The Path Towards Zero Energy District Cooling Plant in Qatar

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Disclaimer:

this is an unscientific presentation, with scientific overtones

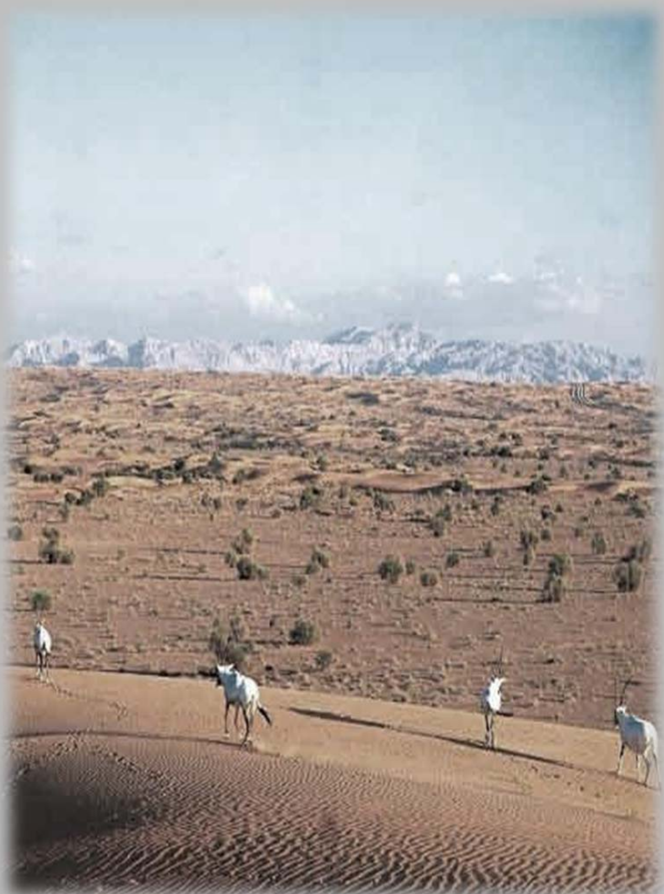
Table of Content

Net-Zero Concept & Boundary Limits

- Net Zero Energy Solution, in the simplest terms, produce as much energy as it consumes.
- Net-Zero Site Energy Use: Export an equal amount of received energy measured over the course of one year.
- Net-Zero Source Energy Use: One energy unit produced on-site could offset three imported units produced off-site.
- Net-Zero Energy Emissions: Offset equal amount of produced carbon emissions through the energy source powering the building.

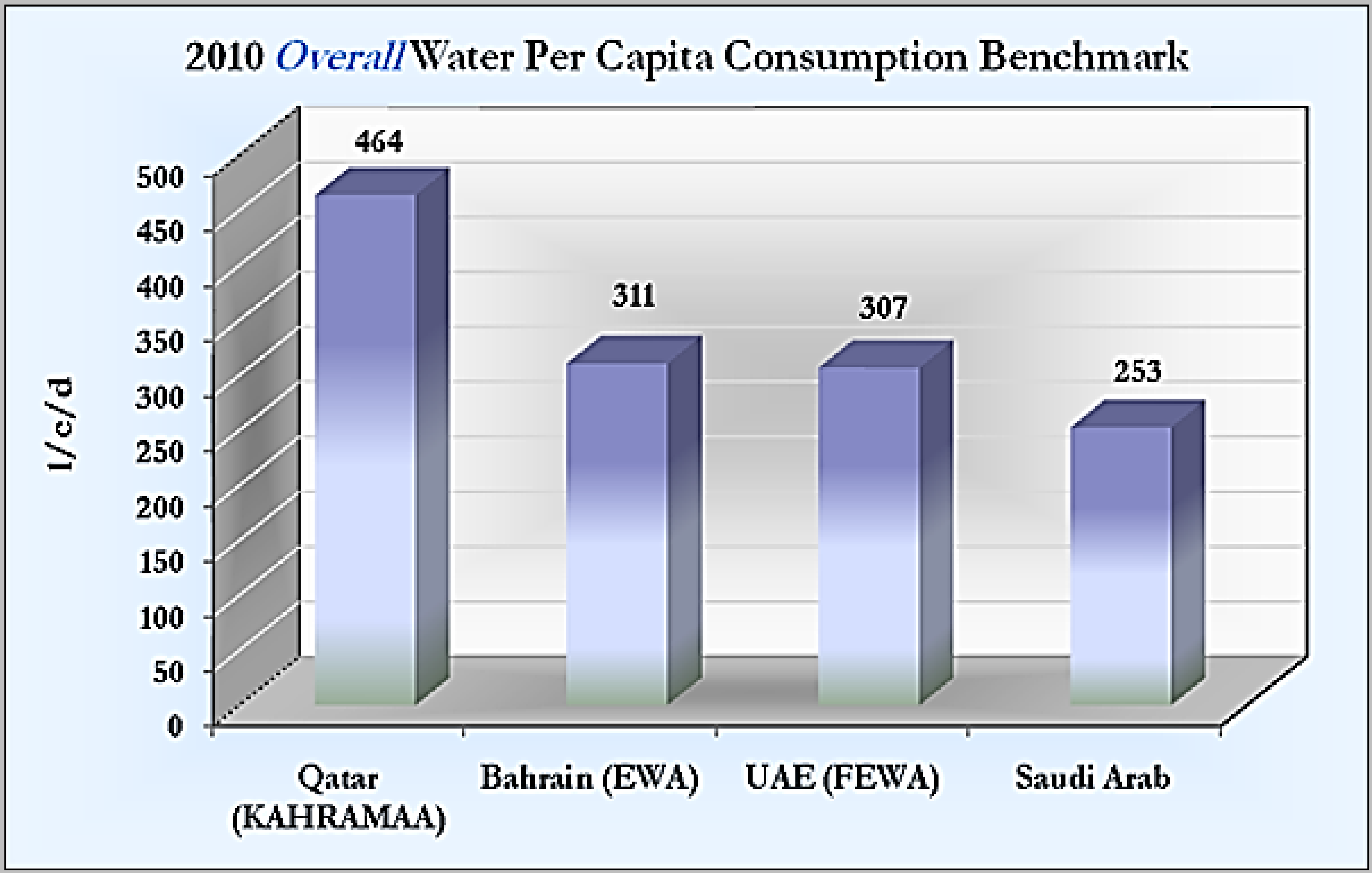
The present is for zero & the future is for positive

Natural Resources State of Affairs in the GCC

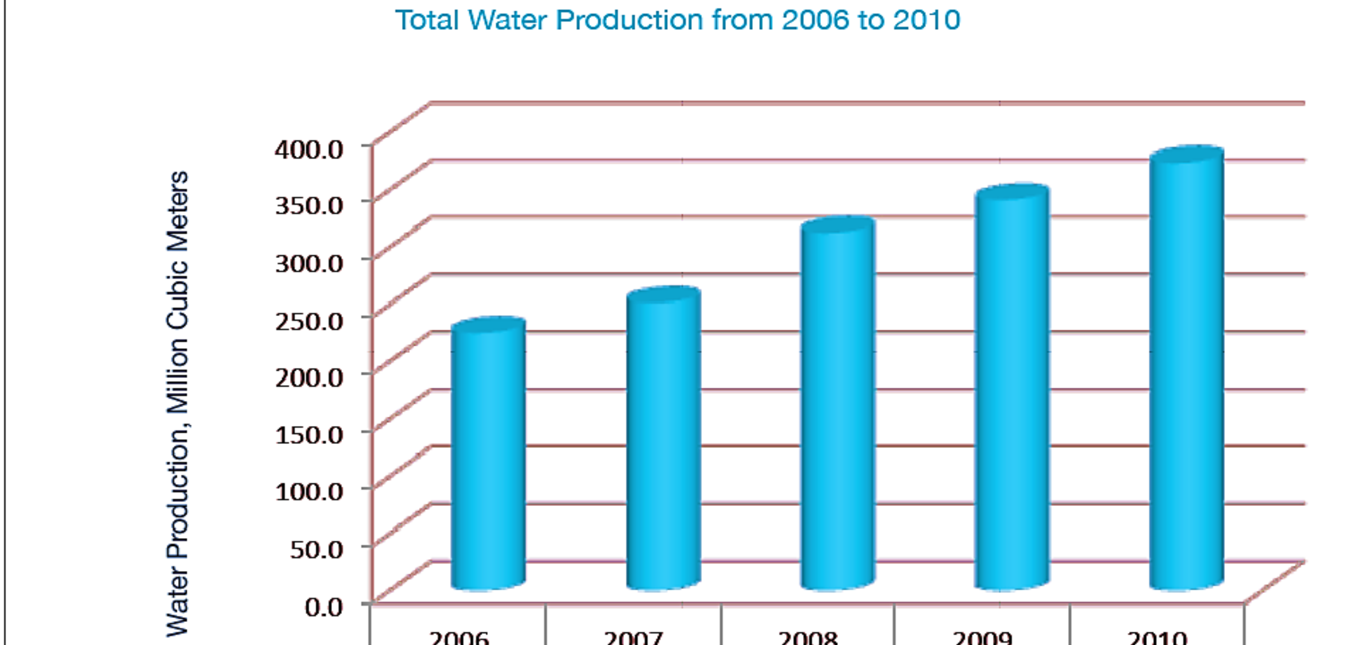


- GCC countries will emerge as world leaders in electricity consumption per capita expected to increase at annual rates of 2.5%.
- Power requirements in Qatar to rise to 10 GW in 2020, compared to 7.6 GW today.
- Water demand in Qatar to double from 1.1 Million m3/day in 2011 to 2.1 Million m3/day in 2020.
- A large part of this increase is attributed to the needs of a growing population and a significant 47% of energy consumption diverted into residential use.
- GCC countries put only 10.5% of their electricity to use in industry, as opposed to 37.7% globally.

