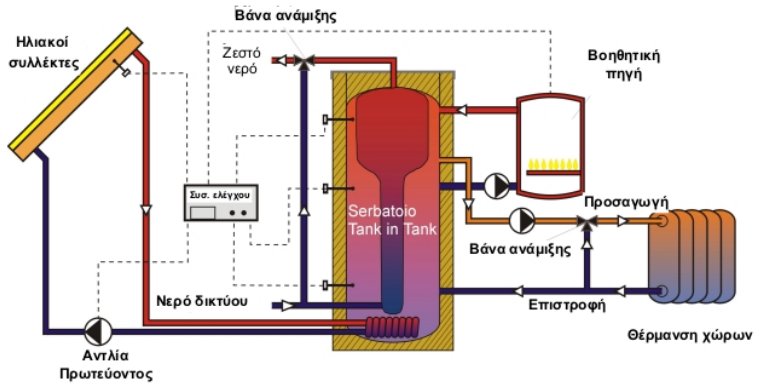


Solar Cooling

TranSolar Workshop in Slovenia

Dimitrios Chasapis
R.E. Systems Technology Eng.
Solar Thermal Dpt. CRES

Solar Cooling or Solar Combi+

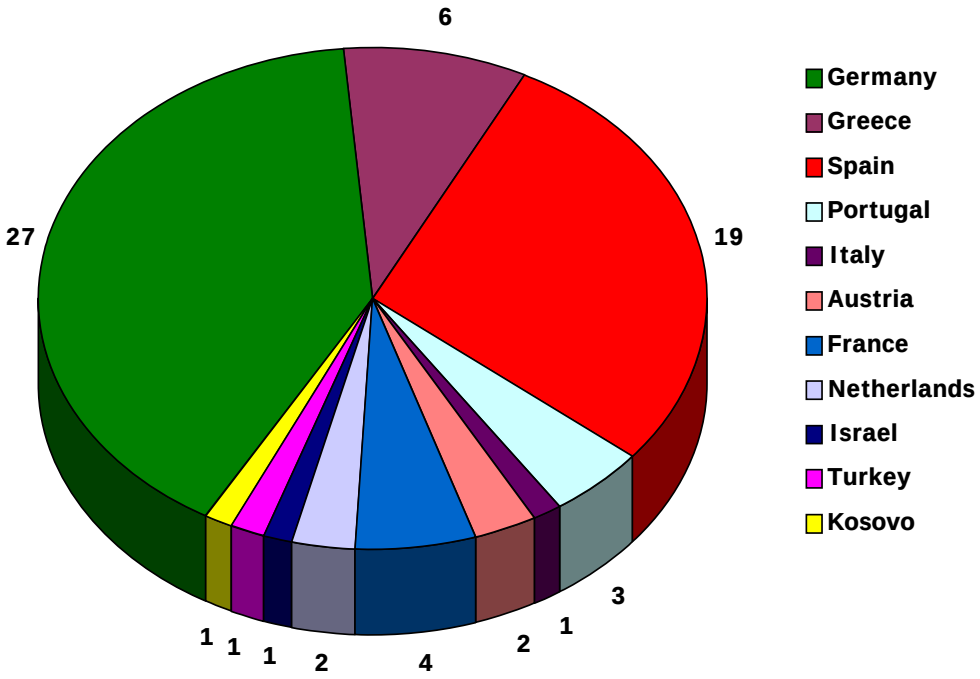
Systems that use solar energy for heating, cooling and DHW preparation

