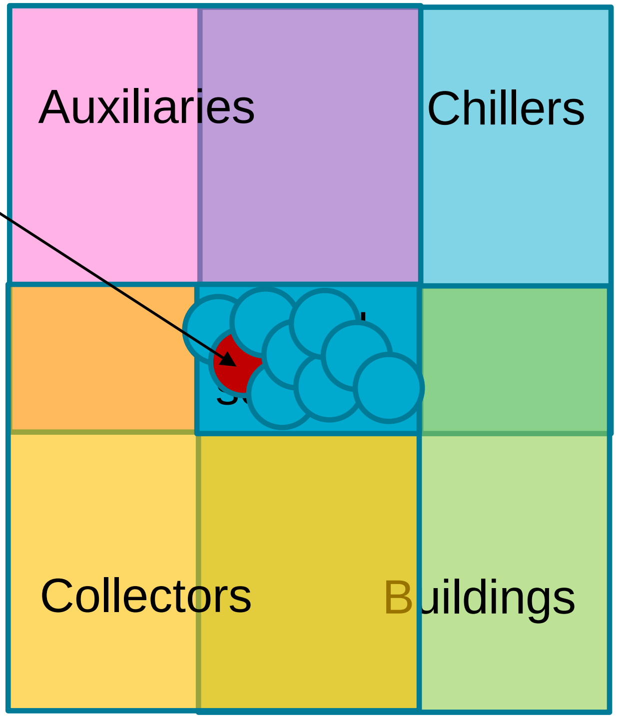
Philosophy/ Aim

- One good solution (of many)
- A complete description.... but limited to
  - A set of scenario constraints (climate, HVAC need) *and*
  - A set of technology constraints (chiller, collector, auxiliaries)
- Likely to be relatively cost effective
- Something that designers could copy with confidence



Advantage of multi-effect absorption chillers

Chiller type	$COP_{thermal}$	Heat Required (kWh/kWh)	Collector Area (% of single effect, 70% DNI)	Heat Rejection (kWh/kWh)
V/C Chiller	~6	na	na	1.17
Single effect	~0.7	1.43	100%	2.43
Double effect	~1.2	0.83	83%	1.83
Triple effect	~1.6	0.63	63%	1.63

Gas as a backup heat source ?

Energy Source	Energy Source Carbon Intensity	Chiller	Chiller COP	Refrigeration Carbon Intensity*
Coal fired	[illegible]	Vapour [illegible]	[illegible]	0.22 kg/kWh$_{refrig}$ [illegible]sitic [illegible]umps)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]sitic [illegible]umps)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]sitic [illegible]umps)
Solar	Nil (parasitic electricity only)	Double Effect Absorption Chiller	1.2	0.07 kg/kWh$_{refrig}$ (parasitic power only)
Solar	Nil (parasitic electricity only)	Triple Effect Absorption Chiller	1.6	0.06 kg/kWh$_{refrig}$ (parasitic power only)

* Parasitic electricity: (i) 0.03 kWh/kWh heat rejected for running the cooling tower pumps & fans + (ii) 0.01 W/W of cold for the absorption chiller

- High solar fraction not required
- Flexibility to run in gas only mode as often/long as required
  - *Undersize collector area*
  - *Continuous chiller operation without large thermal storage/ buffer requirement*

Gas fired chiller with solar boost

!!

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High temperature heat transfer