Water Consumption in the GCC 2010



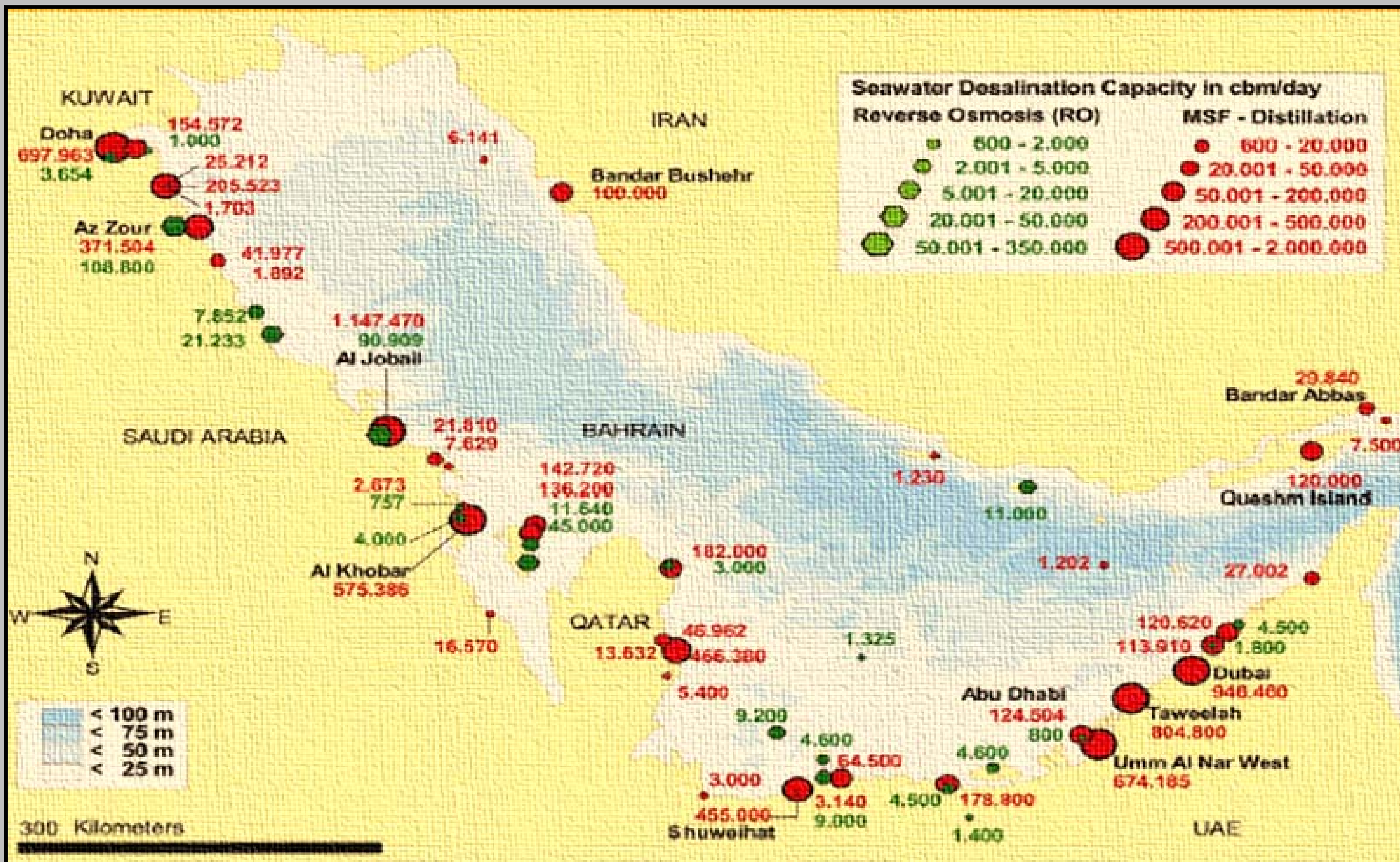
Total Water Production in Qatar



	2006	2007	2008	2009	2010
Water Production, Mm^3	225.1	251.2	312.4	341.0	373.6

Average annual growth from 2006 to 2010 is 13.2%.

Seawater Desalination Limitation



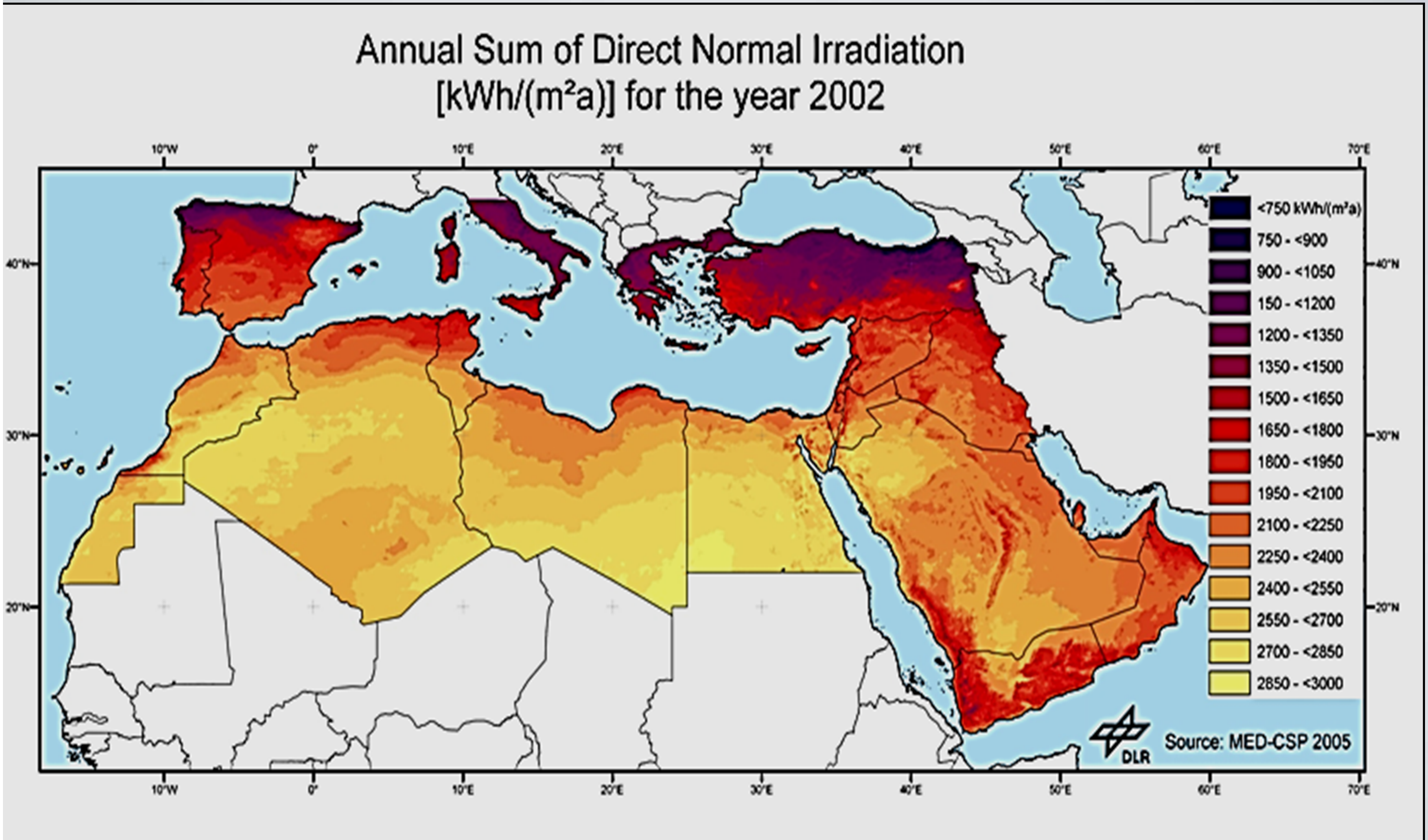
Top 10 Challenges in Achieving Net-Zero

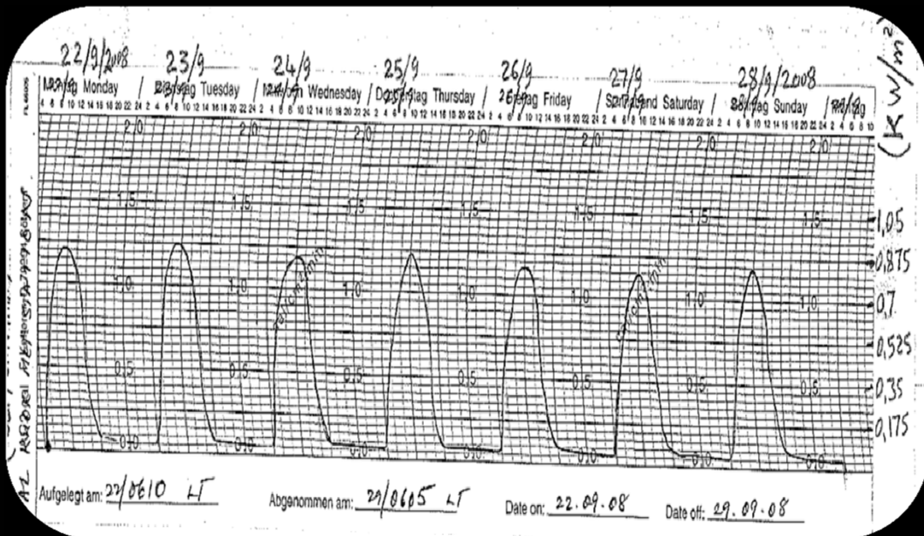
1. Climatic conditions
2. Water scarcity
3. An open air experience
4. Evening matches in summer
5. Safety of athletes
6. Comfort of spectators
7. State of technology
8. Integration & flexibility
9. Infrastructure

Solar Assisted Refrigeration Solution

- Source of the Solution
- Systems of the Solution
- Current System Solution
- Alternative at a larger Scale
- Alternative at a Smaller Scale
- Alternative at the Air Side

