Opportunities for Reduced Scale Solar Cooling Solution in Qatar

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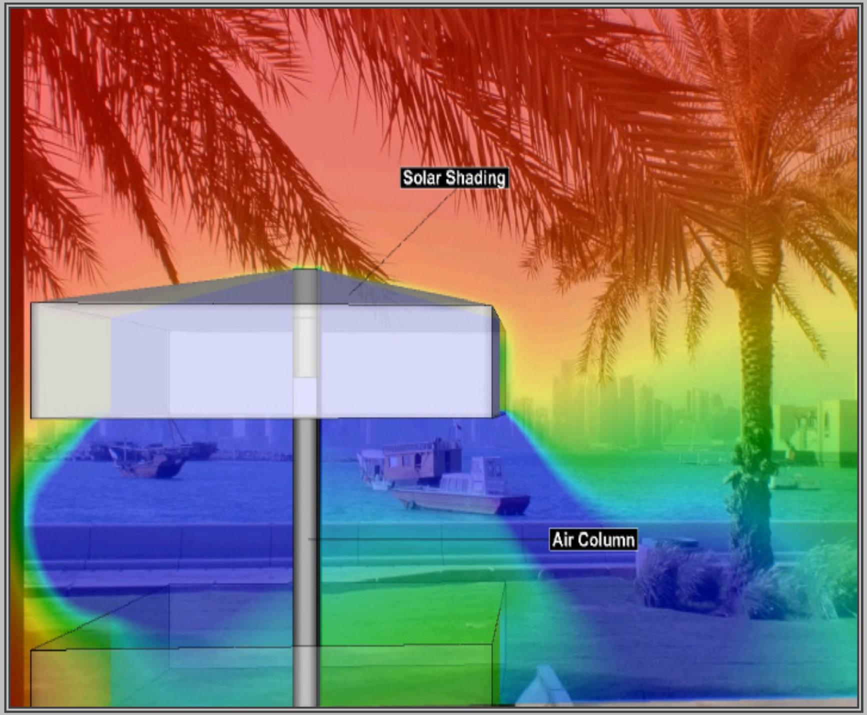


Intent

- Suggesting ideas for a sustainable and reduced scale solar cooling solution for outdoor park in Qatar.
- Viability engineered solution that meets frequently the operational constraints in an economic manner.

Challenges: Temperature & Humidity

Doha

ANNUAL HEATING AND HUMIDIFICATION DESIGN CONDITIONS

Coldest Month

January	
WindSpeed 0.4%	35.9 kph
MC DryBulb 0.4%	18.8 °C
WindSpeed 1.0%	32.8 kph
MC DryBulb 1.0%	19.1 °C

Heating

DryBulb 99.6%	11.1 °C
DryBulb 99.0%	12.6 °C
MC Wind to 99.6% DryBulb	
MC Wind Speed	12.4 kph
PC Wind Direction	290

Humidification

DewPoint 99.6%	-0.6 °C
HumidityRatio 99.6%	3.6 g/kg
MC DryBulb 99.6%	26.9 °C
DewPoint 99.0%	1.7 °C
HumidityRatio 99.0%	4.3 g/kg
MC DryBulb 99.0%	26.2 °C

ANNUAL COOLING, DEHUMIDIFICATION, AND ENTHALPY DESIGN CONDITIONS

Hottest Month

July	
DryBulb Range	10.3 °C
MC Wind to 0.4% DryBulb	
MC Wind Speed	-9.8 °C
PC Wind Direction	350

Cooling

DryBulb 0.4%	43.7 °C
MC WetBulb 0.4%	22.1 °C
DryBulb 1.0%	42.3 °C
MC WetBulb 1.0%	22.4 °C
DryBulb 2.0%	41.2 °C
MC WetBulb 2.0%	22.7 °C

Evaporation

WetBulb 0.4%	31.1 °C
MC DryBulb 0.4%	35.2 °C
WetBulb 1.0%	30.5 °C
MC DryBulb 1.0%	34.8 °C
WetBulb 2.0%	29.9 °C
MC DryBulb 2.0%	34.4 °C

Enthalpy

Enthalpy 0.4%	123.7 kJ/kg
MC DryBulb 0.4%	35.3 °C
Enthalpy 1.0%	121.0 kJ/kg
MC DryBulb 1.0%	34.4 °C
Enthalpy 2.0%	117.9 kJ/kg
MC DryBulb 2.0%	34.3 °C

Dehumidification

DewPoint 0.4%	30.1 °C
HumidityRatio 0.4%	27.4 g/kg
MC DryBulb 0.4%	34.1 °C
DewPoint 1.0%	29.3 °C
HumidityRatio 1.0%	26.2 g/kg
MC DryBulb 1.0%	33.7 °C
DewPoint 2.0%	28.9 °C
HumidityRatio 2.0%	25.5 g/kg
MC DryBulb 2.0%	33.6 °C

EXTREME ANNUAL DESIGN CONDITIONS

Extreme Annual

WindSpeed 1.0%	38.9 kph
WindSpeed 2.5%	34.3 kph
WindSpeed 5.0%	30.4 kph

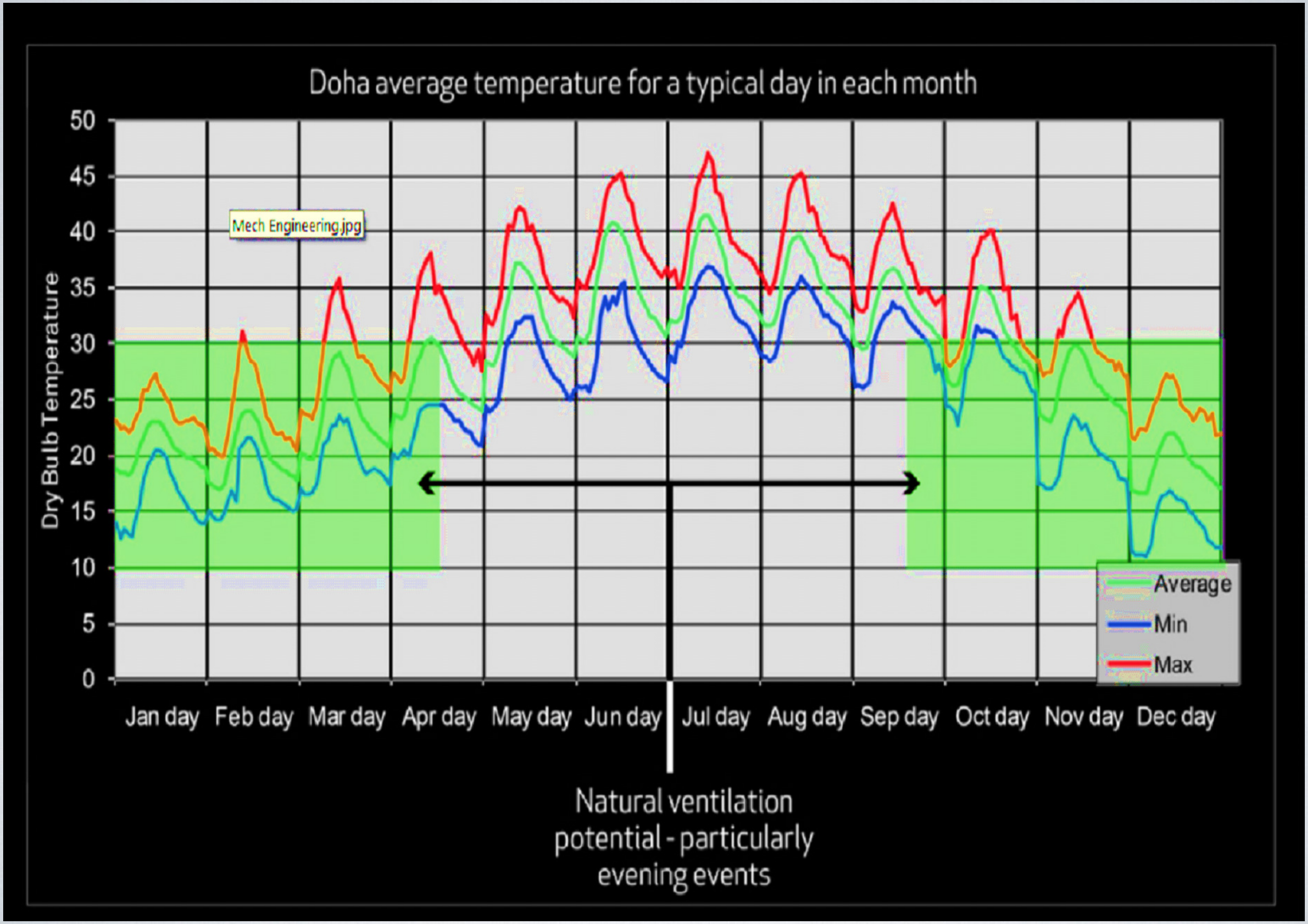
Extreme Annual

WetBulb Max	33.9 °C
DryBulb Mean Max	46.8 °C
DryBulb Mean Min	9.0 °C
DryBulb StdDev Max	0.8 °C
DryBulb StdDev Min	1.7 °C