	Thermal Oil	Pressurized Hot Water

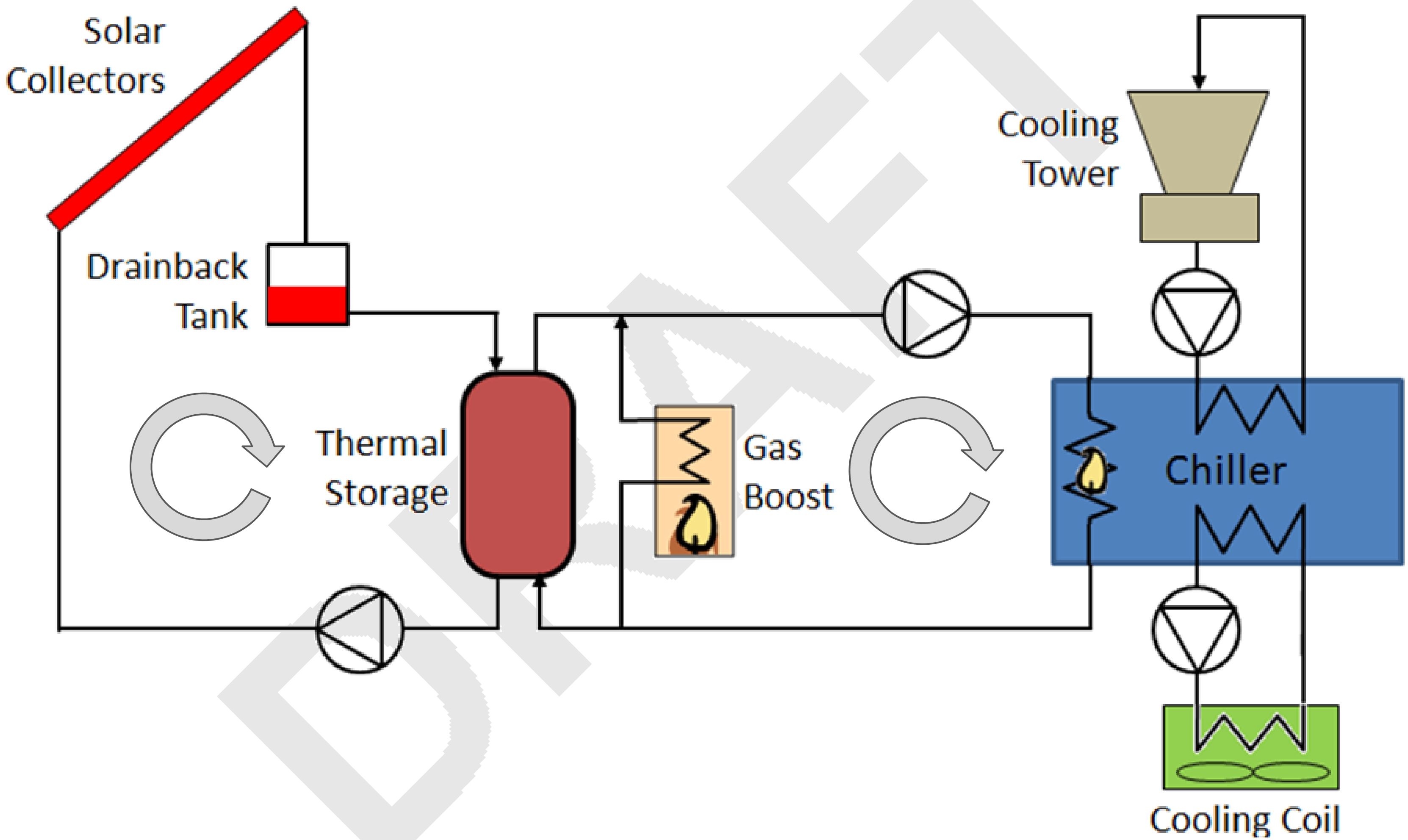
Advantages	• Atmospheric pressure
	• Frost protection
		• Potential for one fluid system/ No secondary heat exchangers
		  o Lower cost
		  o Higher collector efficiency
		  o No temperature reduction over secondary heat exchangers
		  o Less fluid streams to pump/ less parasitic pumping power
		• High heat transfer coefficients
		• Low cost, environmentally friendly fluid

Disadvantages	• Cost of fluid • Environmental management of possible leakage • Large difference in viscosity over the expected temperature range • Not recommended for direct use in the absorption chiller (requires an extra heat exchanger to transfer heat to hot water) • Effects, on the oil, of contamination with water and air	• Must comply with pressure vessel/ steam codes • Frost protection required

The proposed solution

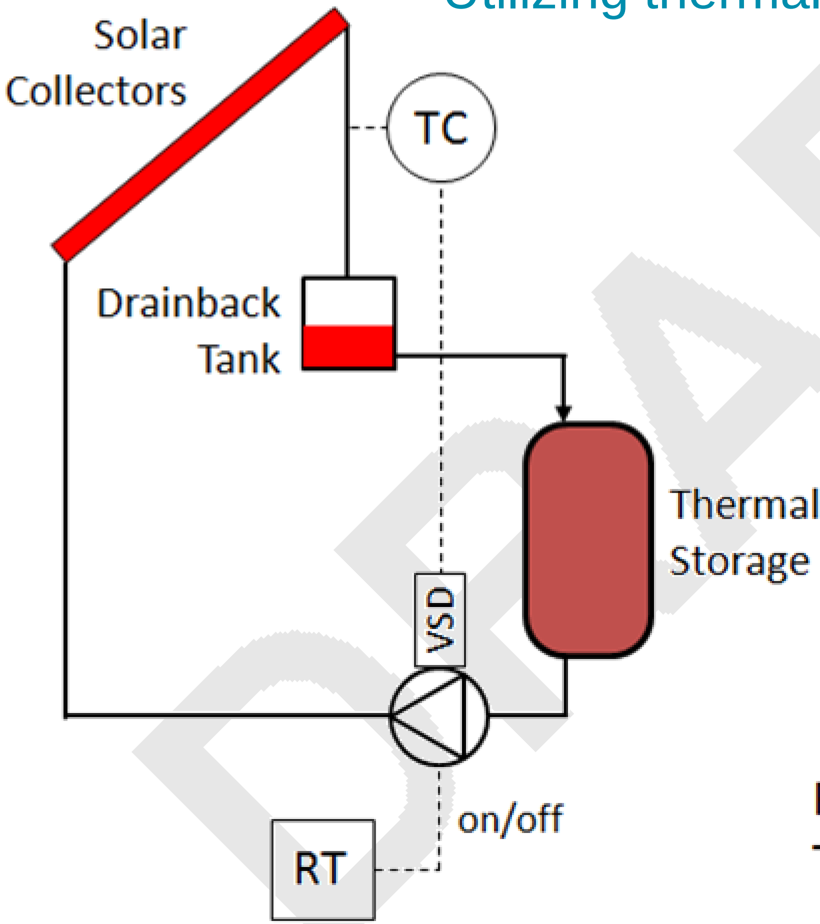
Criteria	Application Description/ Limits
Chiller technology	Double or triple effect absorption chiller
Solar collector technology	Concentrating solar thermal collectors (linear Fresnel, parabolic trough or other high efficiency non-imaging concentrating collector)
Fluid handling media	Pressurised hot water, with hot water buffer storage
Heat rejection technology	Wet cooling tower
Backup cooling technology	Gas burner (either separate or integrated in with the chiller). This design guide should <u>not</u> be used if some other backup or autonomous solar approach is intended.
Size	At least $500kW_{refrigeration}$
Climate	At least 1.3 MWh/m^{2}year of DNI solar radiation