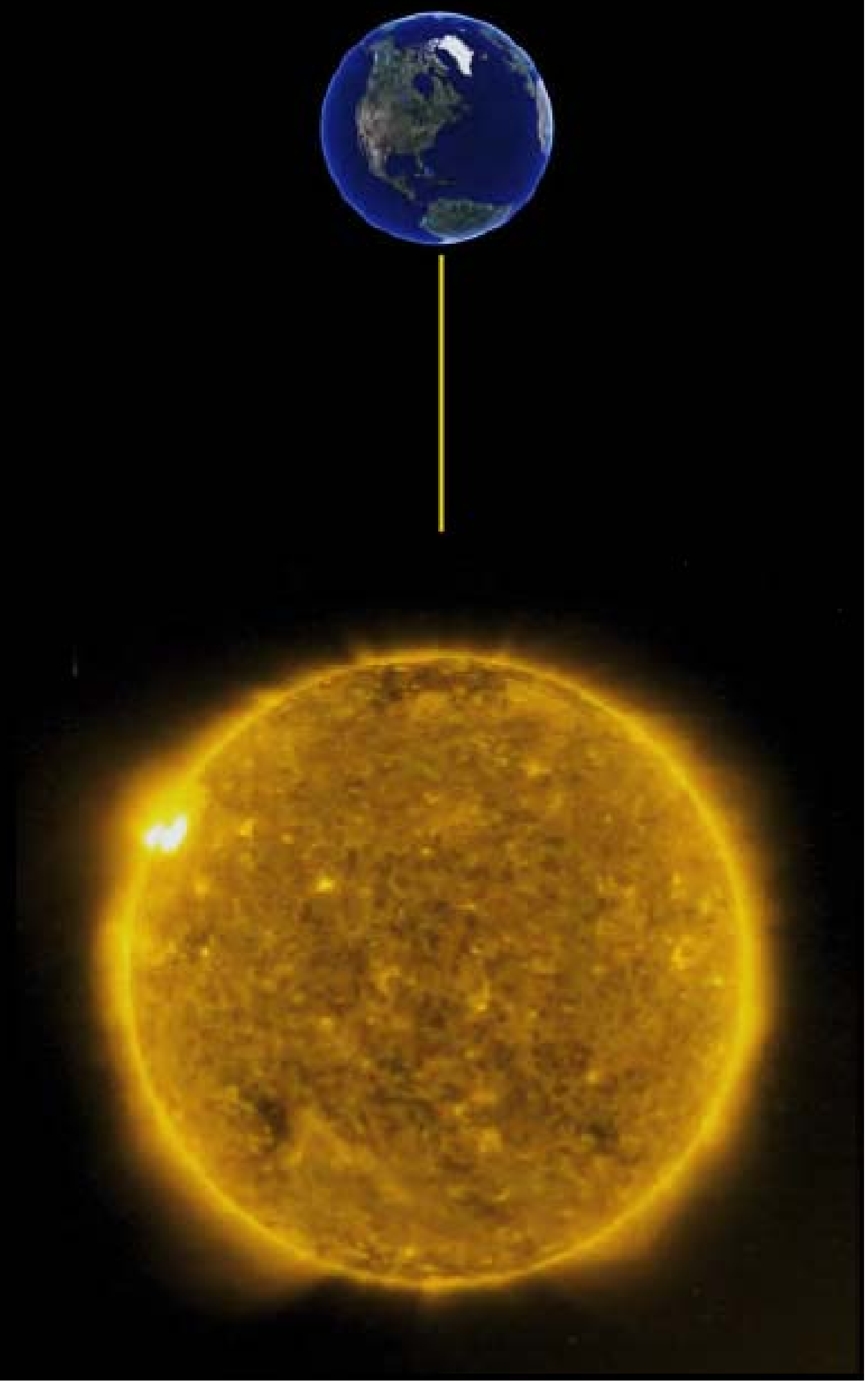
Sun Availability



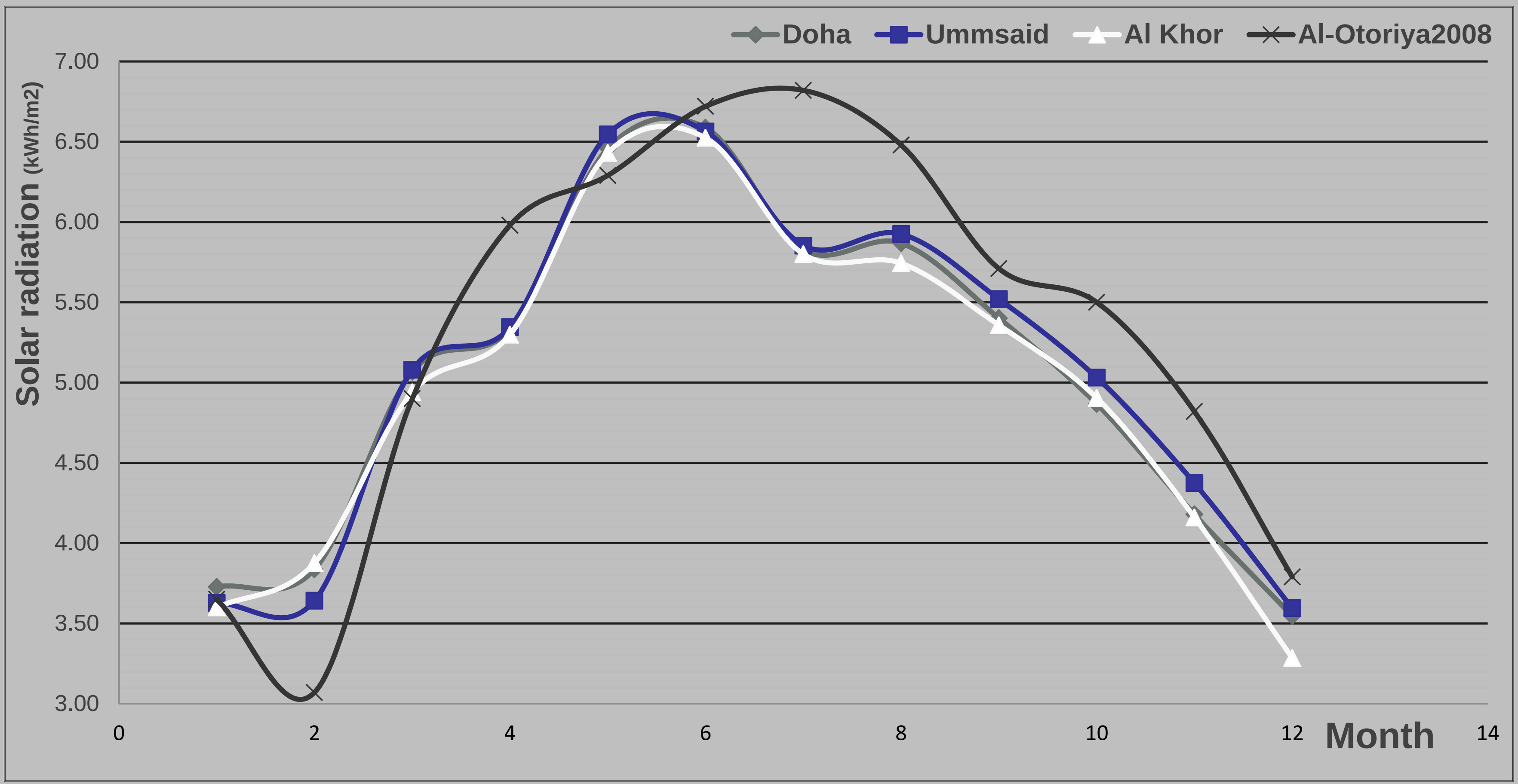


Tested Data: Solar radiation in Al-Khor (kW/m²), Jun. 22-29, 2008

the **source** of the solution



The Source



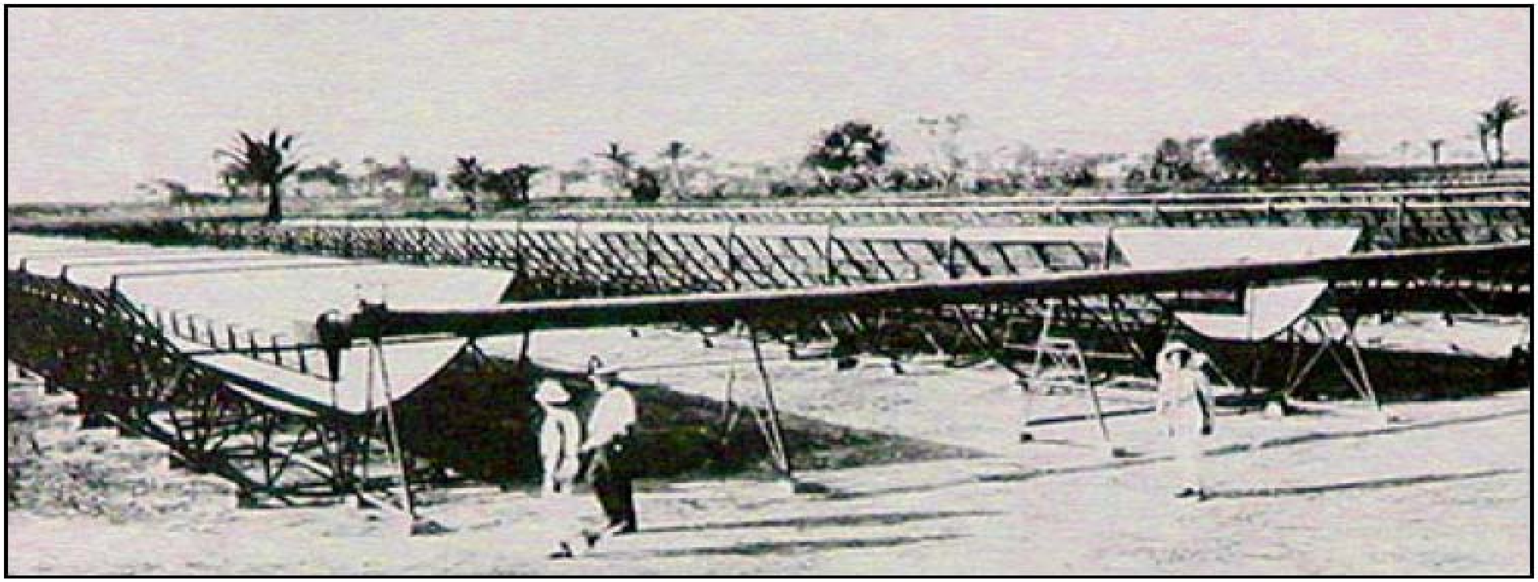
MEAN DAILY GLOBAL RADIATION for Doha, Ummsaid, Al-Khor 1988 and Al-Otoriya 2008 (kWh/m^2)

Amazing but true: It all started here

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.