Use of chillers that utilize hot water as primary energy

- Closed circuit for cold water production
- Open Circuit for air conditioning

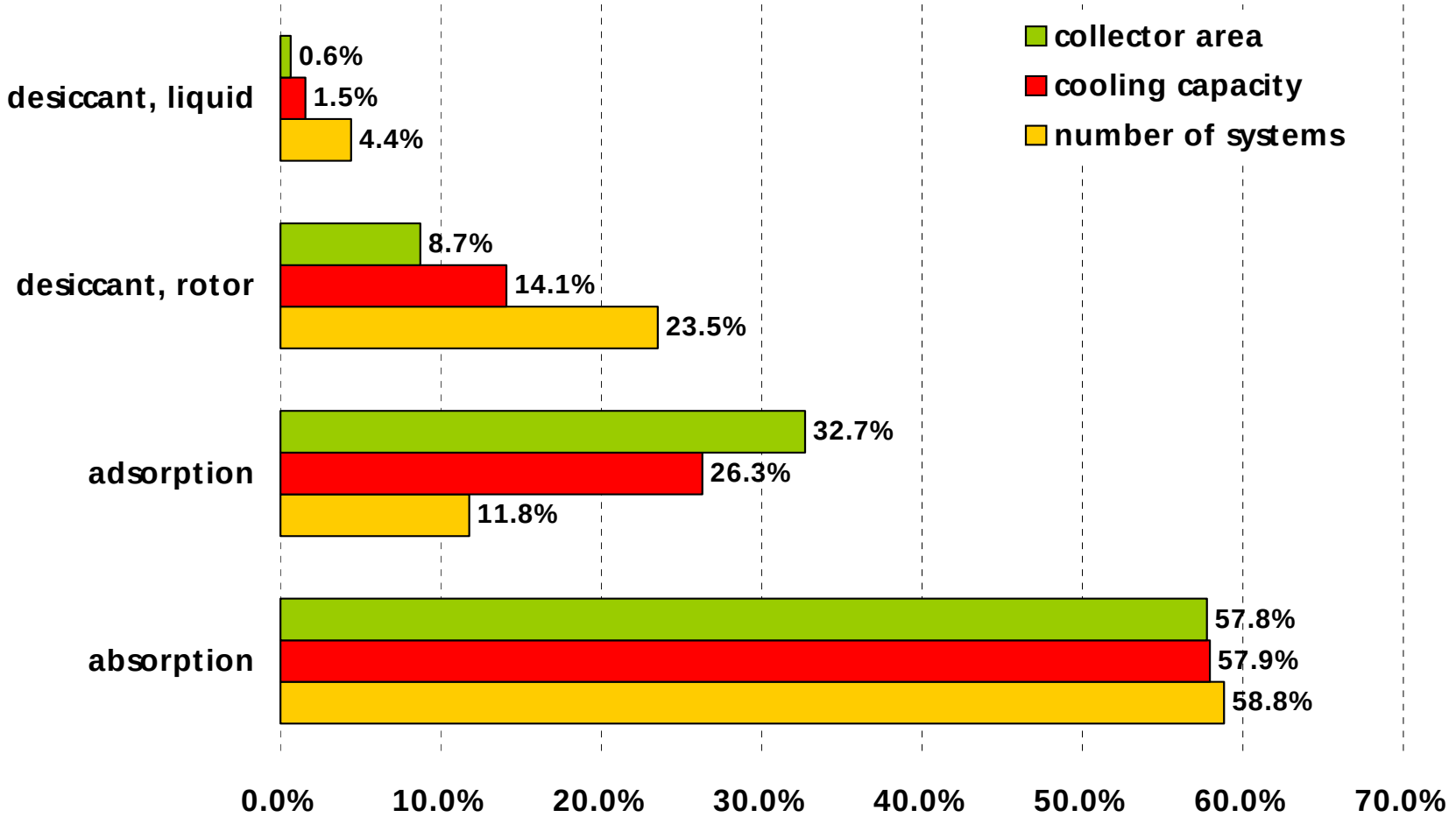
Solar Cooling Systems in Europe (2004)

- 67 Systems
- 6 MW total installed capacity
- 16700 m^2 collectors area



Source: IEA Task 25

Solar Cooling Systems in Europe (2004)