The proposed flow sheet



Solar control strategy

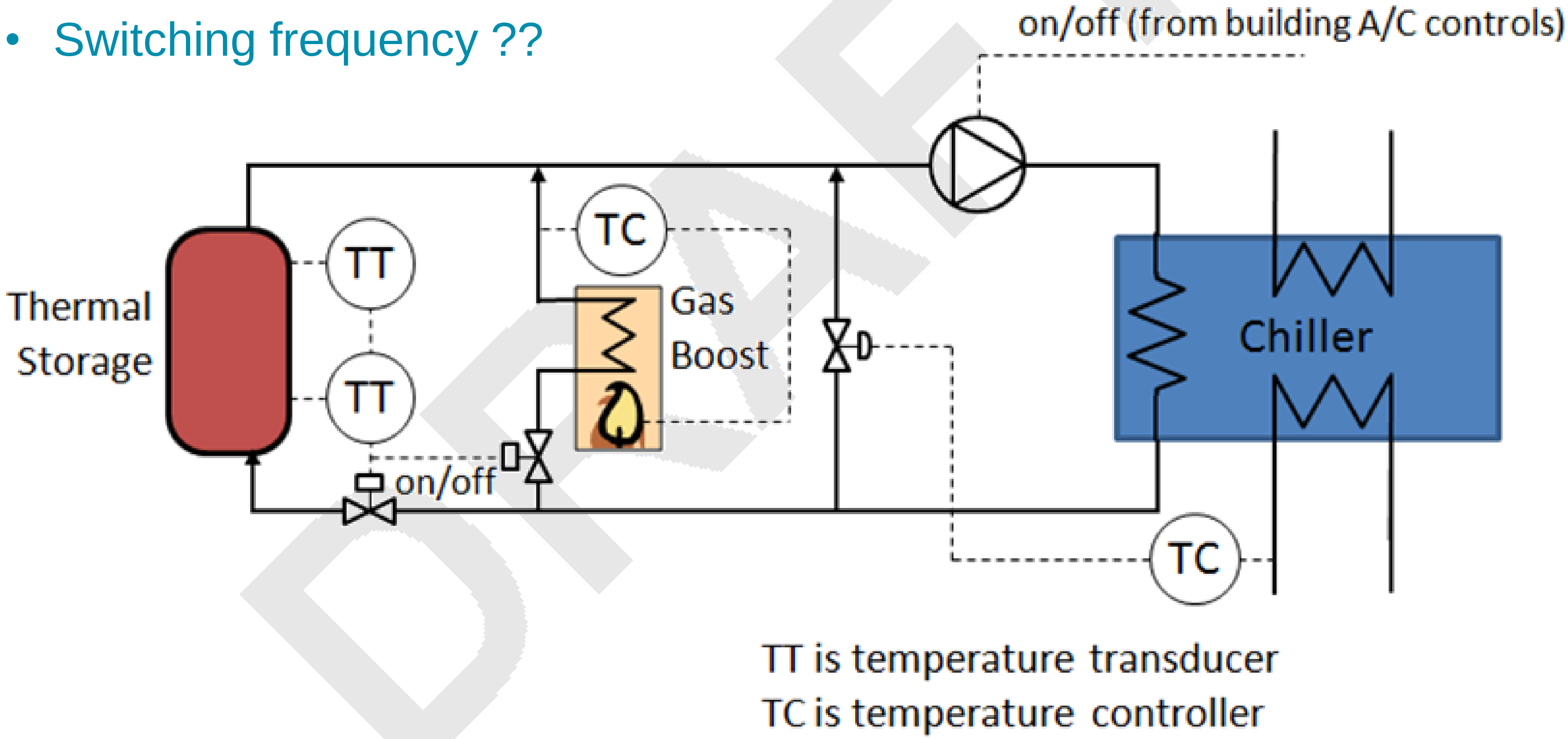
- Chiller always gets design heat source temperature
- Utilizing thermal stratification