Amazing but true: It all started here

ig. 1.9 Detail from the north of the long parabolic-cylinder mirror collectors used in the
human-Boys system. Note the hoops on which the mirror was tilted to follow the sun.

Amazing but true: It all started here

THE ELECTRICAL EXPERIMENTER

H. GERNSBACK EDITOR
H. W. SECOR ASSOCIATE EDITOR

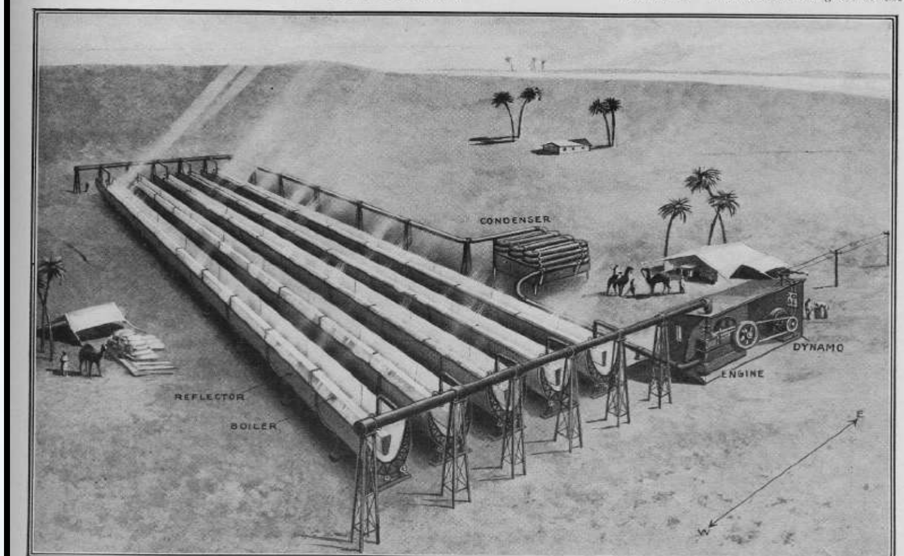
Vol. III. Whole No. 35 MARCH, 1916 Number 11

The Utilization of the Sun's Energy

Years Ago Man Endeavored to Make Practical Use of the Energy Contained in the Sun's Rays—Even Tesla, the Electrical Wizard, Has Patented a Sun Motor, While the Shuman-Boy's Engine and Sun Boiler Has Developed 100 H. P. There Is Great Promise Held Forth to Future Engineers Who May Work on This Problem.

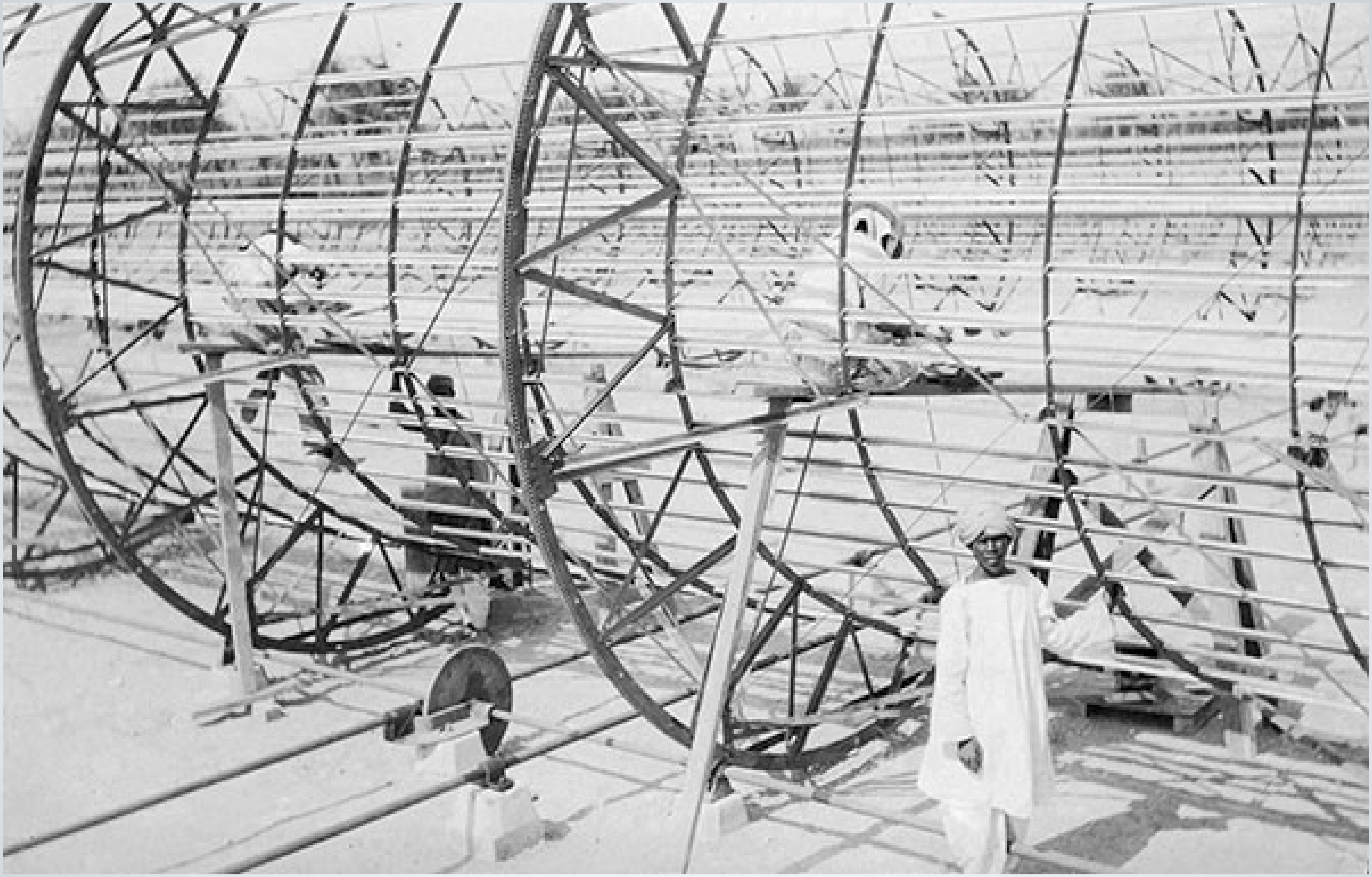
IT has been given to astrophysicists to measure the heat generated by the sun and calculate the force emanating from it. We know that the surface of our luminary gives out a heat estimated to be about 6,000° centigrade, and that its light equals that of 27,000,000,000 candlepower a quarter of a mile away. The heat which the earth receives from the sun in the course of a year would suffice to melt a belt of ice about 55 yards in thickness extending clear around the earth. Only the 2,735-millionth part of the total energy given off by the sun reaches our earth and, if this were lacking, our planet, with all its thousandfold life, its thick forests and fruitful plains, would turn into a dead, rigid ball of rock, for the average annual temperature, which is now one of 13° centigradé of warmth for Europe, would, without the heat of the sun, sink to 73° centigrade of frost, it is calculated.

Every sort of light with which we illuminate our home when the greater light has sunk beneath the horizon, every fire that warms us when the solar rays can no longer do so, is a product originating in the sun. The chip of wood with which the untaught son of nature brightens his hut, the twigs with which he stokes his fire, what are they but pieces of trees that grew in the sunlight? The gas of the city dweller, the coals with which he heats his house and from which the gas has been sucked, what are they but transformed sunbeams? The coal in the grate is the petrified wood of perished forests that covered the earth's surface millions of years ago, and flourished in the rays of the same sun that ripens our corn to-day. Petroleum, that mysterious earth-oil, comes from the bodies of millions of dead and

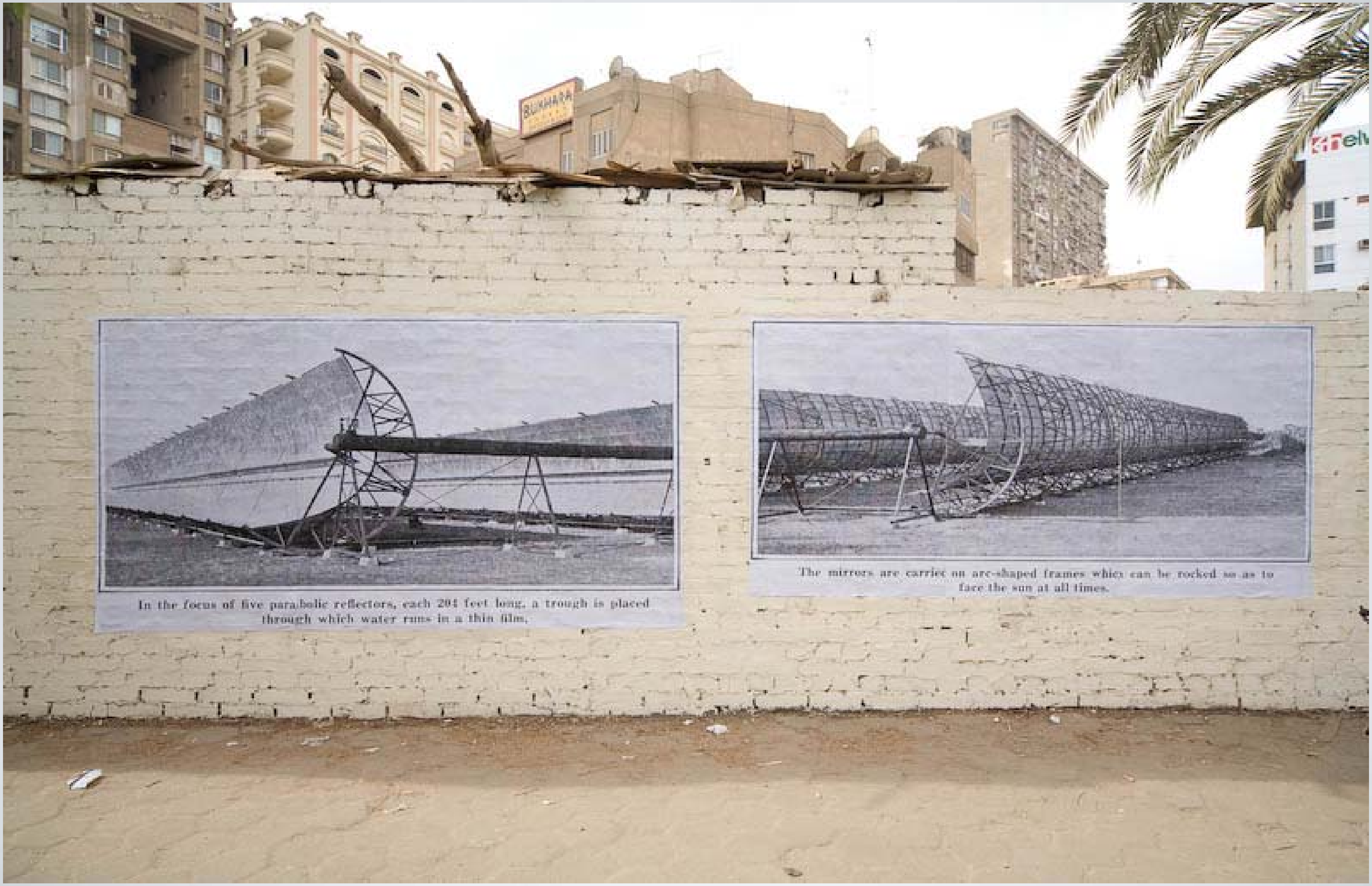


A Successful 100 H.P. Sun Power Plant Located at Meadi, on the Nile, Egypt.