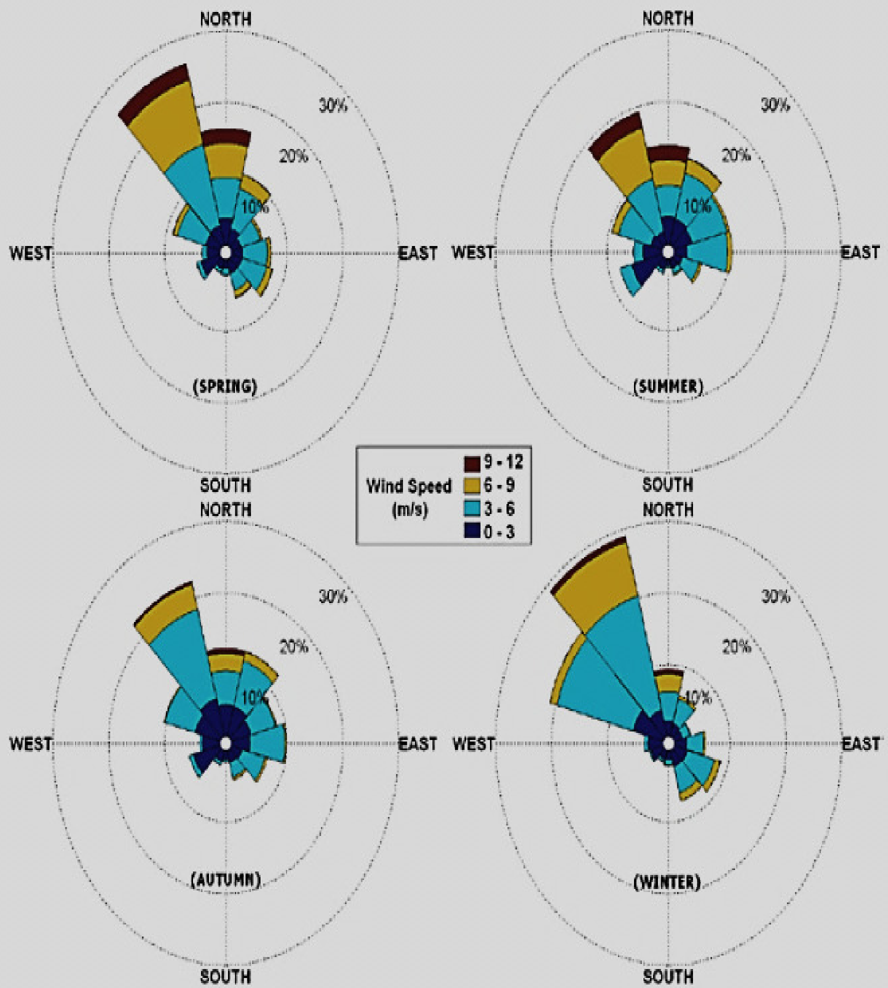
Extreme DryBulb Over Period

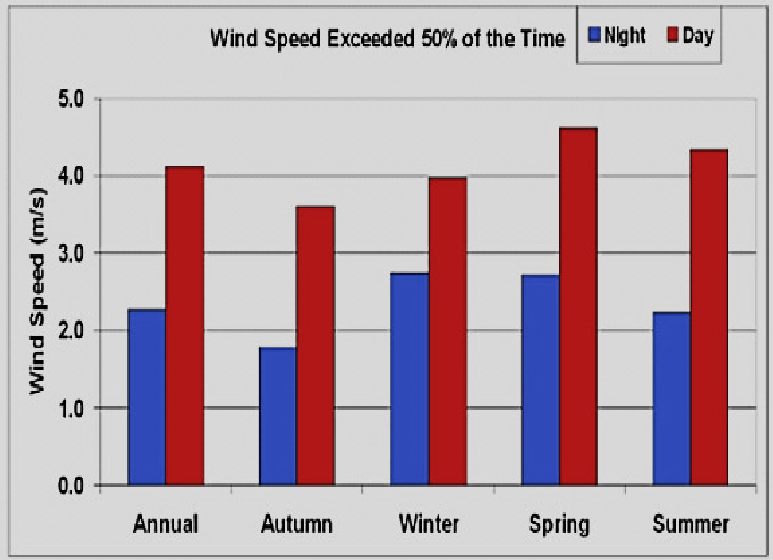
5 Year Max	47.4 °C
5 Year Min	7.8 °C
10 Year Max	47.8 °C
10 Year Min	6.8 °C
20 Year Max	48.3 °C
20 Year Min	5.8 °C
50 Year Max	48.9 °C
50 Year Min	4.6 °C

Challenges: Temperature



Challenges: Wind





Solar Data

Solar Radiation Data

Table 3. Monthly Averaged Direct Normal Radiation (kWh/m^2/day)

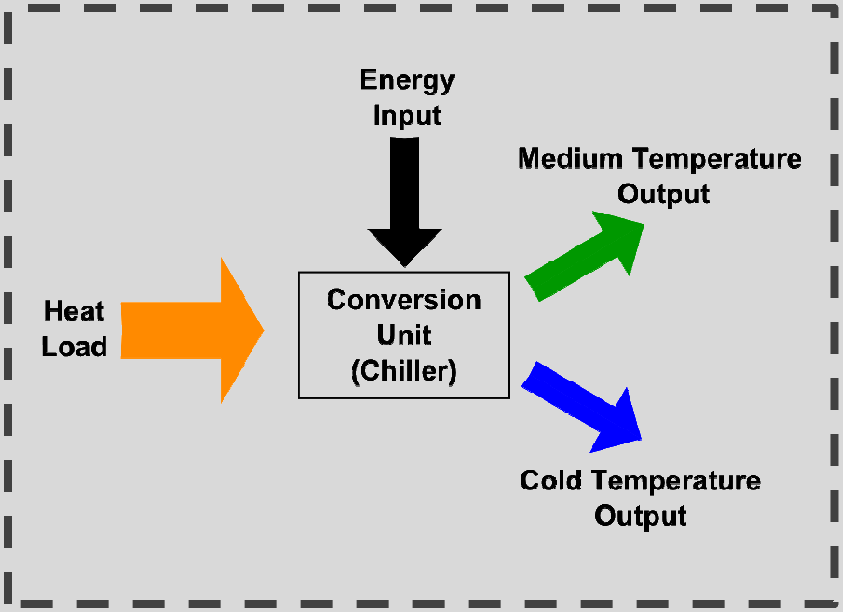
Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual Average
5.04	5.68	5.75	6.2	7.49	8.8	8.33	7.92	7.32	7.12	5.83	4.89	6.7

Table 4. Monthly Averaged Daylight Hours (hours)

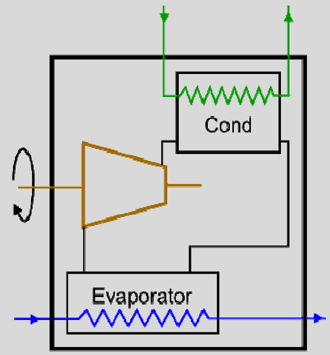
Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual Average
10.7	11.3	12.0	12.7	13.3	13.6	13.5	12.9	12.3	11.6	10.9	10.6	12.12

Sample from the region: Annual solar hours in Riyadh KSA are 4424 (Nasa source)

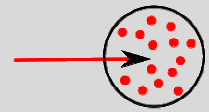
State of Cooling Technologies

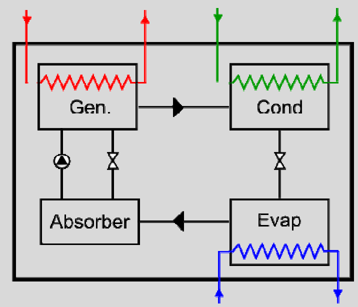


Mechanical Chiller

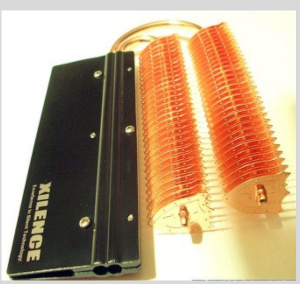


ABsorption Chiller

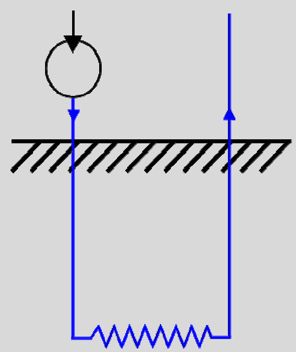




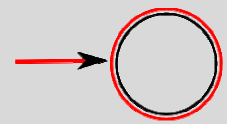
Heat Pipe

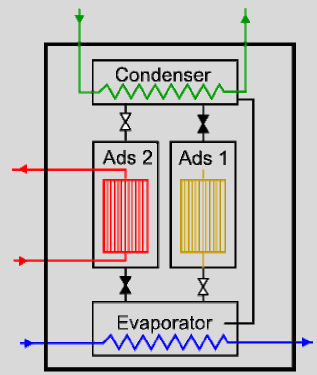


Free Cooling



ADsorption Chiller





Technology & Reality

Conventional System

Most of the air conditioning systems used in the GCC countries are based on conventional vapor compression (VC) technology.

This technology is proven to be reliable and has few disadvantages such as:

- high electricity consumption,
- high electricity peak load and
- negative environmental impact.