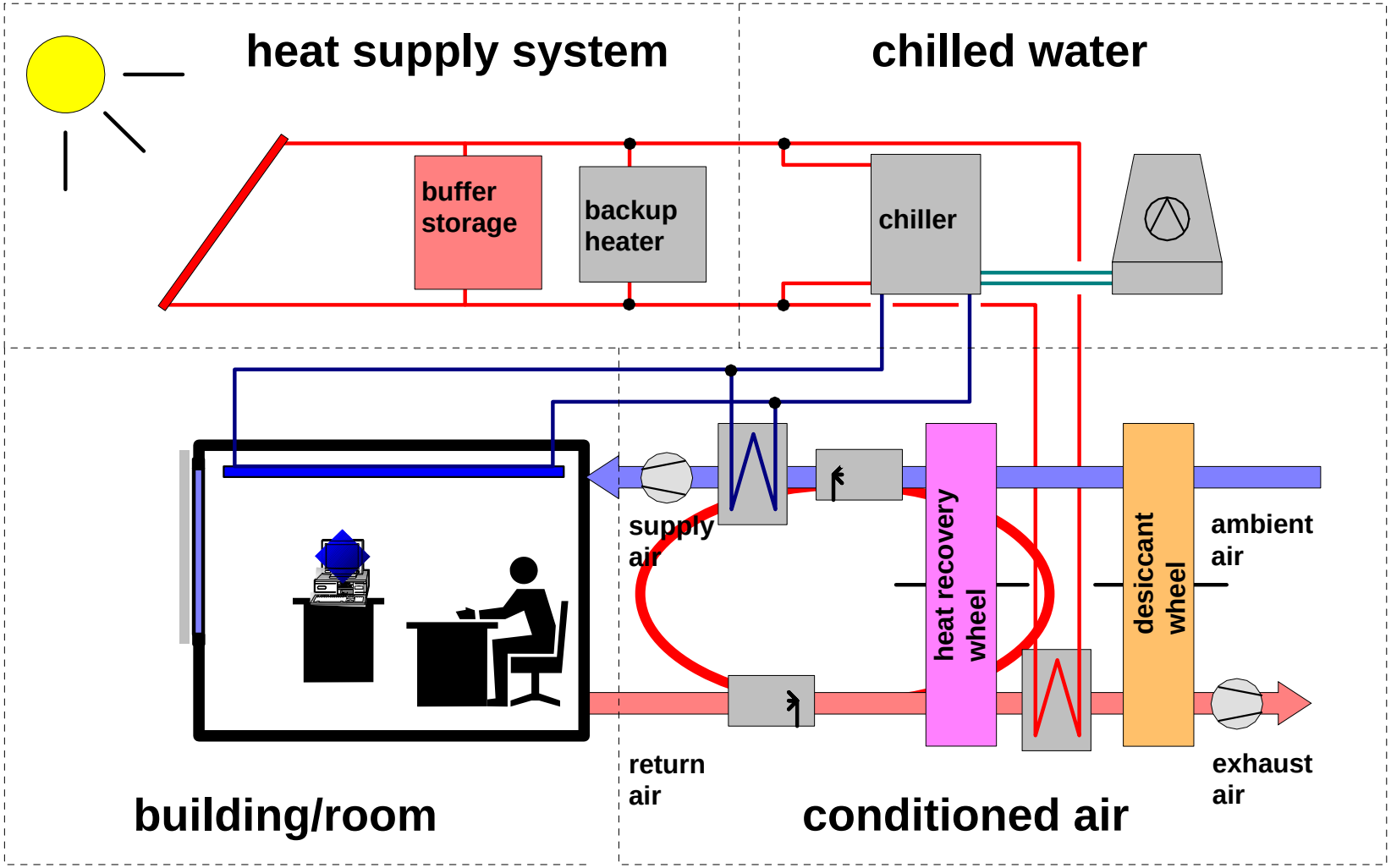


Source: IEA Task 25

Solar Chiller Technologies

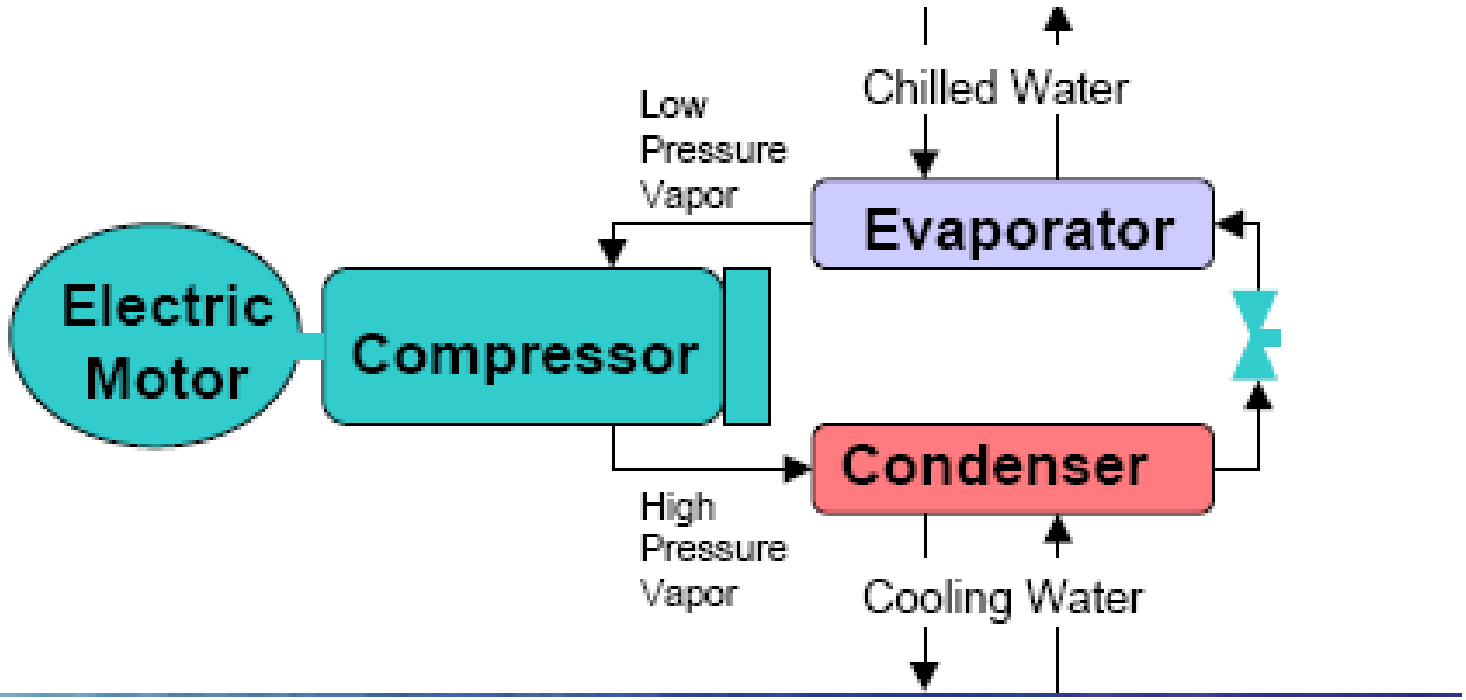
Method	Closed cycle		Open cycle	
Refrigerant cycle	Closed refrigerant cycle		Refrigerant (water) is in contact with the atmosphere	
Principle	Chilled water		Dehumidification of air and evaporative cooling	
Phase of sorbent	solid	liquid	solid	liquid
				
Typical material pairs	water - silica gel	water - lithium bromide ammonia - water	water - silica gel, water - lithium chloride	water - calcium chloride, water - lithium chloride
Market available technology	Adsorption chiller	Absorption chiller	Desiccant cooling	Close to market introduction
Typical cooling capacity (kW cold)	50 – 430 kW	15 kW – 5 MW	20 kW – 350 kW (per module)	
Typical COP	0.5 – 0.7	0.6 – 0.75 (single effect)	0.5 – >1	> 1
Driving temperature	60 – 90 °C	80 – 110 °C	45 – 95 °C	45 – 70 °C
Solar collectors	Vacuum tubes, flat plate collectors	Vacuum tubes	Flat plate collectors, solar air collectors	Flat plate collectors, solar air collectors