Amazing but true: It all started here



Amazing but true: It all started here



Amazing but true: It all started here

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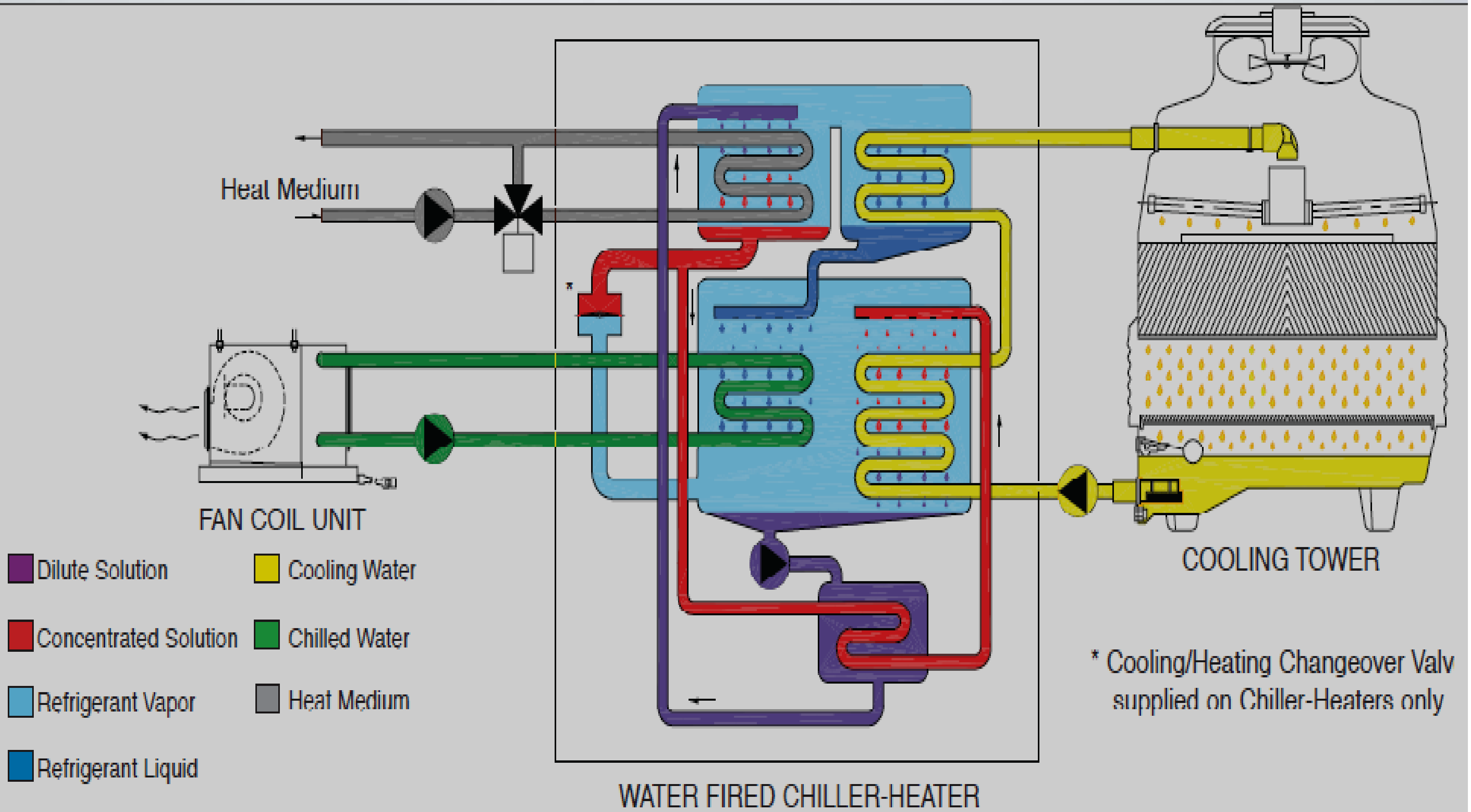
Absorption Refrigeration Cycle

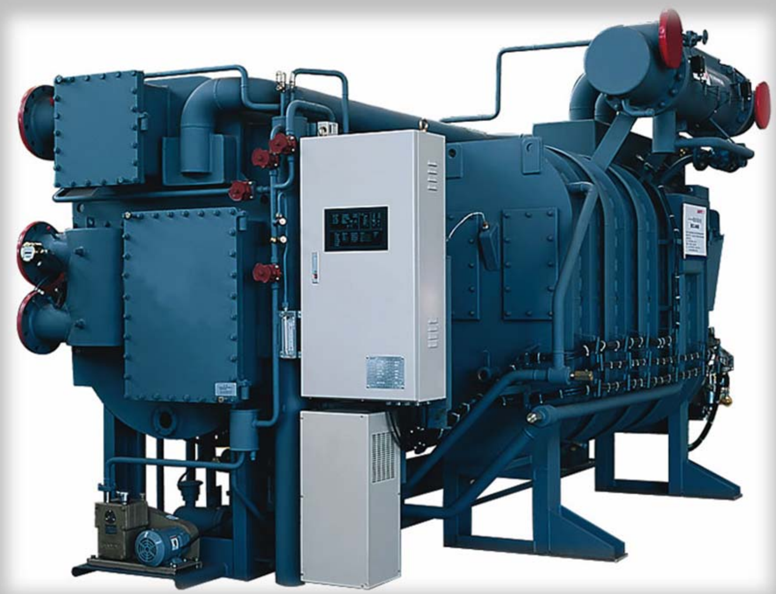


Absorption Chillers Advantages

- Reliable, durable and mature technology
- Significant reduction of electrical comsumption,
- Reduced operating costs
- Reduced CO2 emissions
- Non-flammable & non-toxic
- Ecologically benign
- ozone-friendly working medium LiBr
- Vacuum and LiBr solutions charged in factory ("plug & play")
- Water as refrigerant
- Available for outdoor installations

Absorption Chillers Challenges:

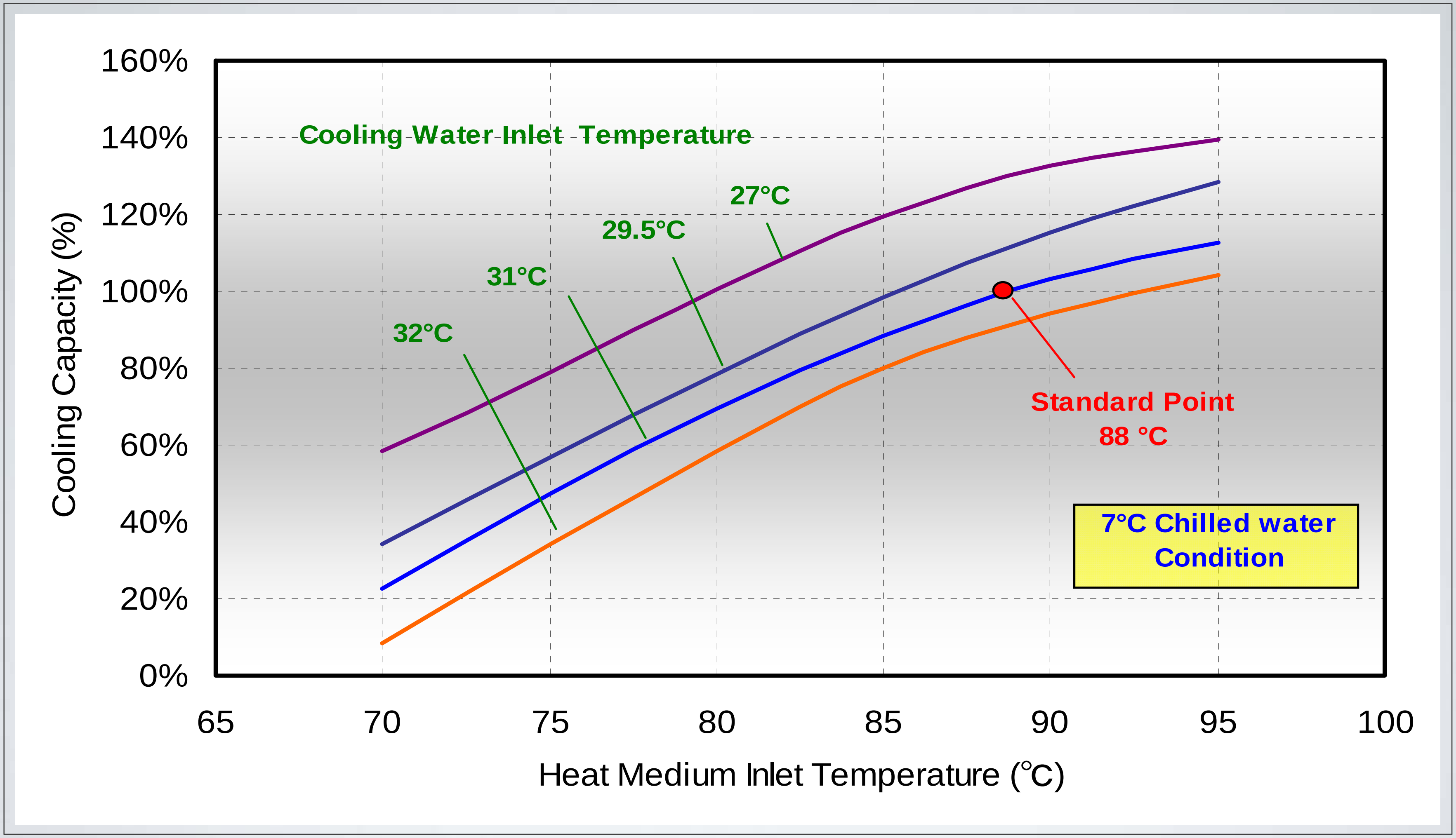
- High sensitivity towards high condenser water temperature
- High make-up water rates (evaporation, blow down & drift loss)
- Relatively high chilled water temperature (7 to 8 C)
- Temperature level of the heat medium, provokes aggressive corrosion
- Large area for solar collectors
- Overall system's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