Alternative Solutions

Where renewable energy is available, thermally driven chillers can be considered as a viable alternative technological solution.

Thermally driven chilling machine (absorption & Adsorption) research has received adequate attention during recent years, especially its potential applications in waste heat recovery and solar energy utilization.

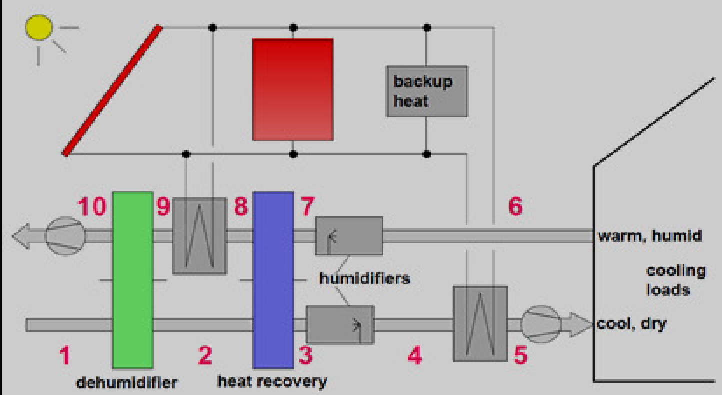
Alternative Solutions

PV Modules	Electrical →	Vapor Compression Cycle

Flat Plate Collectors, Evacuated Tubes	60 to 98 ℃ → Open Cycle, Air & Water System	ADsorption Cycle for Air and Water Dehumidification
Flat Plate Collectors, Evacuated Tubes	50 to 80 ℃ → Closed Cycle, Dry System	ADsorption: H2O/Zeolite, Celica Gel, Methanol/Activated Carbon NH3/ Activated Carbon
Evacuated Tubes, Fresnel, Concentrators	130 to 190 ℃ → Closed Cycle – Wet System	ABsorption: Ammonia NH3-H2O, Lithium Bromide H2O-LiBr

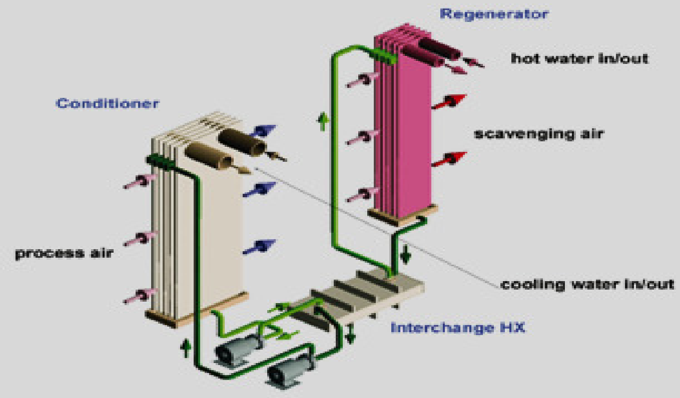
Open Cycle Adsorption System

Air System



Solid Desiccants

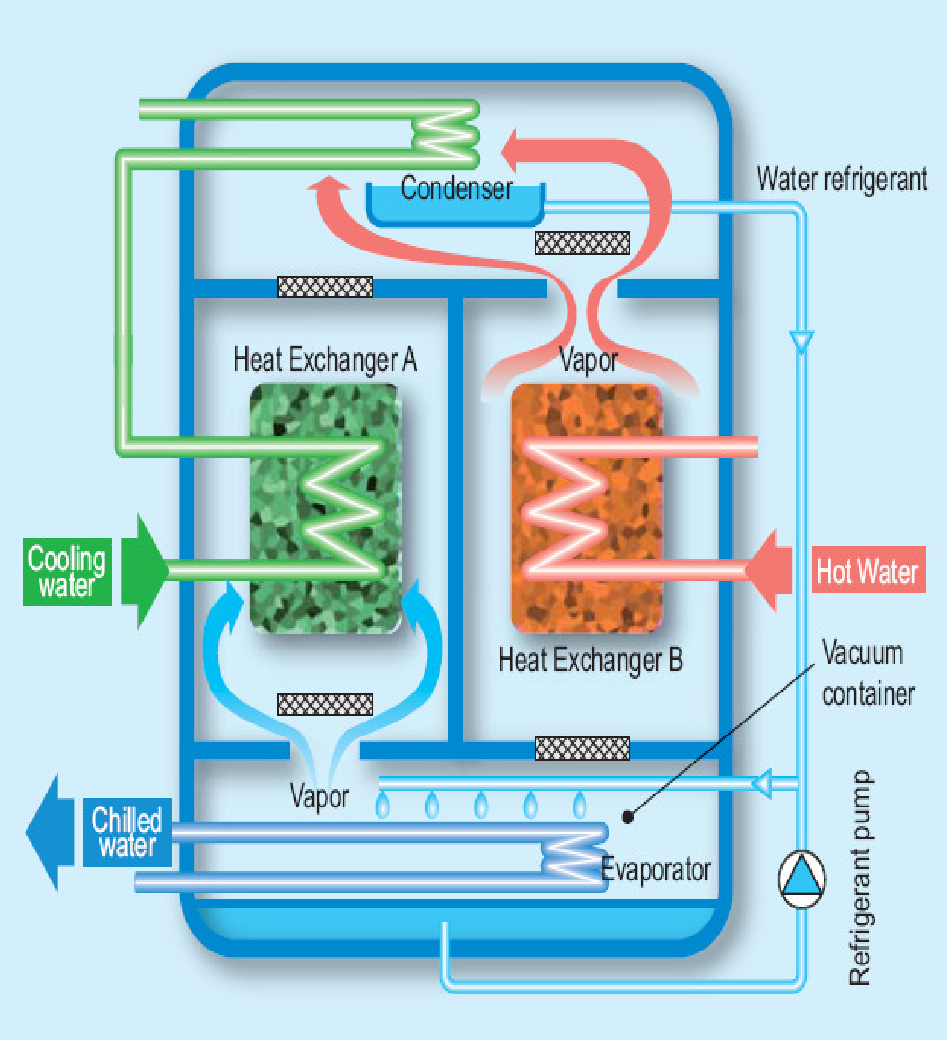
Water System



Industrial and Critical Mission Processes

Closed Cycle Adsorption System

Operating Principle



AdRef-Noa consists of two identical adsorption / desorption heat exchanging sections, one for each evaporative and condensing heat exchanger. Adsorption-desorption process, described below, is interchanged and repeated in these two sections.

ADSOPTION

Water as a refrigerant evaporates in the evaporative heat exchange section. AdRef produces chilled water by using evaporative latent heat. The vapor is then adsorbed by an adsoption heat exchanger A. The heat exchanger generates heat, but removing this heat by cooling water further enhances the evaporating process.

DESORPTION

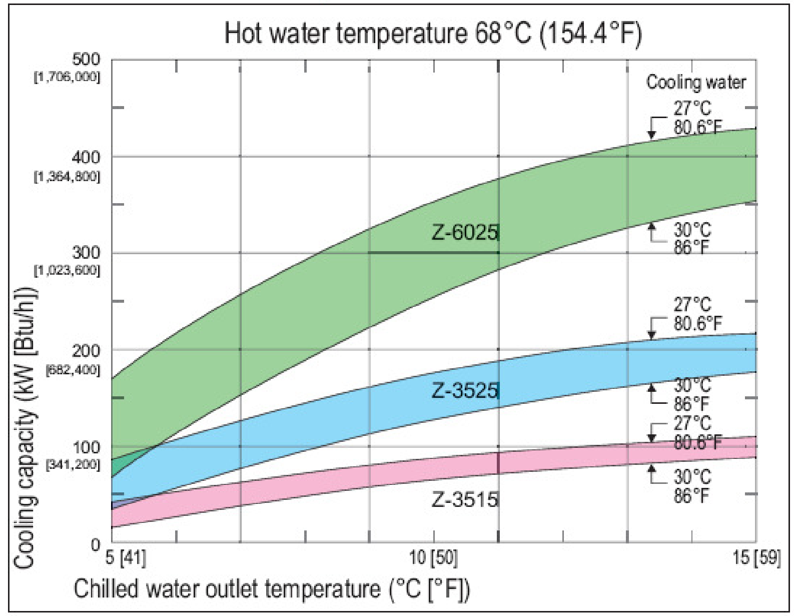
Hot water (the heat source) is used to remove the moisture that is adsorped in the adsorption heat exchanger B. The released moisture enters the condensing section and is condensed for next evaporation.