General Schematic Diagram

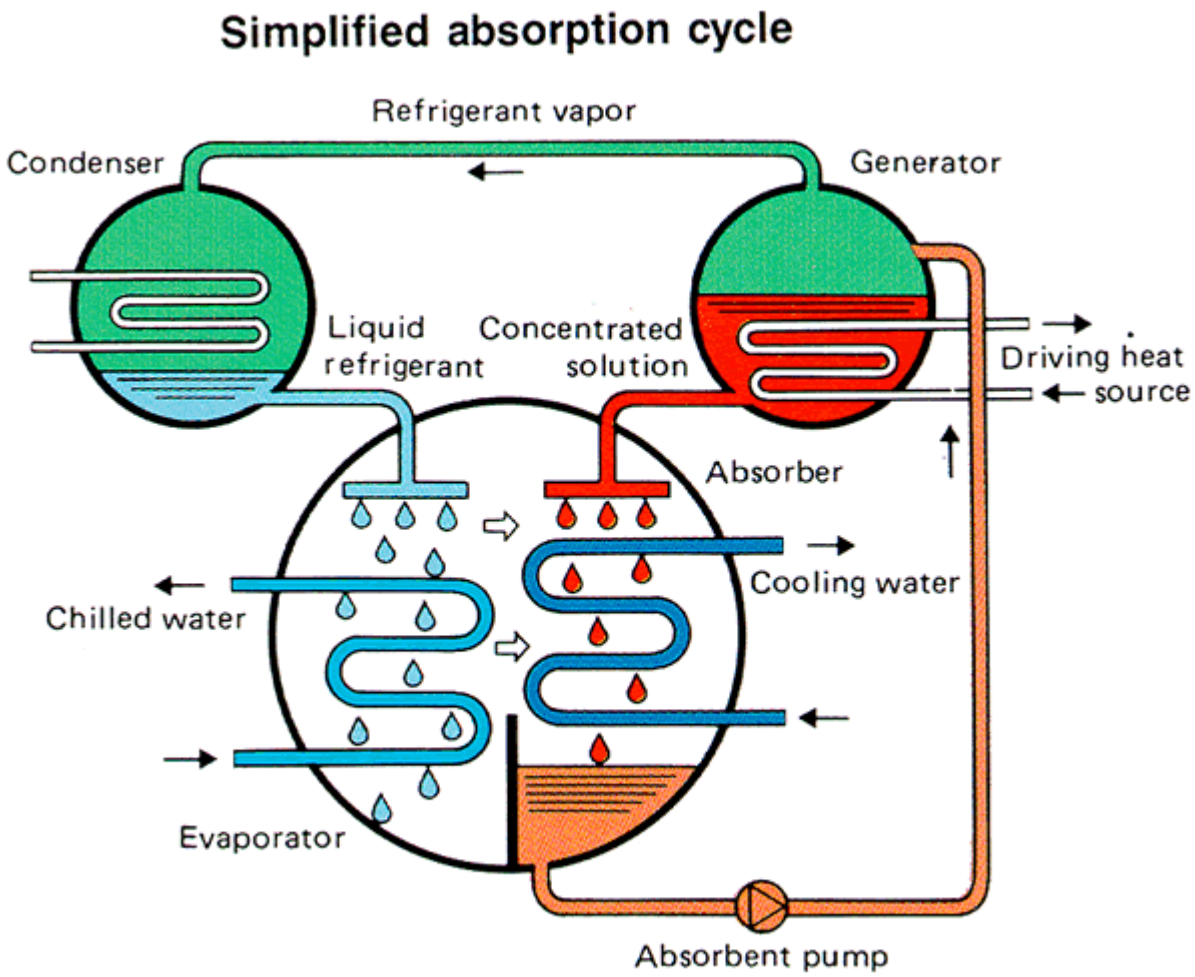


Source: Fraunhofer -ISE

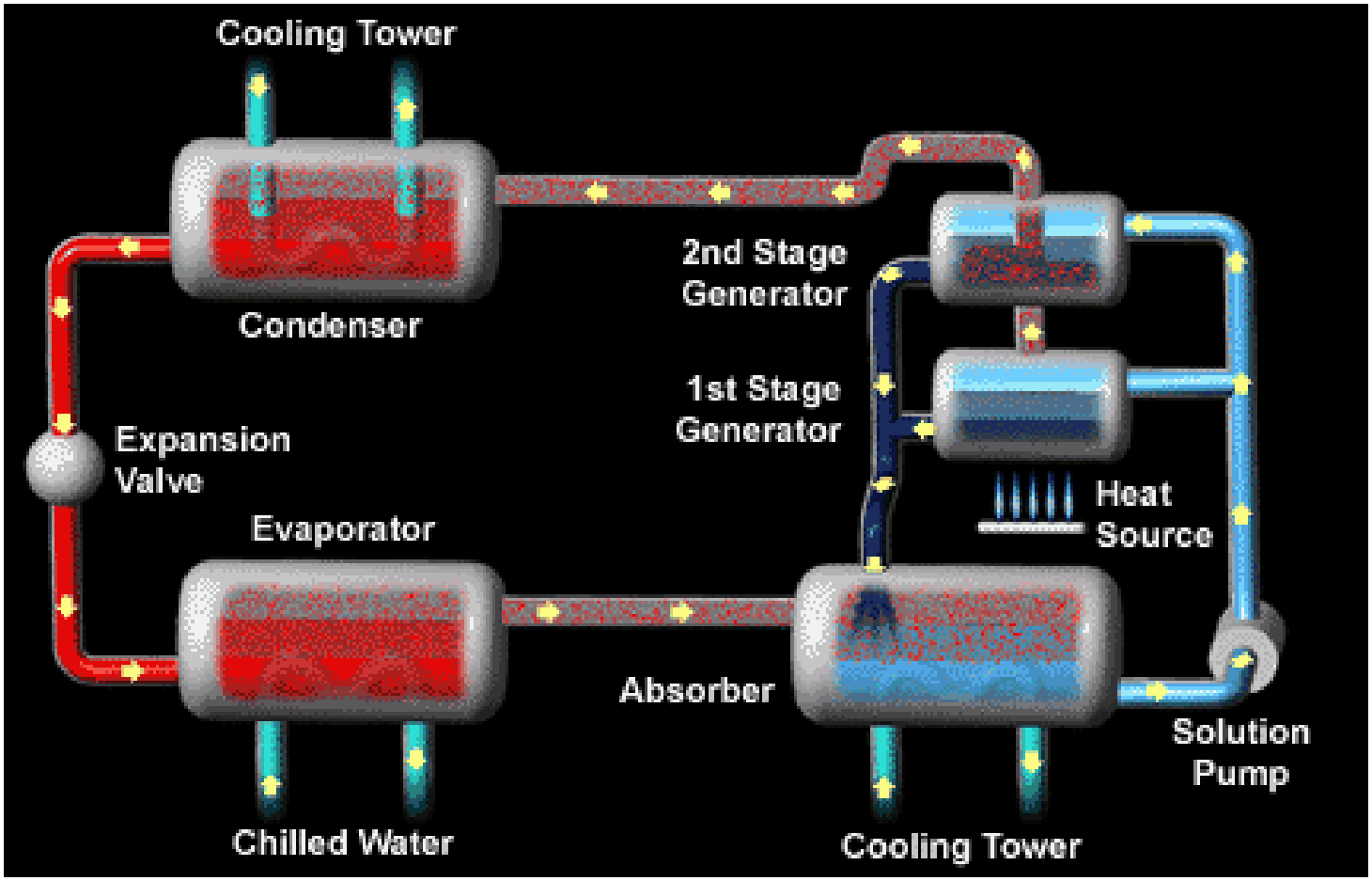
Compression Chiller



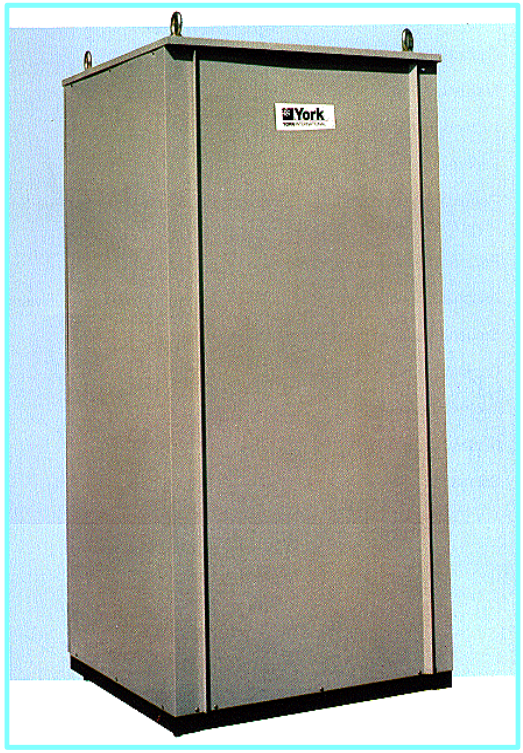
Absorption Chiller



Double Stage Absorption Chiller