Absorption Machines Comparison

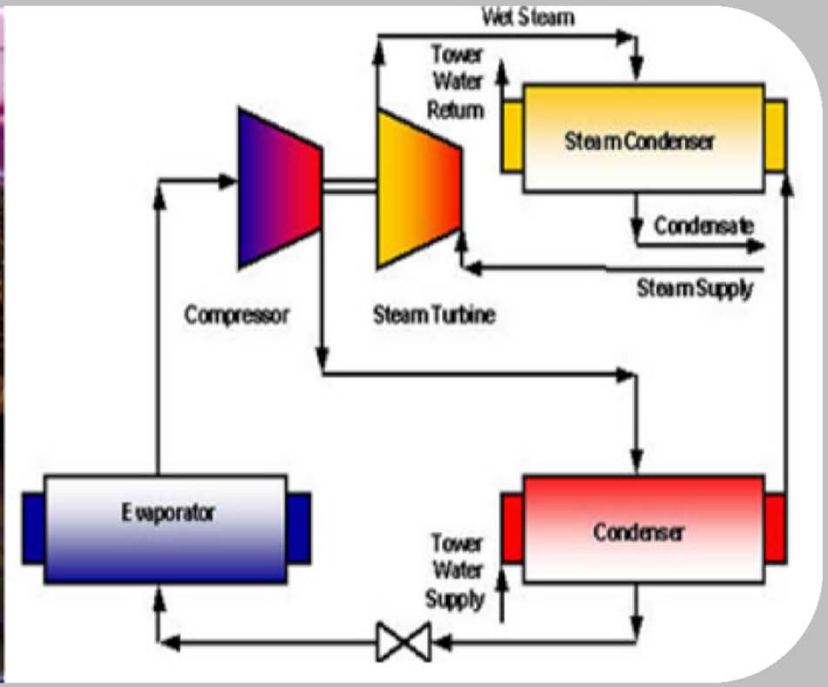
	Double effect $H_2O/LiBr$	Triple effect $H_2O/LiBr$	Single effect NH_3/H_2O
Temperature lift (max)	25 K	25 K	55 K
Temperature of Cold	5-20 °C	5-20 °C	-20 °-20 °C
Driving temperature	140-180 °C	230-270 °C	160-180 °C
Max. COP	1,1-1,4	1,6-1,8	0,6-0,7

Condenser Water Temperature & Efficiency



Steam Driven Vs Absorption Chillers

- Applicable to large tonnage from 100 to 5000 TR with free source of steam
- Machine COP = 1.8.
- Steam driven centrifugal chiller at capacities more than 1000 TR are most cost effective than two-stage absorption chiller.



Steam Driven Centrifugal vs Absorption Chillers

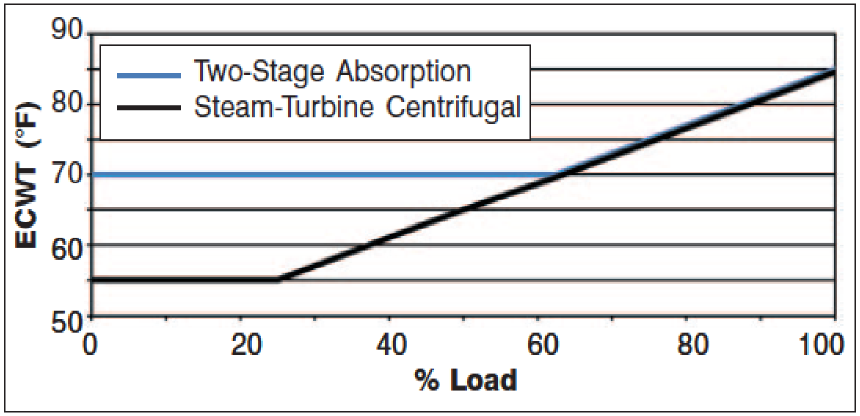


Figure 1: ECWT operating envelope.

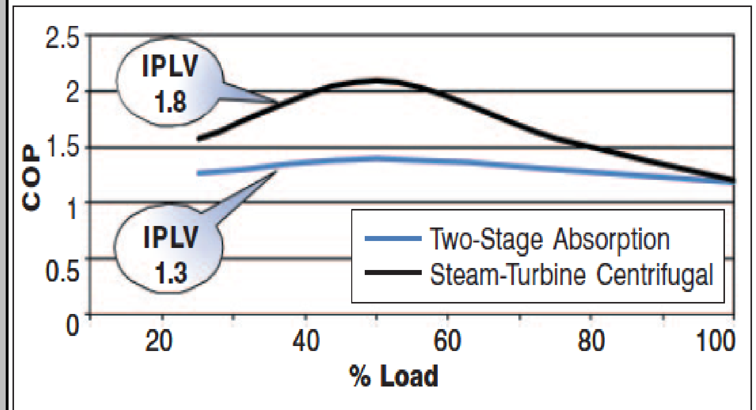
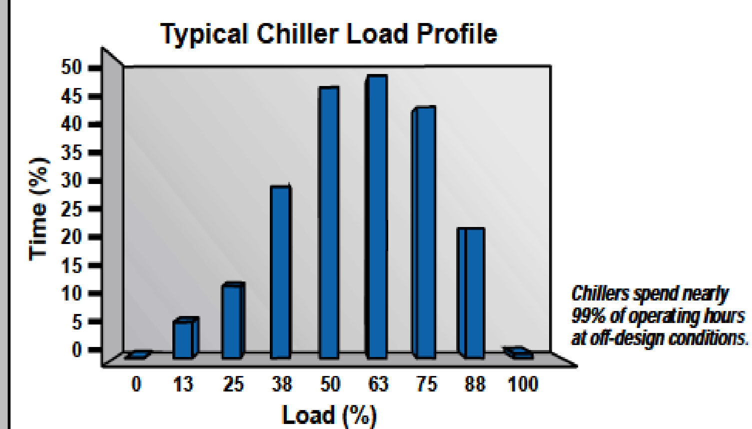


Figure 2: Coefficient of performance comparison.

Chiller Type	IPLV[a] (COP Basis)	Capital Cost Δ[b]
Electric, Constant-Speed Centrifugal	7.0	Base
Electric, Variable-Speed Centrifugal	9.9	+25
Electric Screw	7.5	+0
Steam/Hot-Water, Single-Stage Absorption	0.8	+35
Steam, Two-Stage Absorption	1.3	+220
Steam-Turbine Centrifugal	1.8	+210

a. IPLV values are calculated according to Air-Conditioning and Refrigeration Institute Standards 560-2000 and 550/590-1998.
b. Capital Cost Δ includes the chiller, pumps and tower, but not the boiler.

Table 1: Typical water-cooled chiller efficiencies and costs.



Efficiency Absorption Chiller = (Efficiency @ Full Load)*(0.1356 + 0.3944x + 4.0933x^2 – 4.4598x^3 + 1.6248x^4)+[1-0.00949*(85-ECWT)+0.00014*(85-ECWT)^2]

Adsorption Refrigeration Machines

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Adsorption Refrigeration Machines