RT is solar radiation transducer
TC is temperature controller

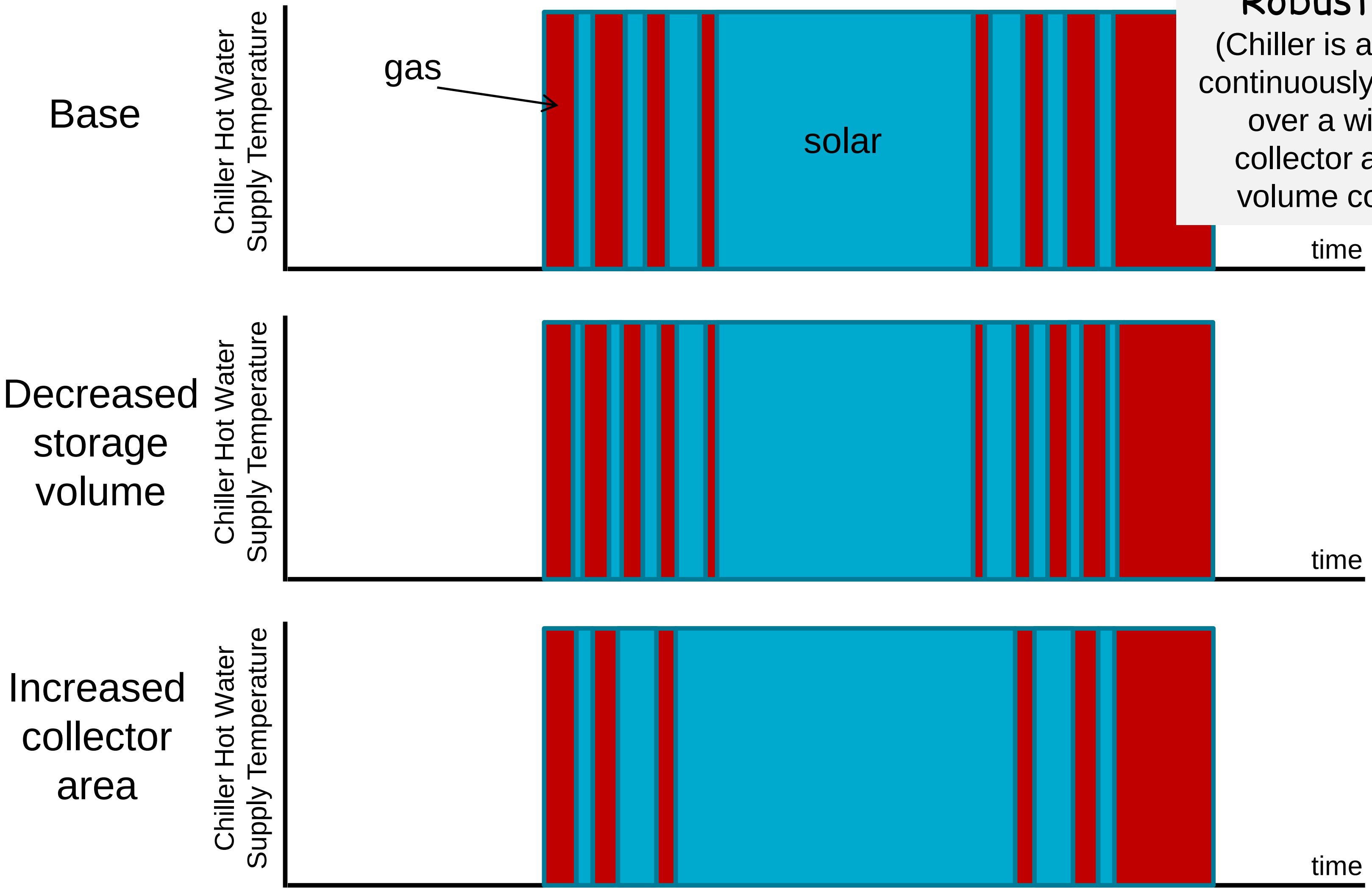
Chiller control strategy

- Chiller always gets design heat source temperature
- Chiller can always deliver name plate capacity
- Gas does not interfere with solar collection
- Switching frequency ??