Closed Cycle Adsorption System

Standard Specifications

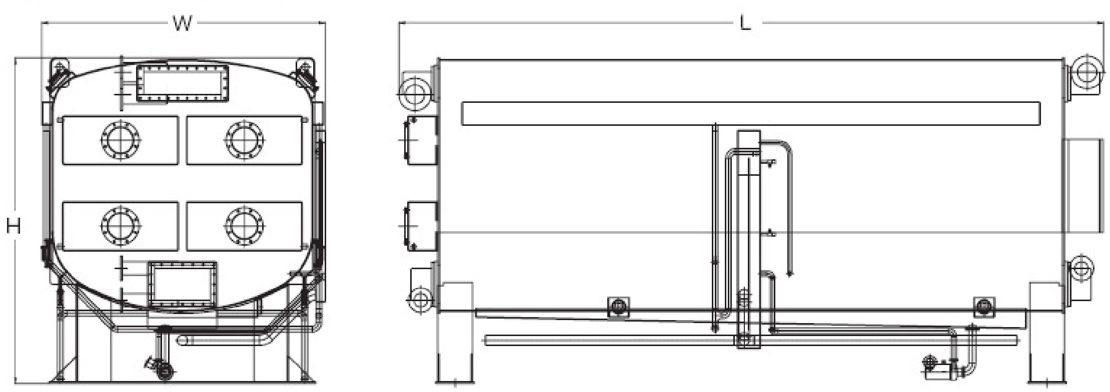
Items		models	Z-3515	Z-3525	Z-6025
Cooling Capacity		kW [Btu/h]	105 [358,260]	215 [733,580]	430 [1,467,160]
Chilled water	outlet temp.	°C [°F]	15 [59]	15 [59]	15 [59]
	flow rate	m³/h [GPM]	12.1 [53.3]	24.3 [107]	48.7 [214.4]
Heat source	inlet temp.	°C [°F]	68 [154.4]	68 [154.4]	68 [154.4]
	flow rate	m³/h [GPM]	20 [88.1]	40 [176.1]	80 [352.3]
Cooling water	inlet temp.	°C [°F]	27 [80.6]	27 [80.6]	27 [80.6]
	flow rate	m³/h [GPM]	50 [220.2]	99 [435.9]	198 [871.9]
Refrigerant pump		kW [HP]	0.3 [0.4]	0.55 [0.7]	1.1 [1.5]
Vacuum pump		kW [HP]	0.4 [0.5]	0.4 [0.5]	0.75 [1.0]
Outer Dimensions	L	mm [inch]	3,700 [145 5/8]	3,700 [145 5/8]	6,100 [240 1/8]
	W	mm [inch]	1,500 [59]	2,450 [96 1/2]	2,450 [96 1/2]
	H	mm [inch]	2,800 [110 1/4]	2,800 [110 1/4]	2,800 [110 1/4]
Net weight		kg [lbs]	6,600 [14,550]	10,000 [22,046]	15,000 [33,069]

Performance comparison between models

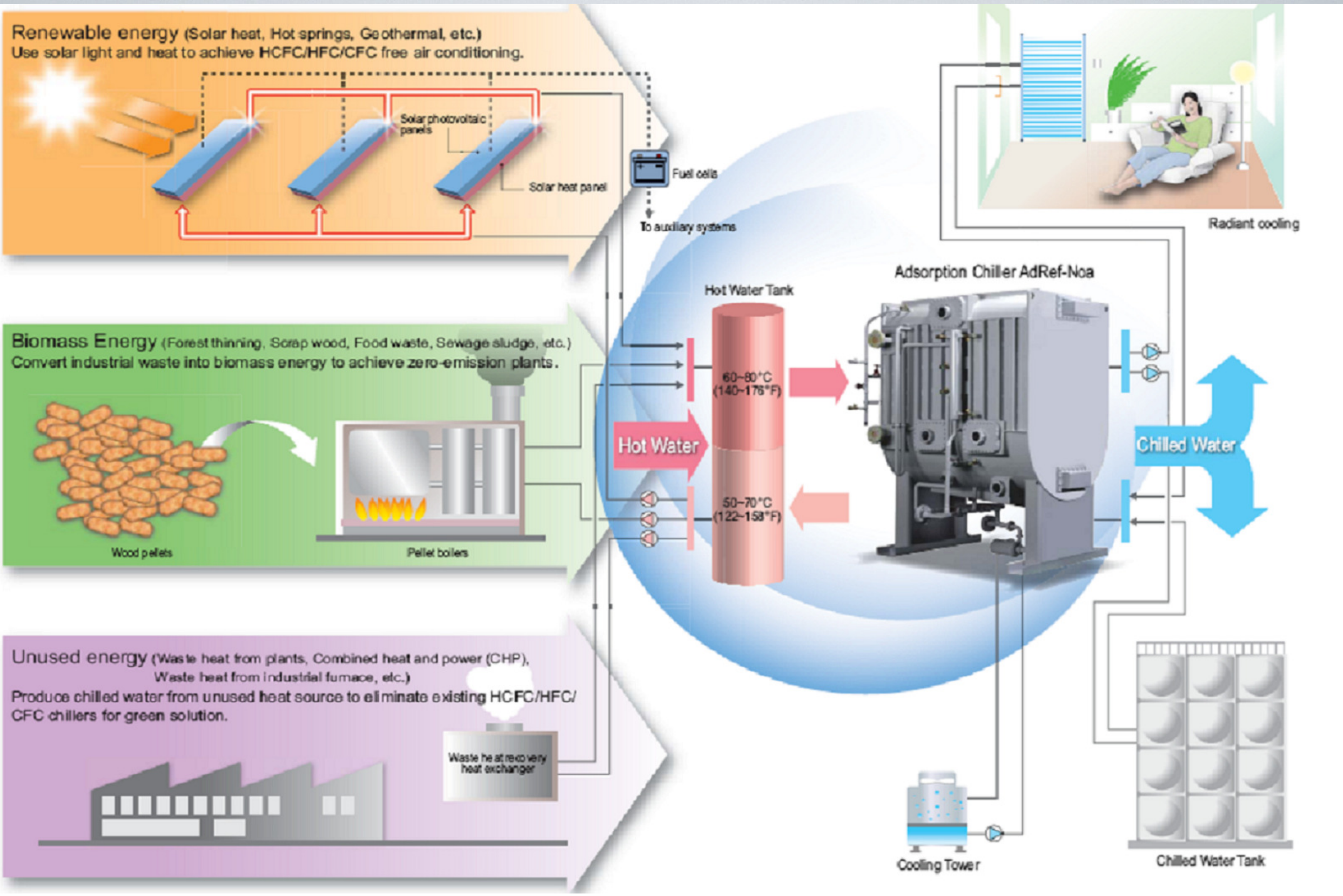


<Standard design conditions> Provided hot water temperature: 60~80°C (140~176°F)
Chilled water outlet temperature: 5~25°C (41~77°F)
Cooling water inlet temperature: 32°C (89.6°F) or less
*Contact us for other conditions.