Leading small capacity adsorption chillers in Europe

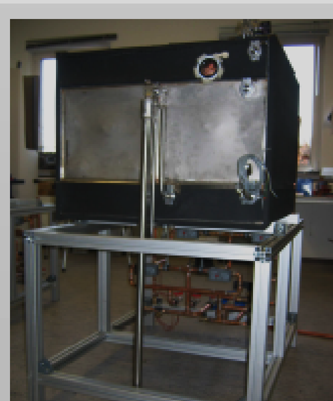
aosol energias renováveis

rotartica

PINK

ClimateWell

EAW

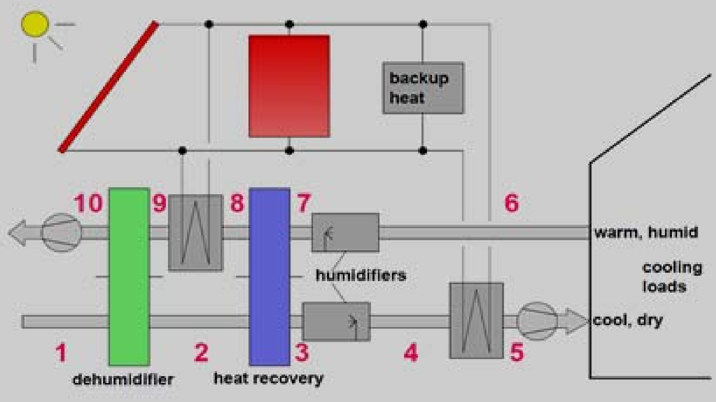


SorTech AG

SK SonnenKlima GmbH

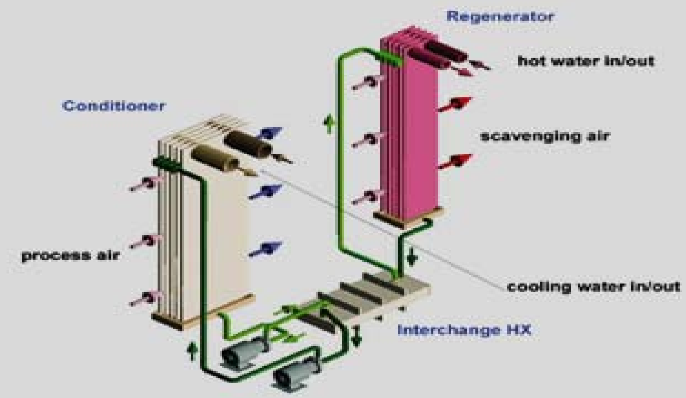
Open Cycle Adsorption System

Air System



Solid Desiccants

Water System



Leading Solar Cooling Experiences

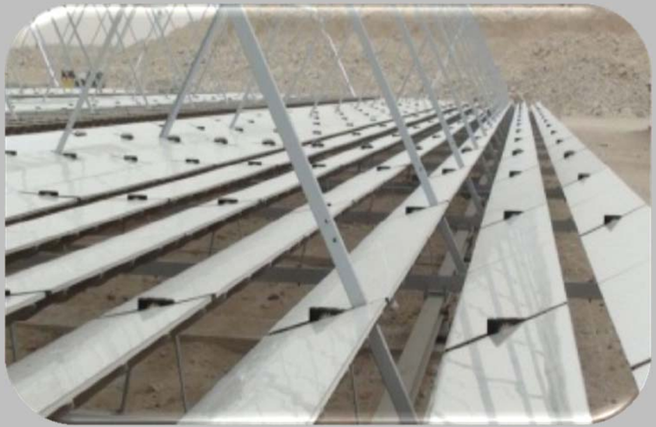
Infrastructure, Competition & Non Competition Venues

1. 2022- bid Showcase Stadium, Doha,
2. Masdar City, Abu Dhabi, UAE
3. ESAB Head Office, UAE
4. UEFA HQ, Nyan, Switzerland

Leading Experiences: Competition Venues

2022-Bid Show Case 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= ?



Leading Experiences: Non Competition Venues

Masdar City Solar Cooling Plant Solution Pilot

- A Sopogy micro-parabolic trough collector with uniaxial tracking and a total mirror aperture area of 334 sq m. Synthetic oil as thermal media.
- Heat is transferred to the system's pressurized water circuit through a heat exchanger.
- A Mirroxx linear Fresnel collector with uniaxial tracking and a total mirror aperture area of 132 m^2 heats the pressurized water directly.
- The two solar thermal collector systems have been in successful test operation already for more than three months.

Leading Experiences: Non Competition Venues

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Masdar City Solar Cooling Plant Solution Pilot

- Schneider Electric provided the control system components for the pilot plant
- Fraunhofer Institute of Solar Energy to analyze the monitored data and assess system performance.
- Collector’s thermal energy has been driving the Broad 50 refrigeration-ton double-effect absorption chiller cooling 1700 m^2 of office building.
- Air delivery system uses chilled beams coupled with fresh air energy recovery units.
- Water consumption : Not Available

Leading Experiences: Non Competition Venues

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.

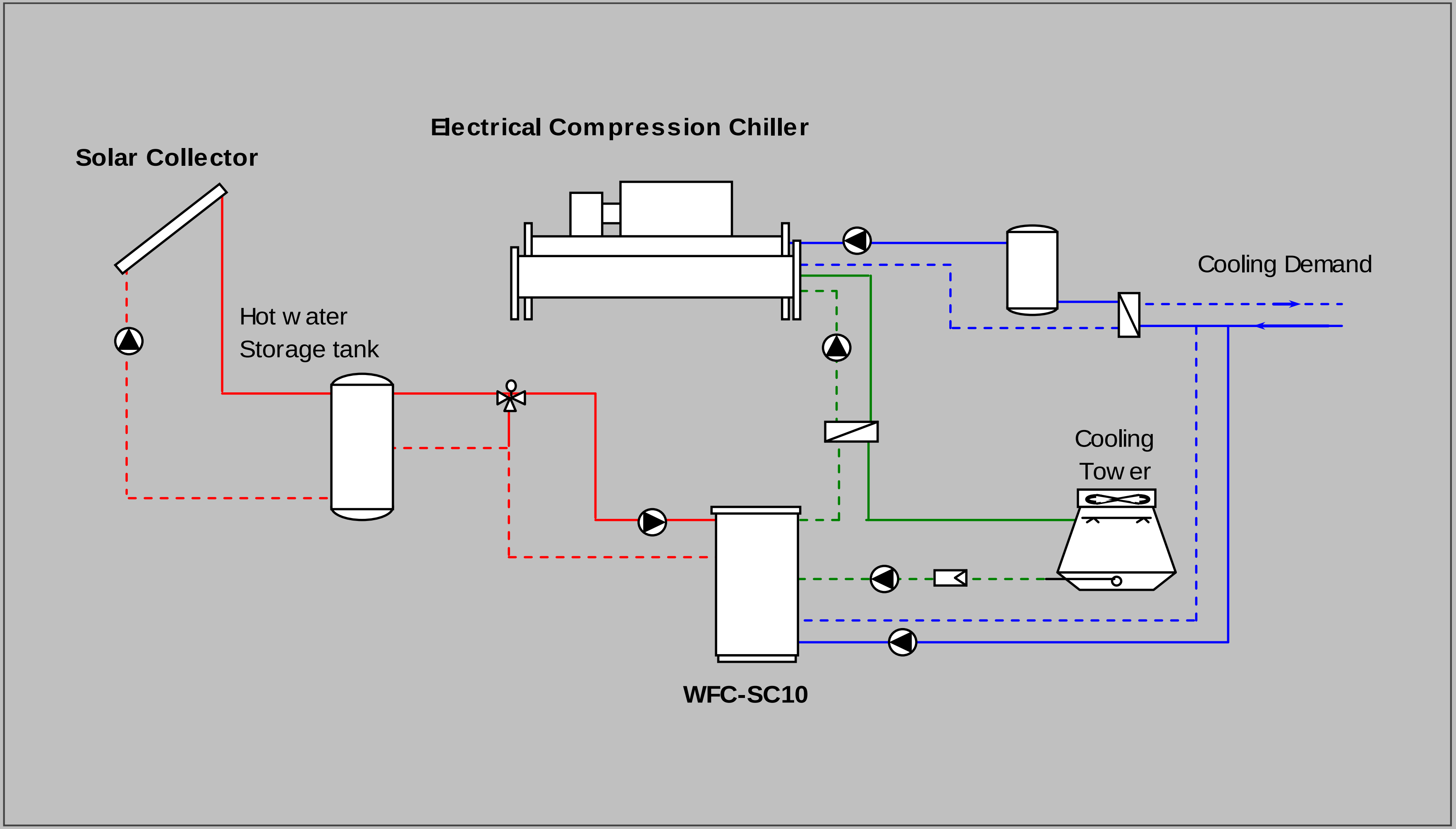
Leading Experiences: Non Competition Venues

UEFA HQ, Nyon, CH

- Design Intent: Must be a sustainable & energy efficient building operating in 2010.
- Building's Cooling Load: 100 TR.
- Renewable Energy Source: Geothermal, Thermal Solar & PV (200 m^2).
- Thermal Array: 90 vacuum tubes over 110 m^2
- area generating 55 KW used for heating and domestic water in winter and cooling in summer to cover 10% only of the loads.
- Water temperature: Hot at 88°C for generator and Chilled water at 7°C.
- Storage tank: 3,000 Liters.
- Refrigeration Machine: absorption chiller with cooling capacity of 10 TR.

Leading Experiences: Non Competition Venues

UEFA HQ, Nyon, CH



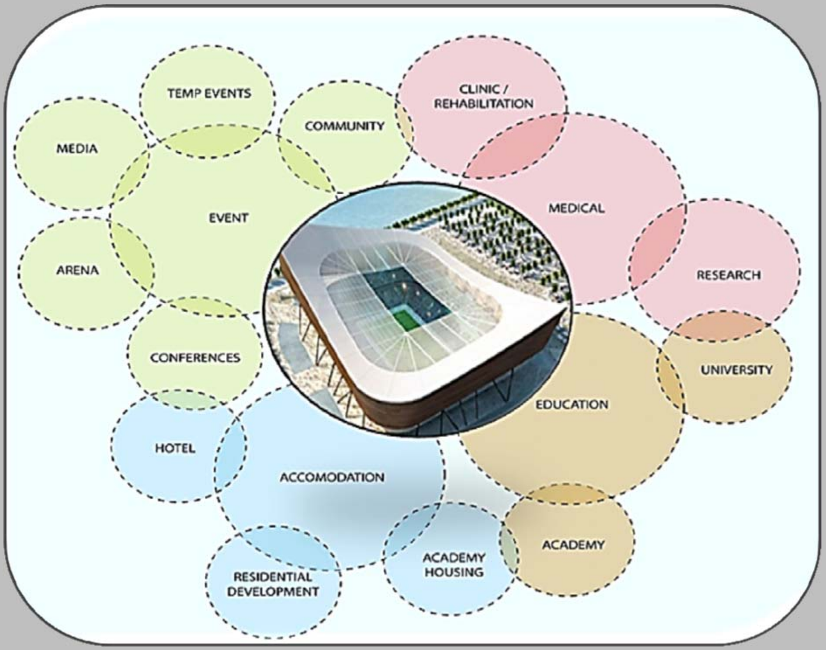
Delivering Promises

- Comparison
- Scalability
- Context Integration
- Infrastructure integration
- The bath towards net-zero
- Controls Integration Challenges
  Simulation outputs video

Context Integration

- Integration with other aspects:

  Event, Accommodation, Medical, Mobility & Education
- District cooling plants locations
- Chilled water reticulation optimization
- Solar fields location
- Relationship with other utilities
- Use recycled water for heat rejection
- Used cooling tower blow down water for irrigation