Illustrative control strategy function

Robust solution:
(Chiller is able to operate continuously at full capacity over a wide range of collector area/ storage volume combinations)



Draft design performance checklist

Item	Performance Specification
Absorption Chiller	COP>1.2 at T_{CHW} = 7°C and T_{CW} = 30°C P_{elec} < 0.01 W_{elec} /W_{cool} excl pumps & fans
Collectors	2^e chiller η >70% @ T_{amb} = 30°C, T_{HW} = 170°C and DNI = 900 W/m^2 3^e chiller η >65% @ T_{amb} = 30°C, T_{HW} = 210°C and DNI = 900 W/m^2 At top 1/10th radiation intensity the collectors will not provide more than the rated heat required by the absorption chiller Parallel rows, with east-west tracking, and axis of orientation aligned at an azimuth of less than 20° from due North Pressure drop across each balancing valve shall be no more than 25% of the total collector pump head

Draft design checklist (con)

Item	Performance Specification
Thermal storage tank	Minimum volume equal to 15 minutes of continuous flow of the pressurized hot water to the absorption chiller Length to diameter ratio between 2 and 4 and mounted in the vertical orientation. Tank to contain perforated baffles at fluid entrances to promote stratification Tank insulation to give overall heat loss coefficient < 1. 5W/m^{2}K
Drain back tank	Tank to be mounted below the solar collectors and above the thermal storage tank (or incorporated into storage tank), with a continuous drainage gradient. Tank should be located in a space where it can reasonably be expected that temperatures will not go below freezing. Volume sufficient to maintain a liquid level during operation and not overflow when the collectors empty into the tank Tank insulation to give overall heat loss coefficient < 1.5W/m^{2}K.

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Draft design checklist (con)

Item	Performance Specification
Solar flow loop pump	Centrifugal pump with pressure head < 10m Pumping efficiency > 50% at design flow Pump to have a variable speed drive, controlled to achieve a constant return temperature from the solar collectors. The pump to be able to operate at temperatures up to 220°C. The pump shall not have a non return valve at the discharge (to facilitate drain back)
Chiller flow loop pump	Centrifugal pump Pressure head < 10m Pumping efficiency > 50% at design flow The pump to be able to operate at temperatures up to 220°C.

Draft design checklist (con)

Item	Performance Specification
Cooling water flow loop pump	Centrifugal pump Pressure head < 15m Pumping efficiency > 50% at design flow
Cooling tower fan	Motor to have a variable speed drive isentropic efficiency > 60% at design flow