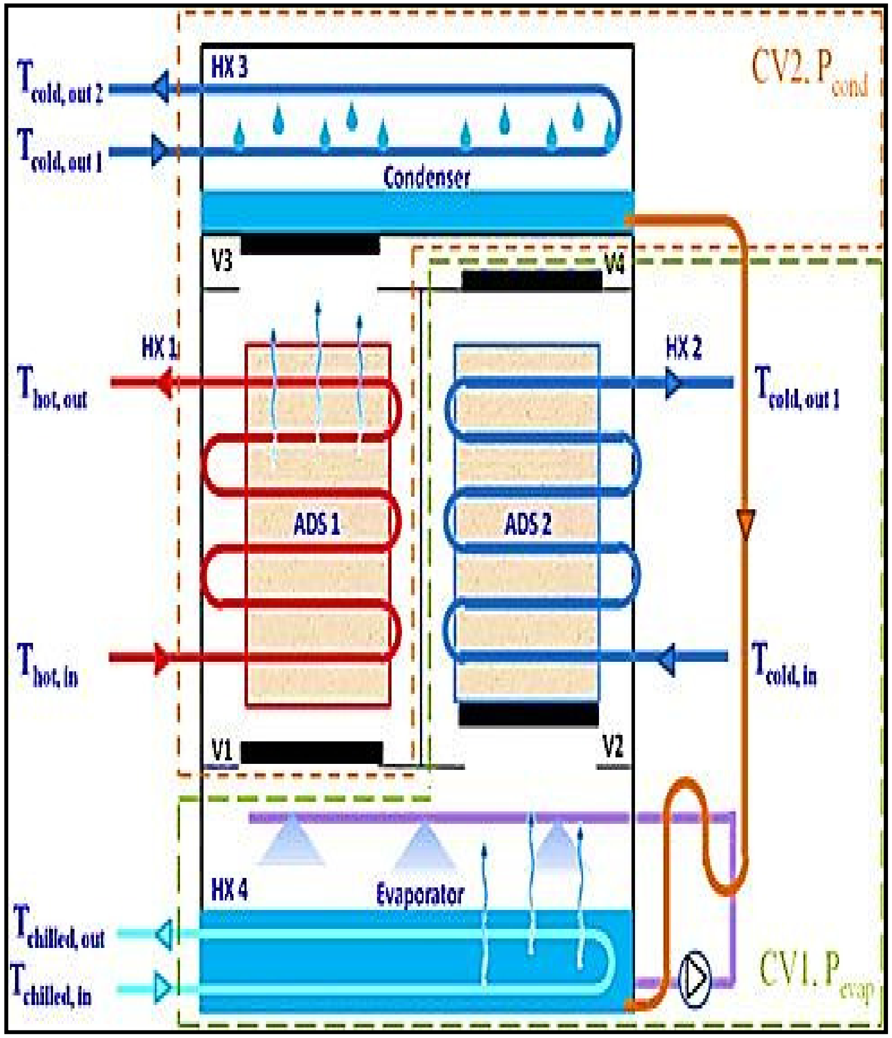
Outer Dimensions



Closed Cycle Adsorption System



Closed Cycle Adsorption System



Adsorption Chiller with Zeolite

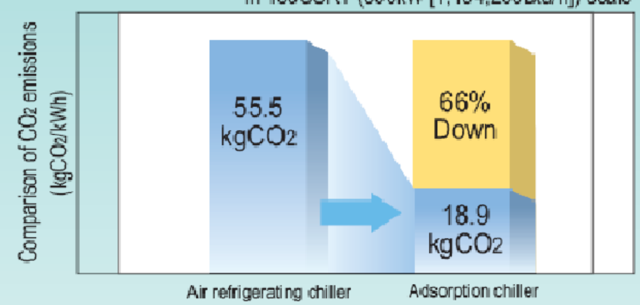
■ EFFECTS

2

Achieving COP 10 *Electricity COP

■ The system comparison in 100USRT scale

in 100USRT (350kW [1,194,200Btu/h]) scale



Comparison of CO_2 emissions

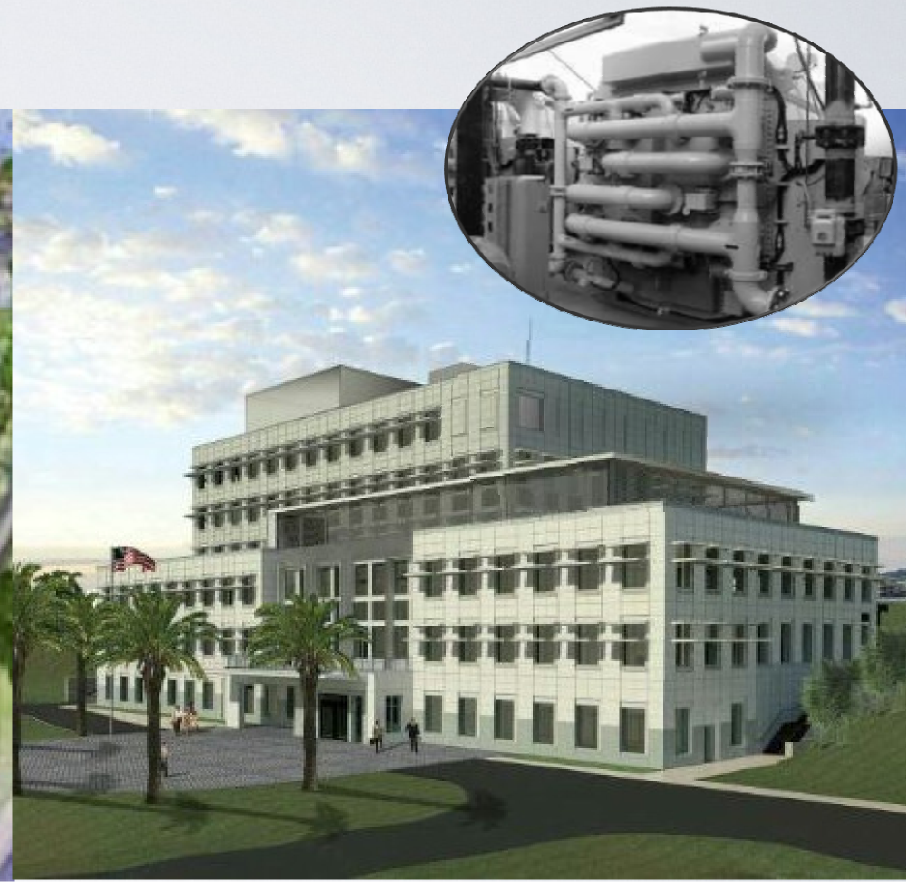
* CO_2 emissions factor 0.555kg CO_2/kWh

<Air refrigerating chiller>		<Adsorption chiller>	
Driving power	100kW (134HP)	Driving power	1.1kW (1.5HP)
		Cooling tower fan	16.5kW (22.1HP)
		Cooling water pump	11kW (14.8HP)
		Hot water pump	5.5kW (7.4HP)
Total	100kW (134HP)	Total	34.1kW (45.8HP)

Closed Cycle Adsorption System

Case Study: U.S. embassy, Monrovia & Dakar

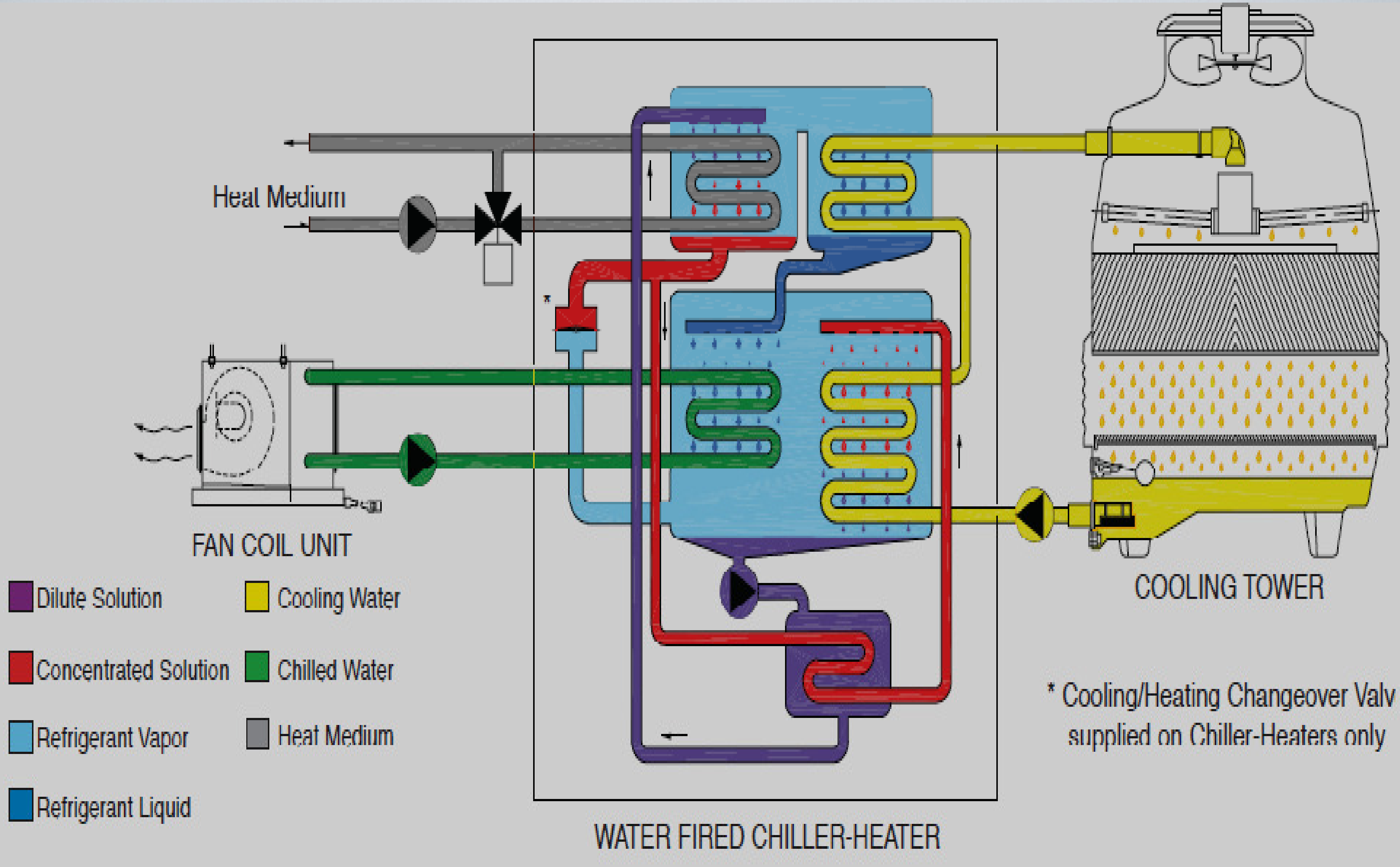
- Two ECO-MAX chillers have been ordered for the new U.S. embassy in Senegal and Liberia. Once for the Dakar embassy, each chiller has a capacity of 76 tons of refrigeration.
- The hot water to drive the chillers comes from the tri-generation system serving the embassy.



Case Study: Commercial Building- Singapore

Solar-powered AD Chiller plant (45 RT).