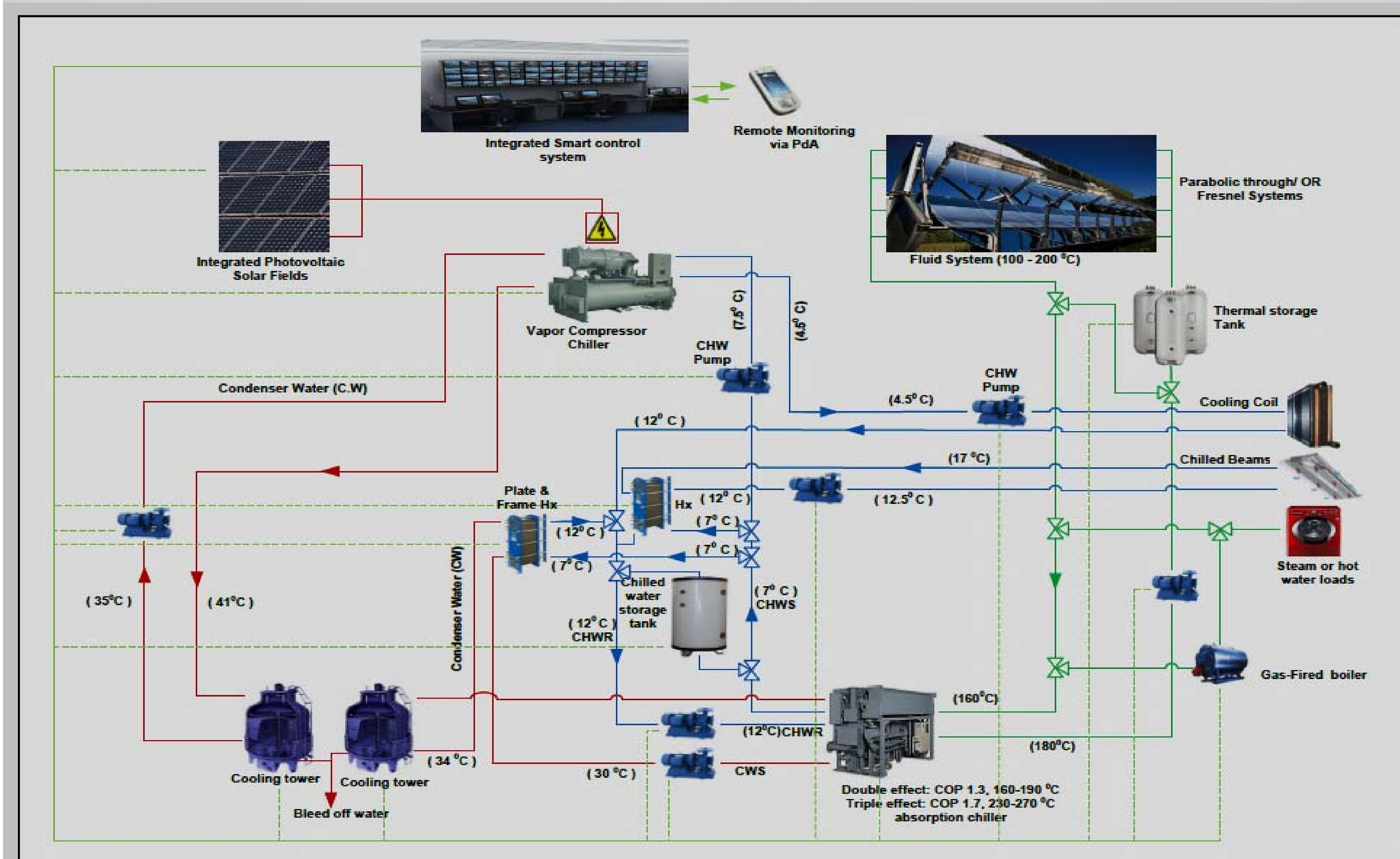
Systems Selection Justification

Systems Descriptions	Evacuated tube collector, single effect absorption chiller		Parabolic trough, double effect absorption chiller		Flat collectors & adsorption chiller	
Solar Collector efficiency	60	%	50	%	55	%
Chiller efficiency (COP)	0.75		1.3		0.45	
Temperature ©	80 to 110		144 (4 bar)		60 to 85	
Solar Irradiation on collector surface	1,000	kW	1,000	kW	1,000	kW
Collector's efficiency	60	%	50	%	55	%
Heat absorbed by the captor supplied to the Chiller	600	kW	500	kW	550	kW
Absorption Chiller COP	0.75		1.3		0.45	
Heat absorbed by Chiller	450	kW	650	kW	248	kW
Overall system performance	**45%**		**65%**		**25%**	
Increase in cooling yield		**44%**			**-81.82%**	

Cost Effectiveness

- Thermal absorption solar refrigeration system cost almost 3 to 4 times the cost of a conventional vapor compression system.
- Double effect direct-fired/steam absorption chiller cost between 1.8 to 2 times the cost a vapor compression chiller.
- The cost of reduced scale cooling system using adsorption machine is almost 4 times compared to a non-solar assisted system.
- The cost of a direct-fired & steam absorption chiller is 35% higher than the direct-fired chiller.
- The cost of a direct-fired & hot water absorption chiller is 35% higher than the direct-fired chiller.
- The square meter of a thermal solar flat collector cost between 1700 to 3400 QR
- The square meter of solar evacuated tubes cost between 3400 to 3970 QR

QPM Approach



System’s Integration

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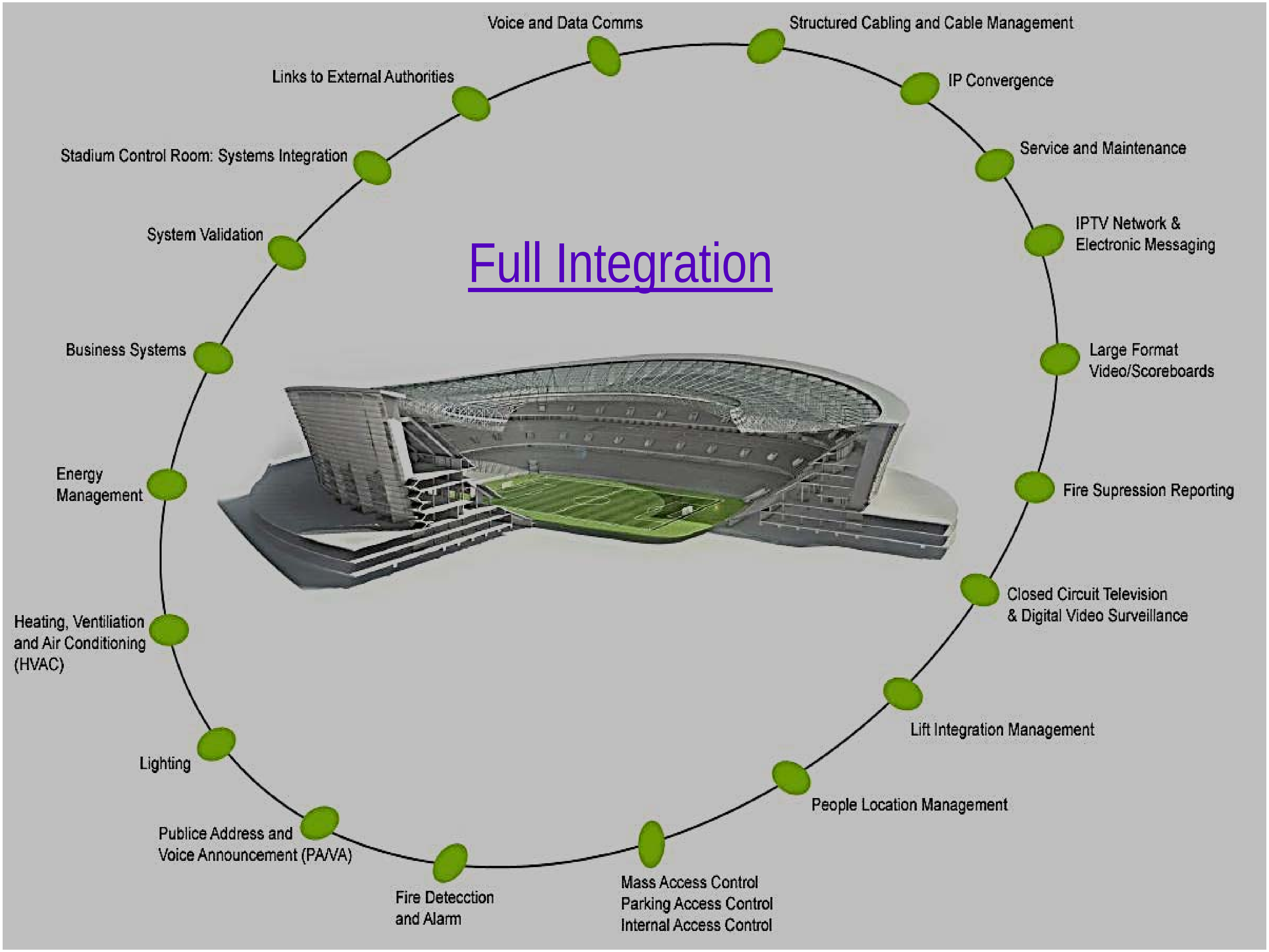
- At the present, most solar cooling systems are assemblies of single components and don’t provide a fully integrated system, these components in many cases have their own control units.
- The performance of the solar cooling solution depends a lot on the availability of a single source centralized control.
- The industry will follow the market momentum in embracing a fully integrated solution for solar cooling system.


Full Integration
Voice and Data Comms
Structured Cabling and Cable Management
IP Convergence
Service and Maintenance
IPTV Network & Electronic Messaging
Large Format Video/Scoreboards
Fire Supression Reporting
Closed Circuit Television & Digital Video Surveillance
Lift Integration Management
People Location Management
Mass Access Control
Parking Access Control
Internal Access Control
Fire Detecction and Alarm
Publice Address and Voice Announcement (PA/VA)
Lighting
Heating, Ventiliation and Air Conditioning (HVAC)
Energy Management
Business Systems
System Validation
Stadium Control Room: Systems Integration
Links to External Authorities

CFD Simulation Video

Conclusion

1. Major benefit of performing this study is to show the feasibility of a carbon neutral solution for a cooling plant at different scale
2. Cooling system efficiency is sensitive towards high condenser water temperature
3. Adverse impact of dust/ humidity on system's efficiency
4. High rates of water depletion and pollution (evaporation & bleed-off)
5. Higher cost
6. Needs a vast area for solar field (15 to 20 times the football pitch size)
7. Requires a single source control system for all system's components
8. Cooling plant reticulation needs be integrated in the city infrastructure
9. "Opportunity Document" needs to be developed for each venue

THANK YOU