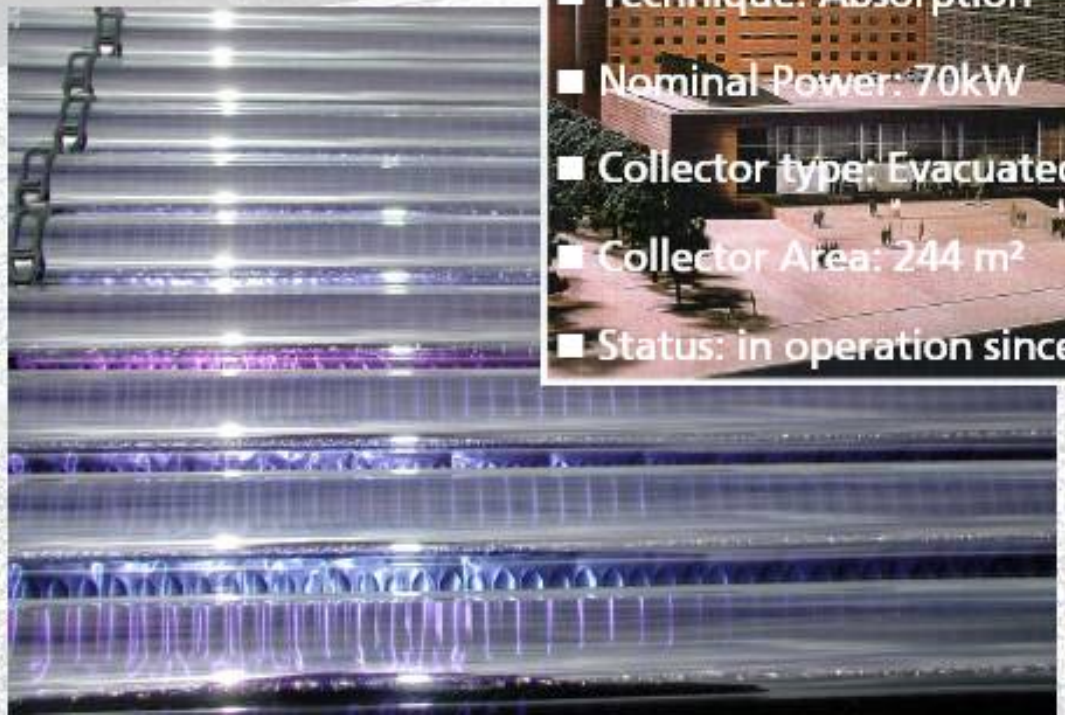
Absorption Chiller

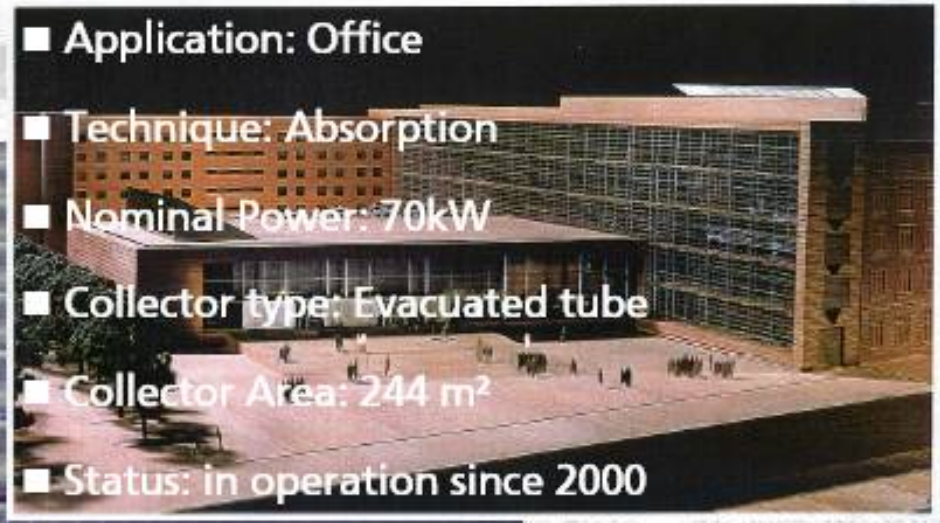


- Most chillers of high capacity (> 200 kW)
- 13 chillers of low capacity (<100 kW)
- The produced cold water can be used for air conditioning in air chillers or for direct space cooling (fan coils, chilled ceilings,...)
- Smallest chiller 4.5 kW
- Usual supply temperatures 75°C - 100°C
- Usual supply temperatures of double stage systems > 150°C with COP 1.2
- Usual COP 0.68-0.78