Process and instrumentation drawing

tba

Safety checklist

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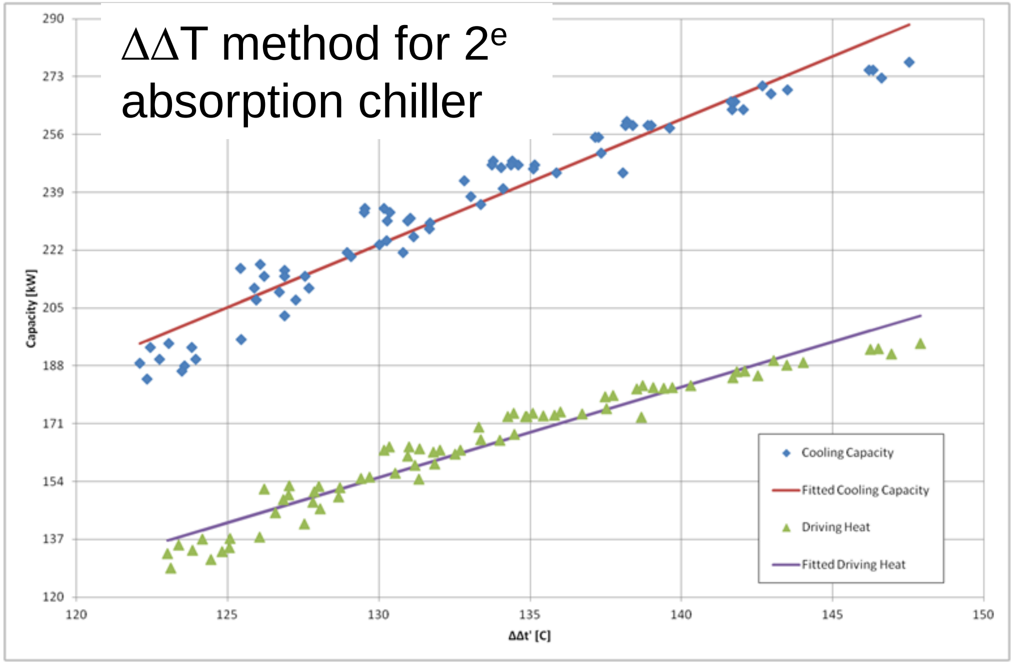