Closed Cycle Absorption System

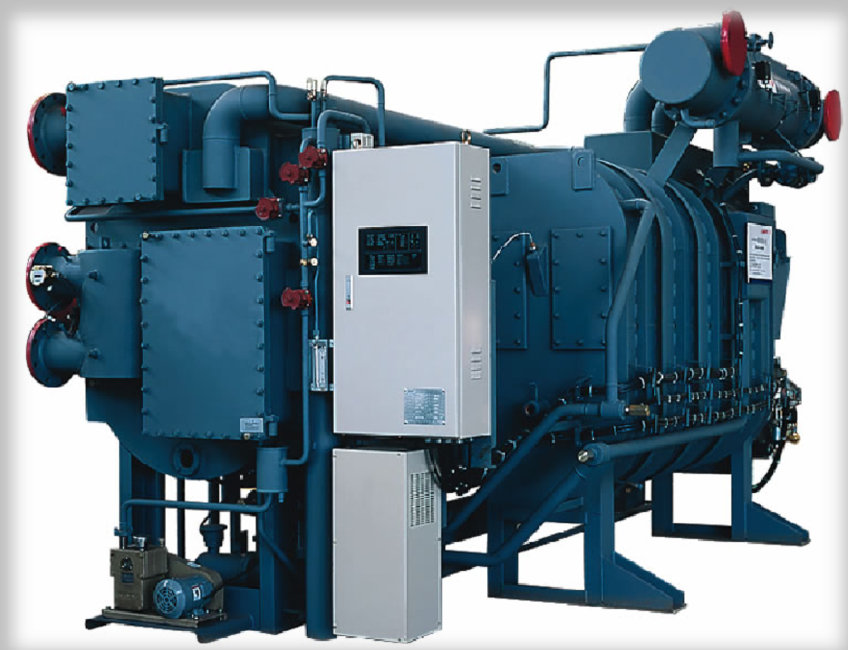


Advantages of thermally driven chillers

- Reliable, durable and mature technology
- Significant reduction in electrical demand & comsumption
- Reduced operating costs
- Reduced CO2 emissions
- Ecologically benign
- Ozone-friendly working medium
- Could be coupled with recovered heat and harvested solar power
- Contribute greatly in achieving green certification (GSAS, LEED, BREAM, etc.)

Disadvantages of thermally driven chillers

- High sensitivity towards high condenser water temperature
- High make-up water rates (evaporation, blow down & drift loss)
- Relatively high chilled water temperature (7 to 8 C)
- Temperature level of the heat medium, provokes aggressive corrosion
- Large area for solar collectors
- Overall system's efficiency
- Assisting rather than driving



Case Study 1: 500 Seats Stadium, Doha

- 500-seats model stadium with retractable roof.
- A Mirroxx linear Fresnel collector with uniaxial tracking and a total mirror aperture area of 1040m^2 heats the pressurized water directly.
- Thermal storage PV arrays for electricity generation with a monitoring system and not connected to the local electrical grid.
- Double-Effect 150 TR Thermax absorption chiller with dual fuel source and underground chilled water storage thank.
- Displacement ventilation for air delivery System for the pitch coupled with UFAD for Spectator stands.
- Water consumption= ?

Case Study 2: ESAB Head Office, Jafza, UAE

- 6,500 m^2 built to achieve LEED Platinum.
- $1million solar thermal cooling system, one of the large-scale applications in the region.
- Solar system use 1,500 solar vacuum tubes.
- 70% Energy Reduction compared to a As-Usual Building by using solar thermal and efficient lighting systems.
- Six Packaged Absorption Units (Climate Well) to serve roof mounted AHUs handling latent loads.
- Radiant Cooling System using Thermo-deck approach (hallow core ceiling slab) handling sensible loads.

Outdoor Cooling Solution for Parks

Comfort for Outdoor Park

Outdoor Park : open spatial experience whereby all the features offer a high quality outdoor comfort for optimum performance.

The approach is based on the following axes:

1. Operate: activate or operate sustainable technologies in accordance with the functional needs of this environment, 8 hours a day, and 150 days of the year.
2. Interact: encourage and stimulate a social dynamic where the life, values and vision of the population of Lusail Marina evolve.