Absorption Chiller Examples

Bundespresseamt Berlin/ Germany



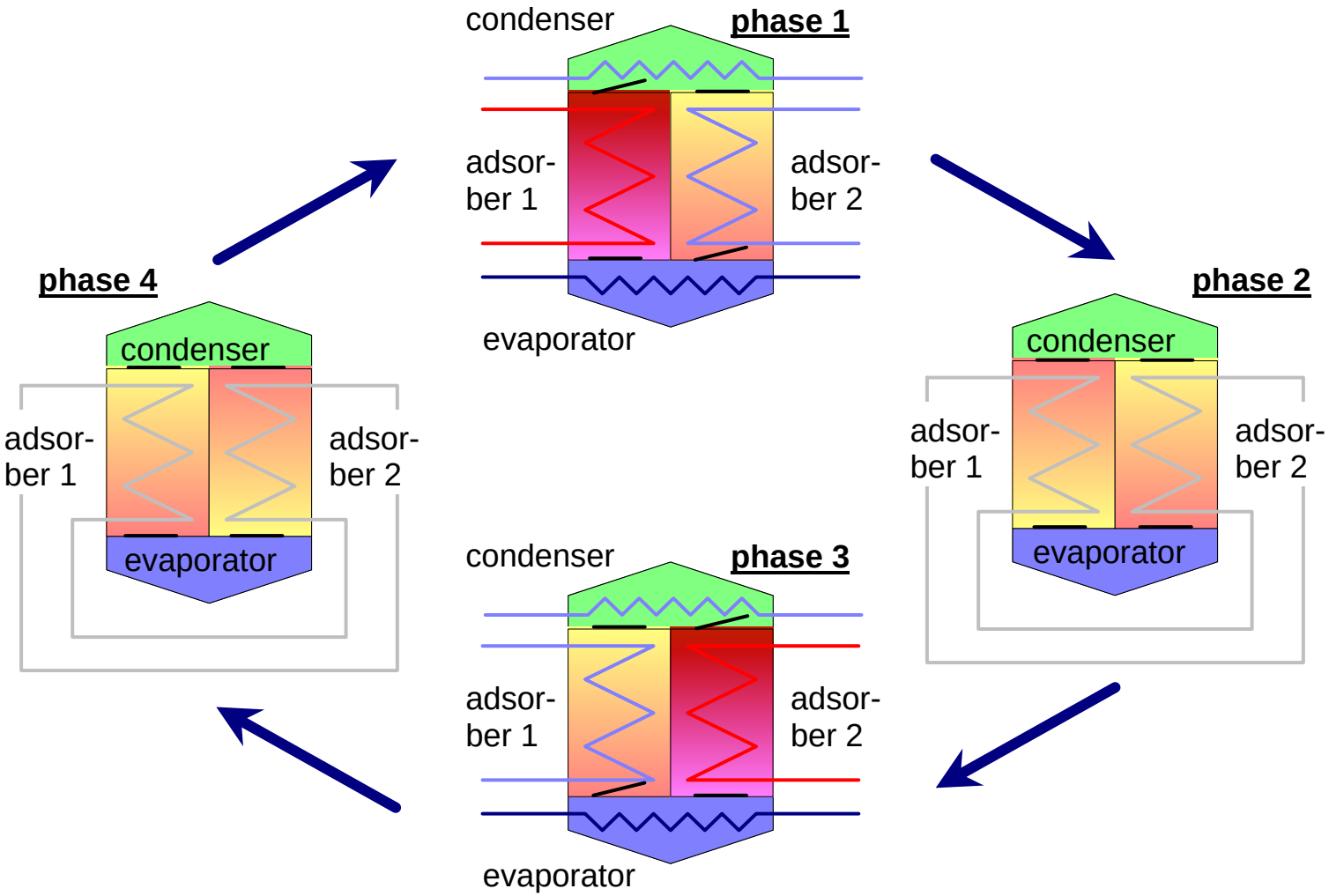


- Application: Office
- Technique: Absorption
- Nominal Power: 70kW
- Collector type: Evacuated tube
- Collector Area: 244 m²
- Status: in operation since 2000

A Solar Absorption System in southern France for Cooling a wine cellar

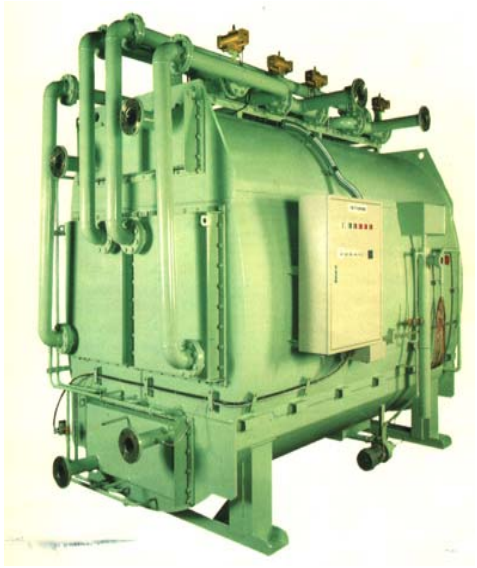
- Application: Cooling a wine cellar
- Technique: Absorption
- Cooling Capacity: 52 kW
- Collector type: Evacuated tube
- Collector Area: 130 m²
- Status: in operation since 1991

Adsorption Chillers



Source: Fraunhofer -ISE

Adsorption Chillers



- The produced cold water can be used for air conditioning in air chillers of for direct space cooling (fan coils, chilled ceilings,...)
- Usual chiller capacity range 50 kW - 400 kW
- Smallest Capacity 7.5kW
- Usual supply temperature > 55°C
- COP 0.65

Adsorption Chiller Examples

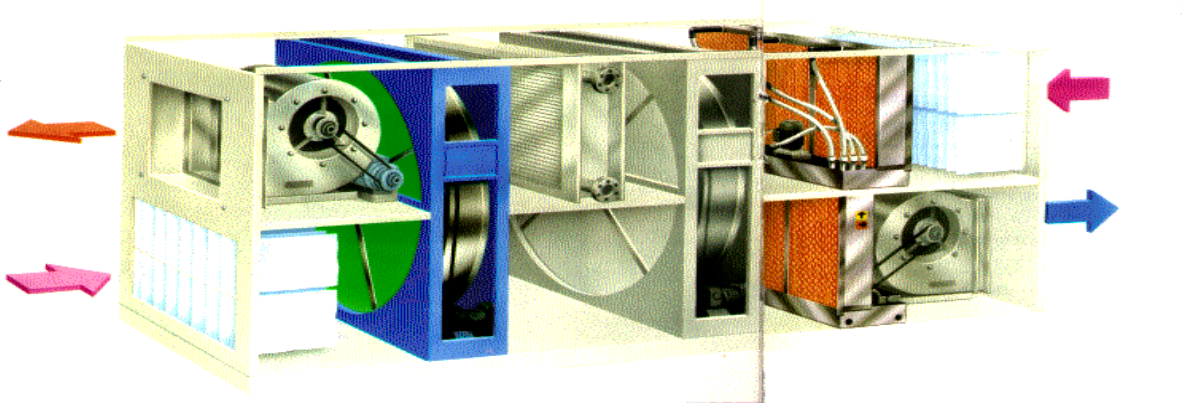
Sarantis COSMETICS FACTORY in Aharnes, Greece