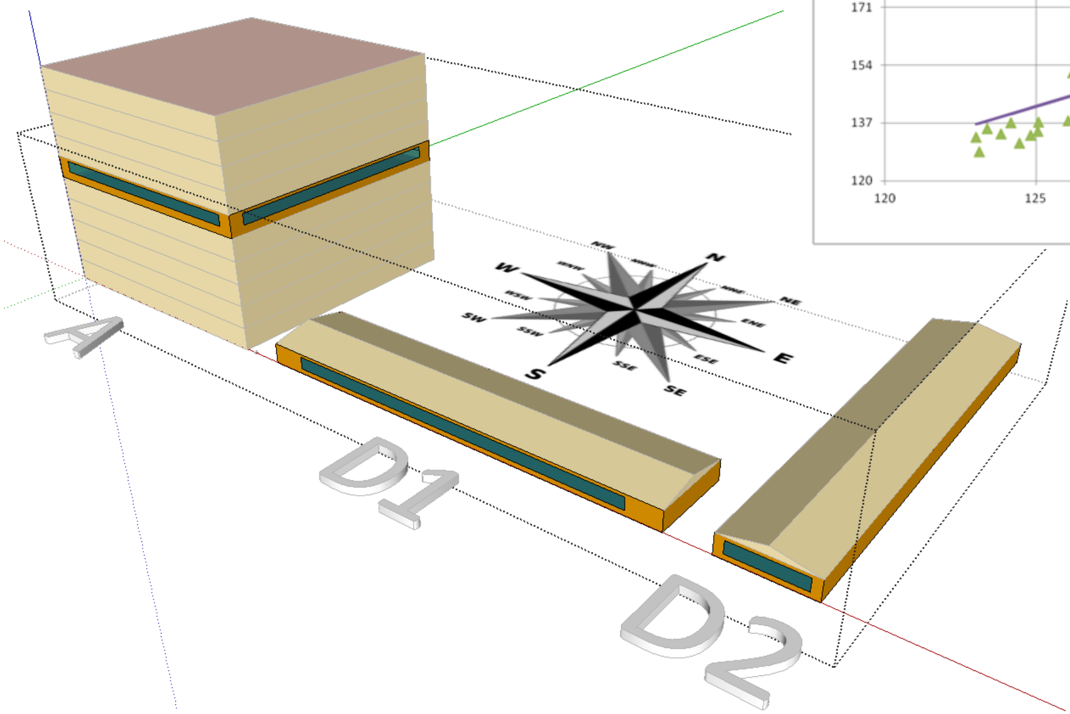
TRNSYS Design

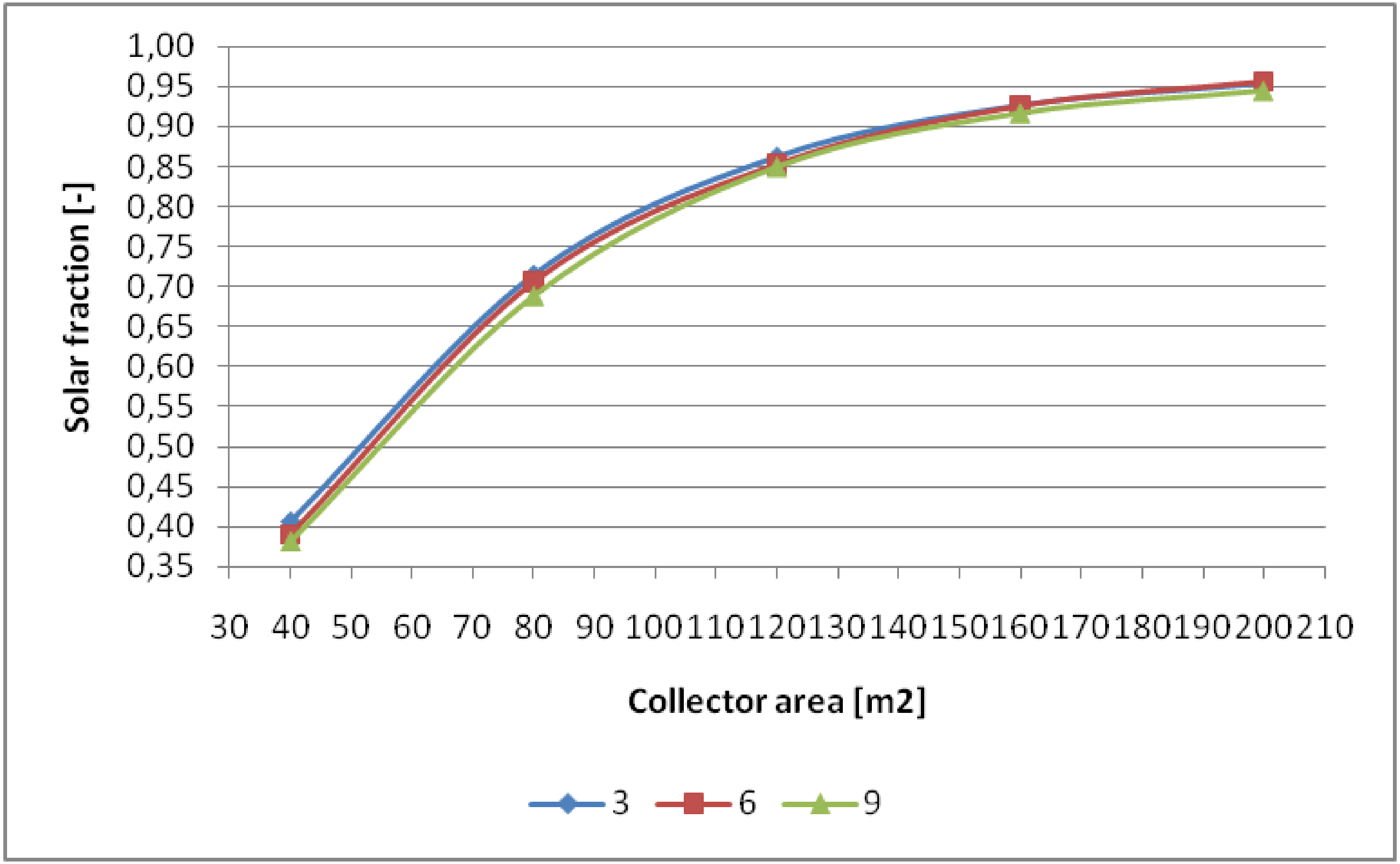
$\Delta\Delta T$ method for 2e absorption chiller