Fundamentally Wrong

Solution that goes above & beyond Misting system

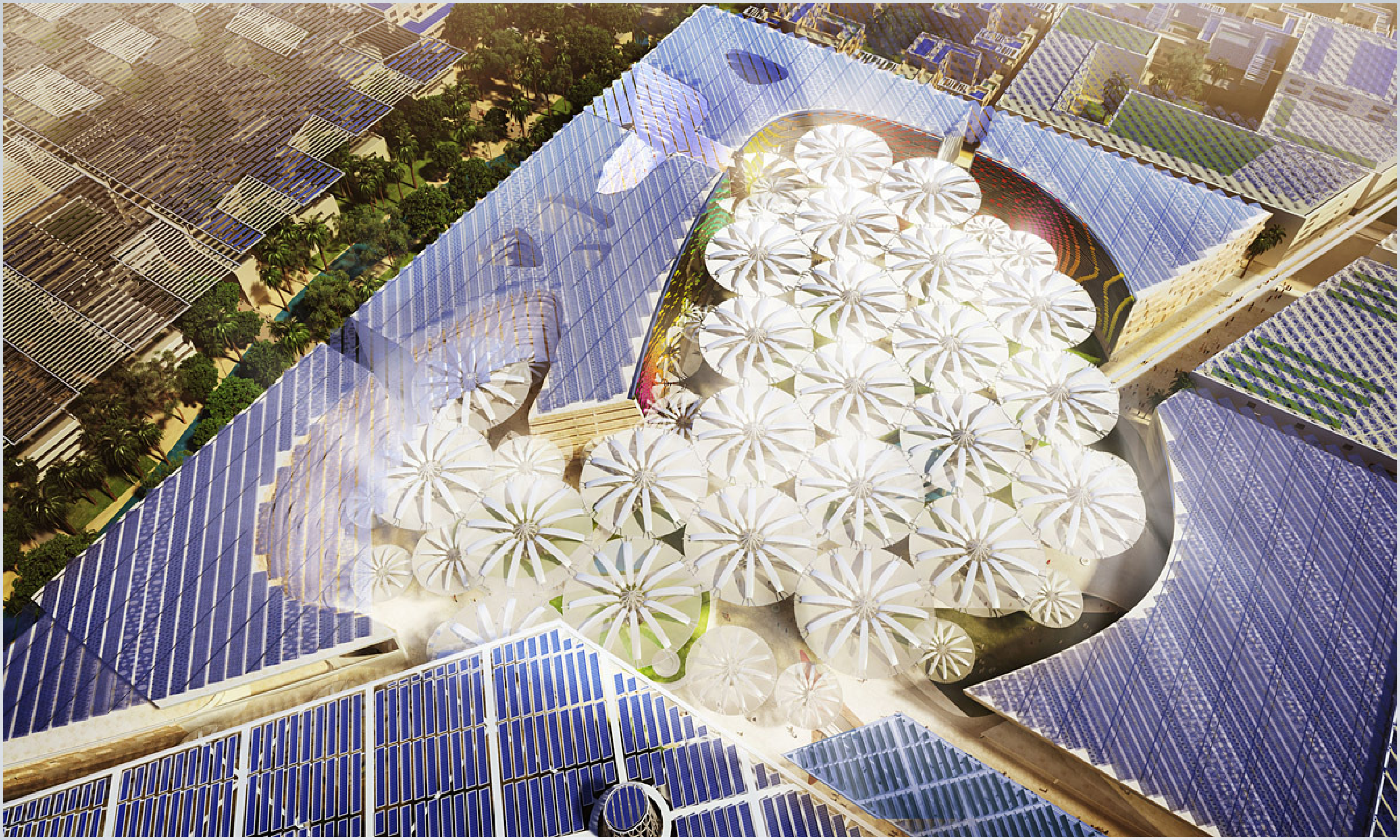
Starts with Shading

Starts with Shading

Case Study 3: Masdar City, UAE

Diurnal Experience

QPM
MANAGING FOR A BETTER FUTURE



Diurnal Experience

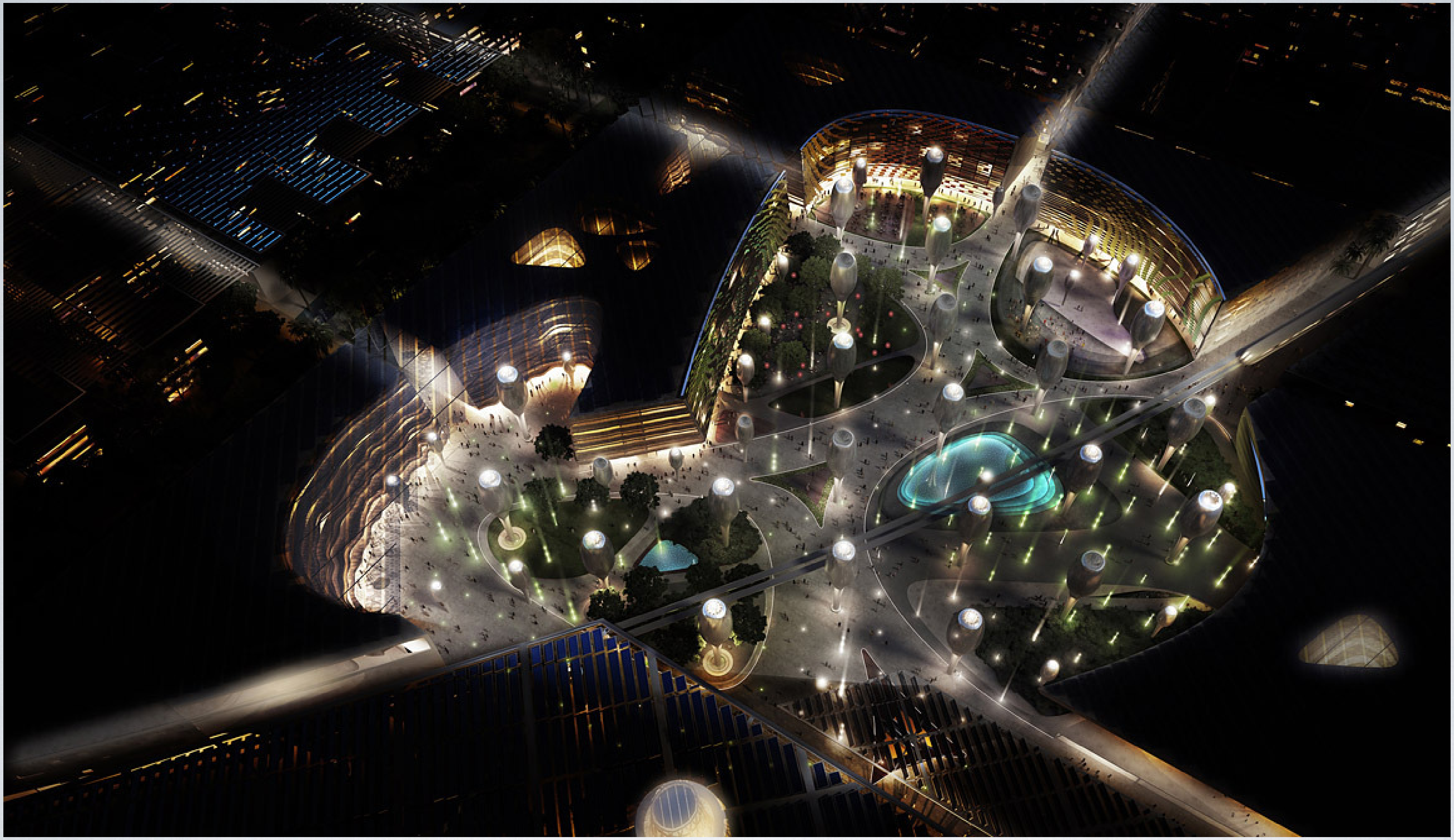
Diurnal Experience

Nocturne Experience

QPM
MANAGING FOR A BETTER FUTURE

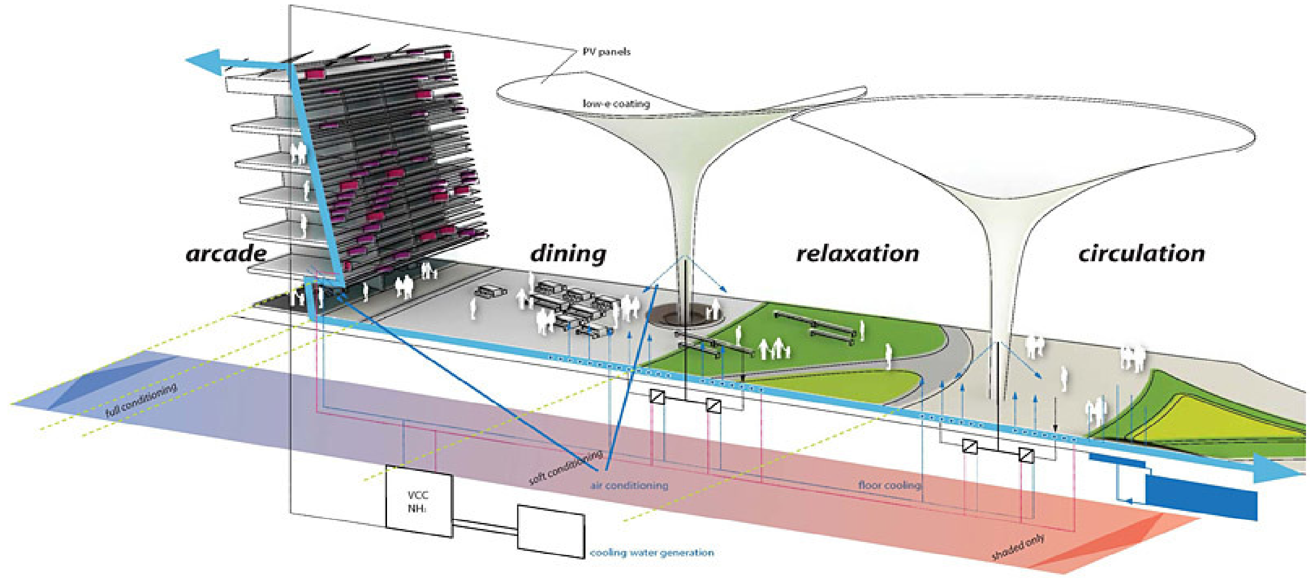
Nocturne Experience

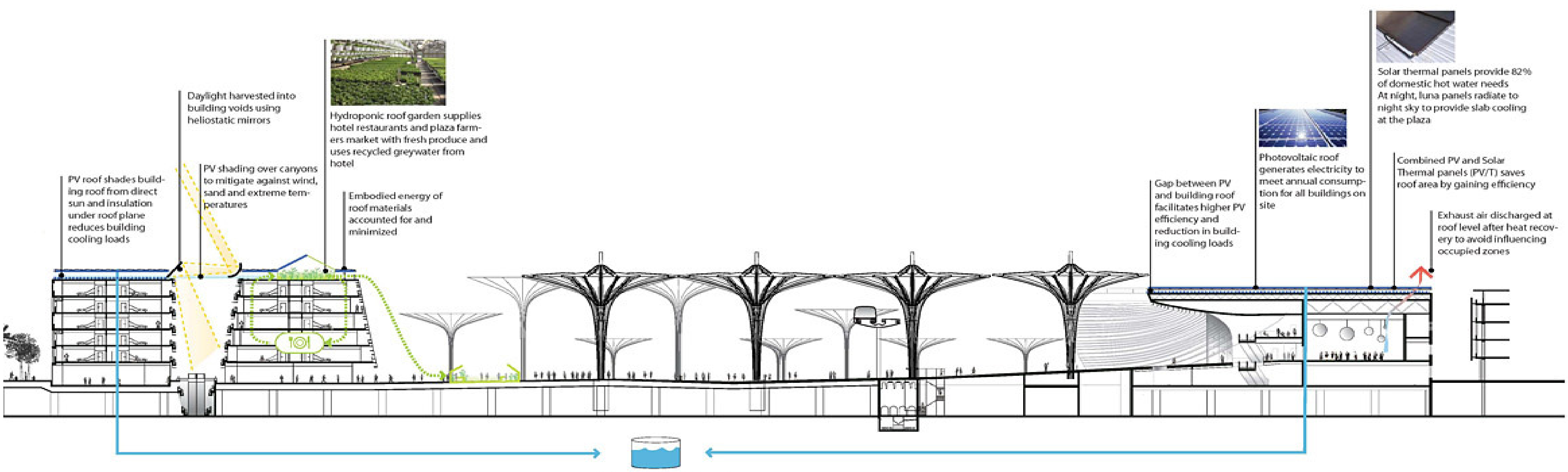
Nocturne Experience



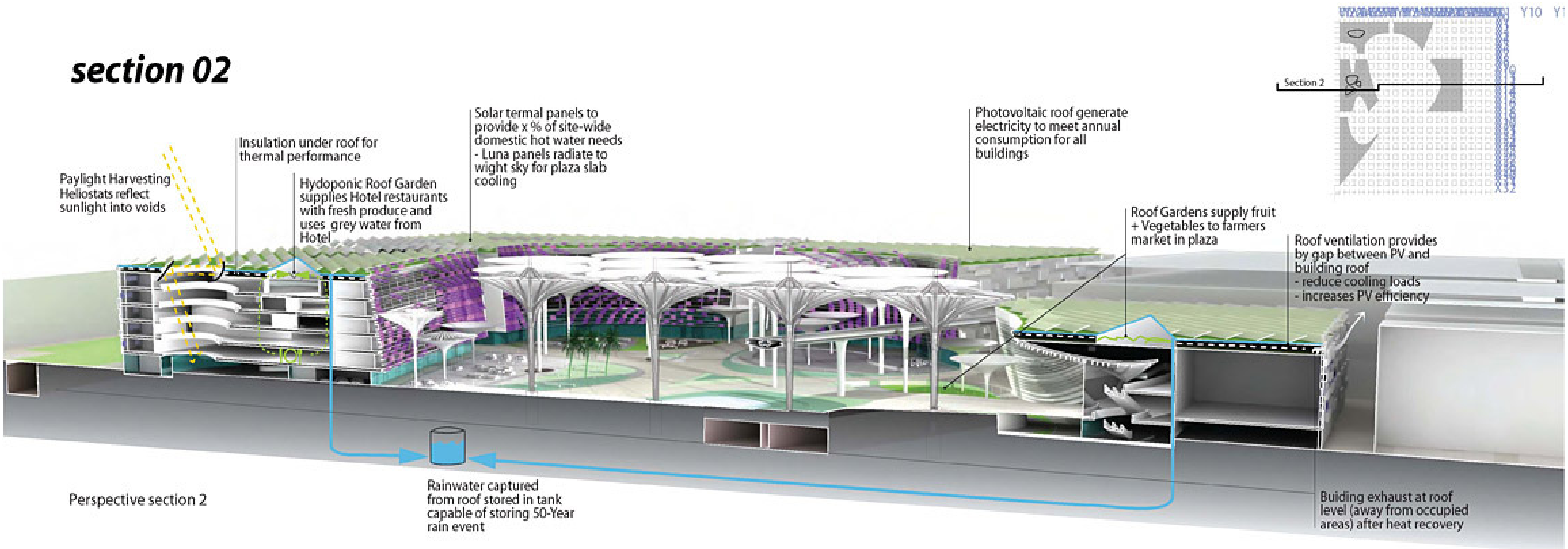
Nocturne Experience

Fully Integrated Approach

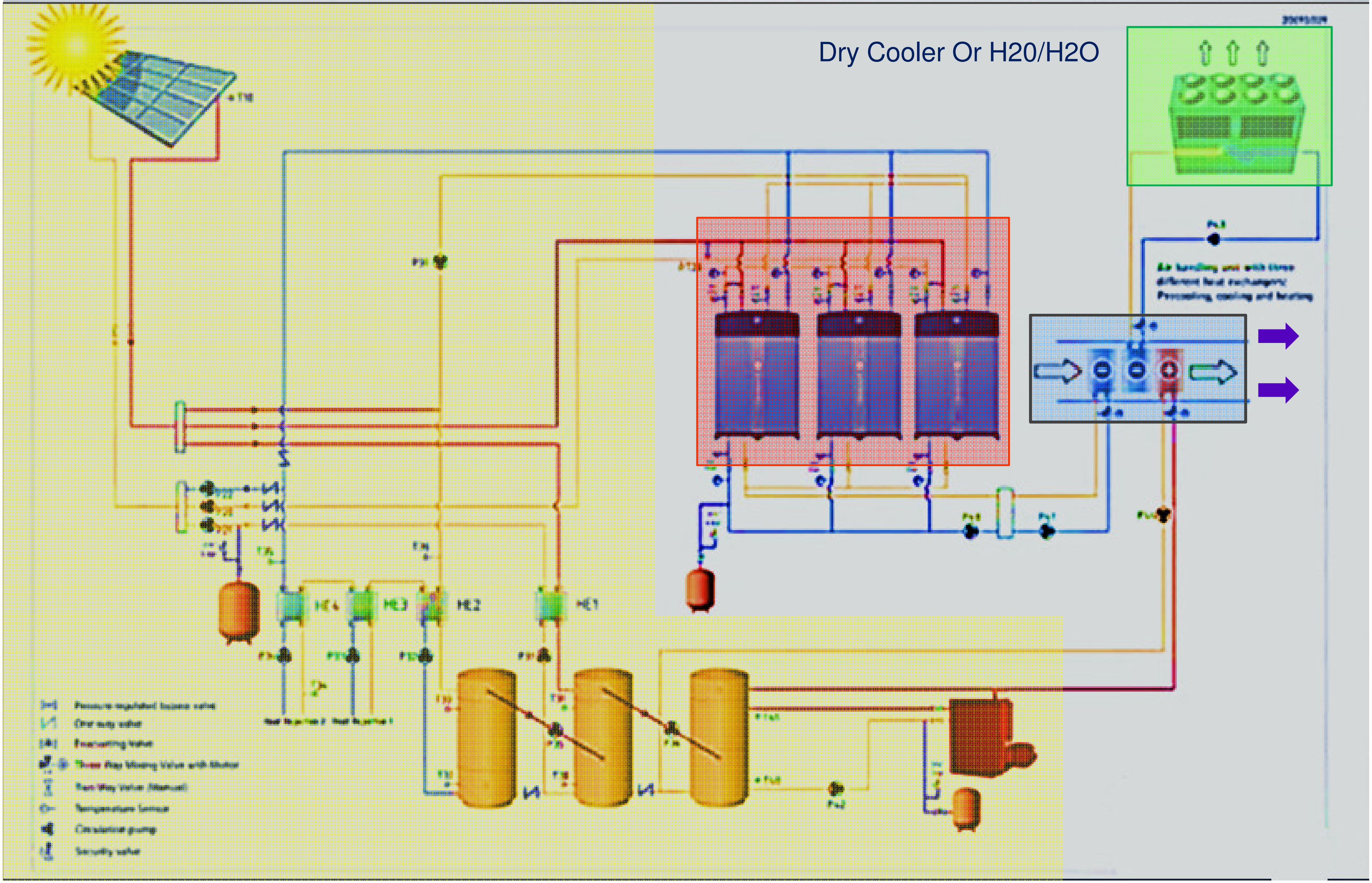




Fully Integrated Approach



Scalable Solution – Standalone System



[redacted]

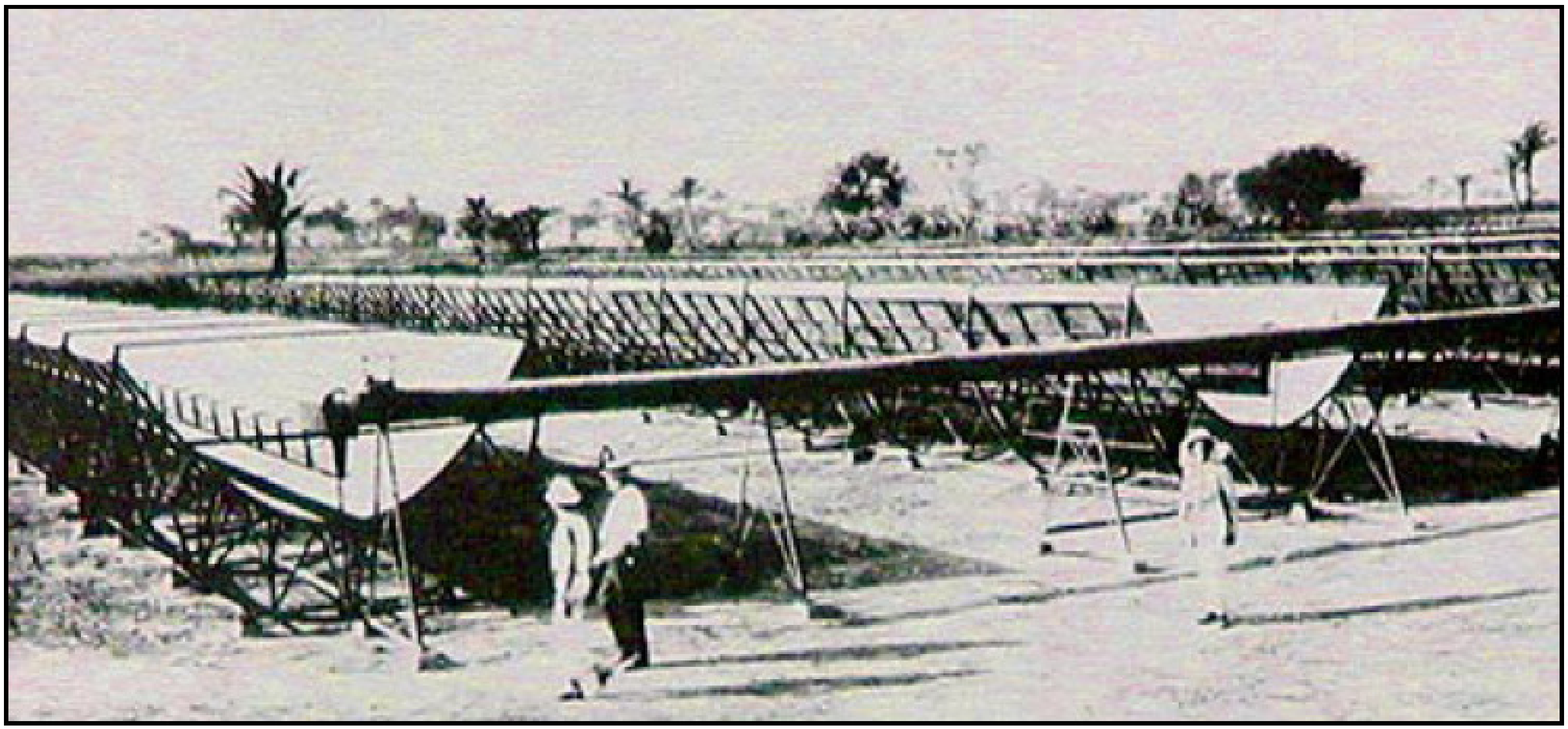
Conclusion

1. Major benefit of performing this study is to show the feasibility of zero energy for a reduce scale cooling solution.
2. Cooling system efficiency is sensitive towards high condenser water temperature
3. Adverse impact of dust/ humidity on solar system's efficiency
4. High rates of water depletion for evaporative cooling towers
5. High initial cost
6. Needs space to accommodate solar panels
7. Requires a single source control system for all system's components
8. "Opportunity Document" needs to be developed for each case
9. Further study is needed couple radiant cooling solution.

MAADI INTRODUCES SOLAR ENERGY TO THE WORLD IN 1913

Amazing but true, in August 1913 Maadi was the site of history-making innovation when American inventor-engineer Frank Shuman (1862-1918) chose this still-nascent nileside suburb to launch his amazing contraption--a solar panel power plant.

Here's how the *Egyptian Gazette* described this groundbreaking event in its 12 July 1913 issue.



Question