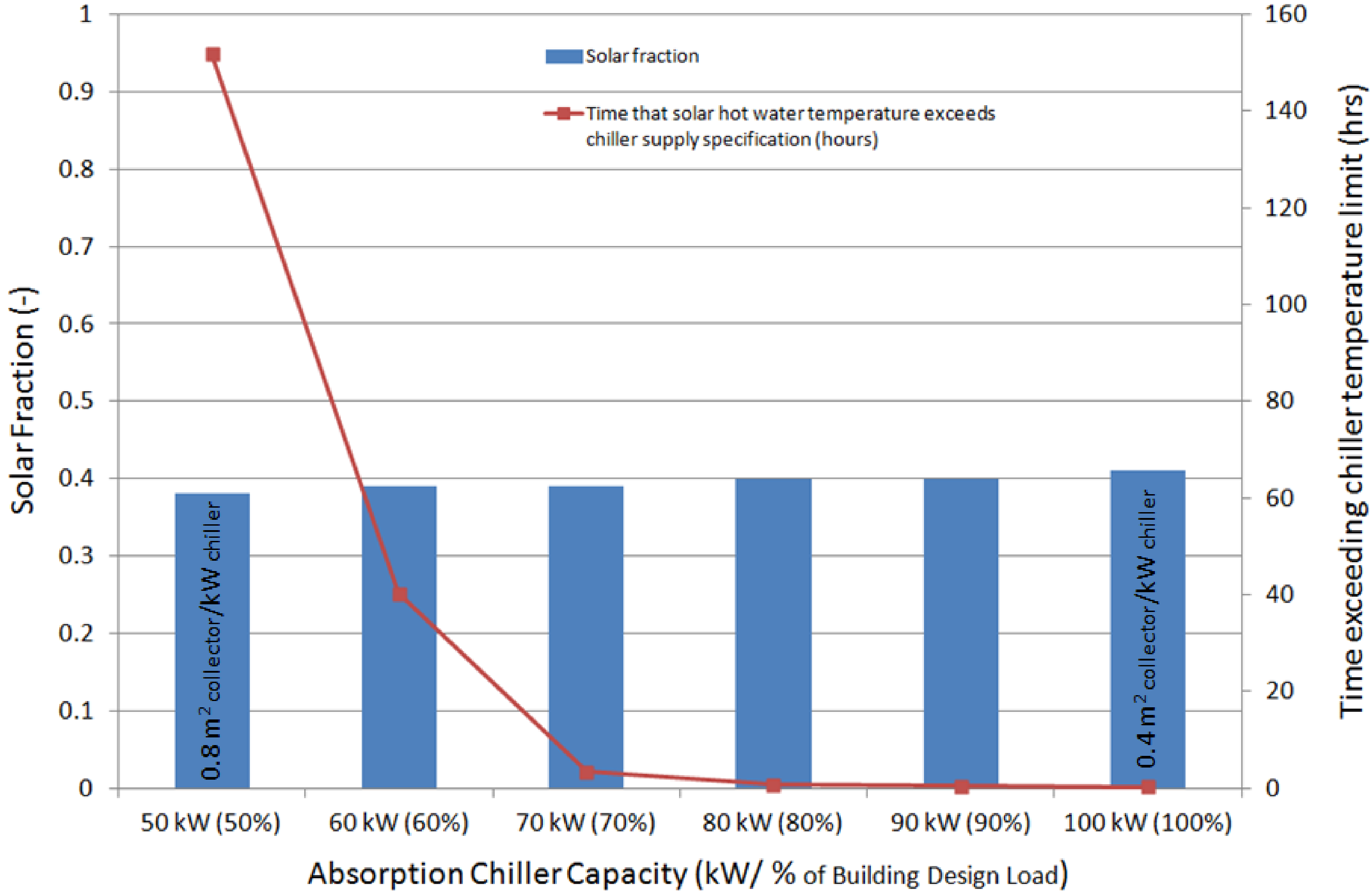
3 Building designs
4 Climates



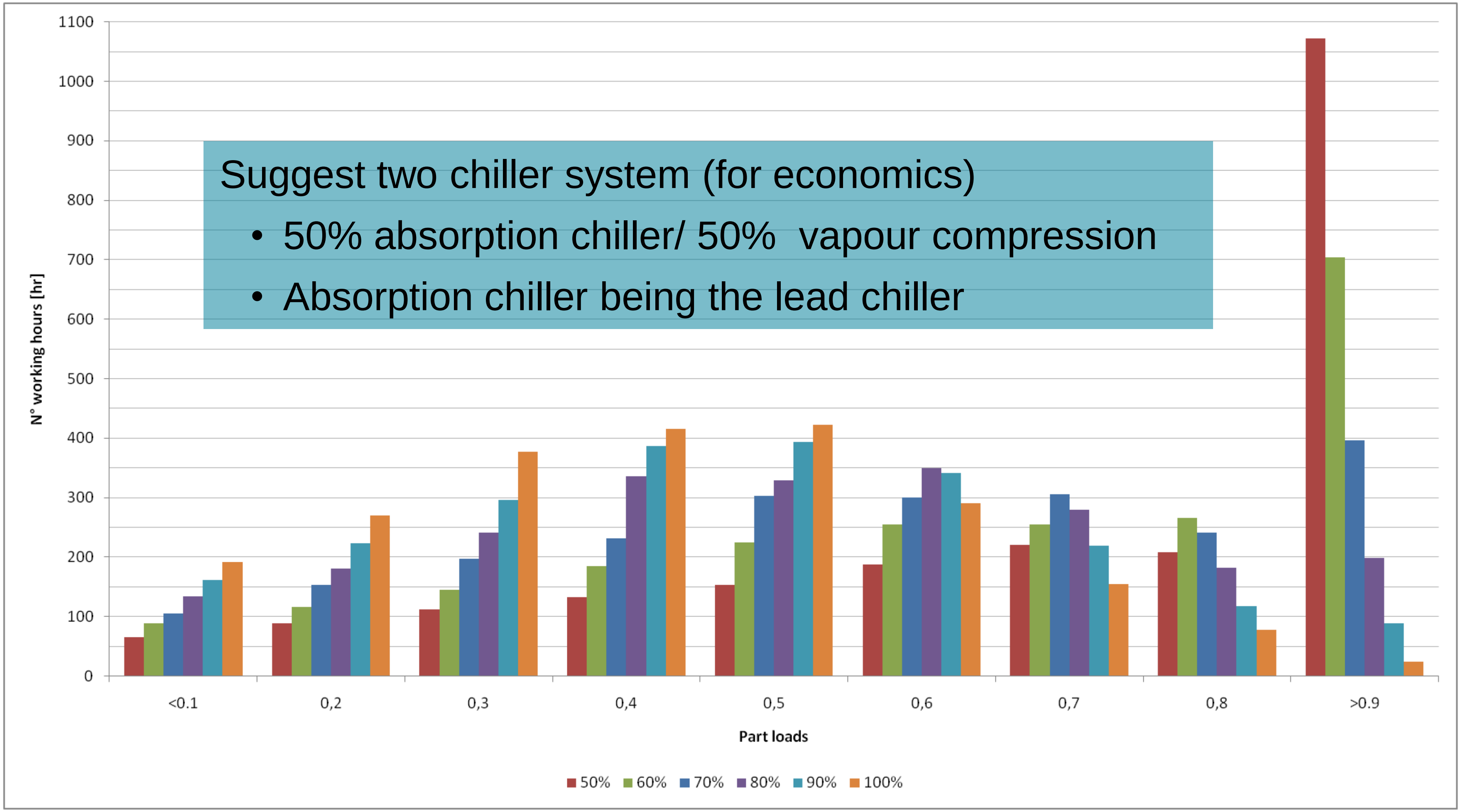
Adelaide, building A results



Reducing chiller capacity at 40m² collector area



Chiller utilization at reduced capacity



Thank you

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