- Application: Air-Conditioning of a Factory
- Technique: Adsorption
- Cooling Capacity: 700 kW
- Collector type: Flat plate
- Collector Area: 2700 m²
- Status: in operation since 1999

Universitätsklinik Freiburg/ Germany

- Application: Medical Facility
- Technique: Adsorption
- Cooling Capacity: 70 kW
- Collector type: Evacuated tube
- Collector Area: 170 m²
- Status: in operation since 1999

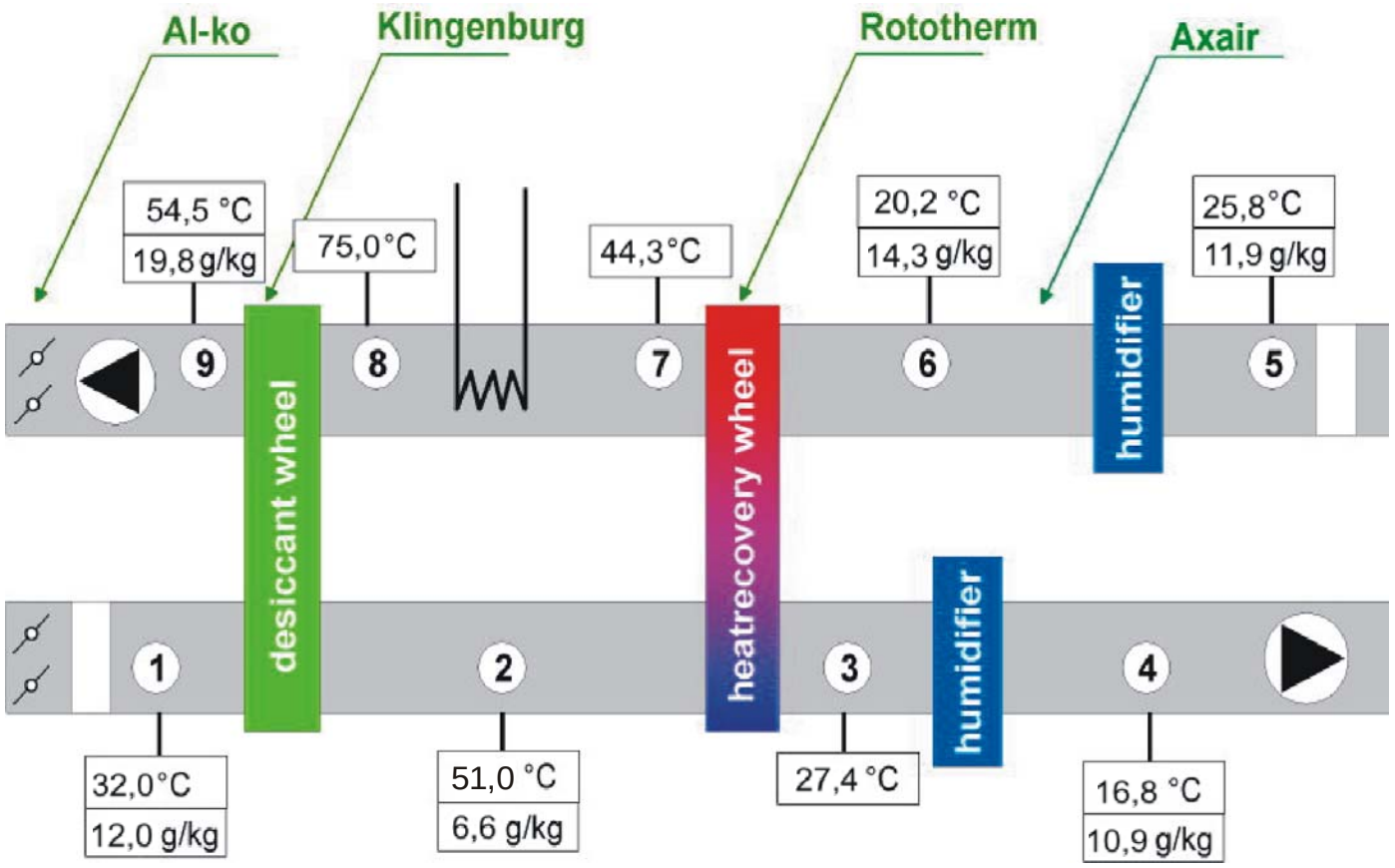
Desiccant Evaporative Cooling (DEC)



- Simple mechanism, use of common materials
- About 6 desiccant wheel manufacturers worldwide
- Use of low temperatures (down to 45°C)
- Chemical storage and higher COP by the use of liquid desiccant (ClLi)
- ✘ Large installation area

Source: Fraunhofer -ISE

DEC: Operating Principle



DEC Examples

- **Air Collectors : 100 m^2**
- **DEC system (10200 m^3/h) with *silica gel***
- **Seminar room chilling – Chamber of Commerce in Freiburg / Germany**

➔ **Simple collector system with direct integration in the conditioning unit**

➔ **No back-up system and storage**

➔ **Best use of solar chiller since cooling load is proportional to sun radiation**

Source: Fraunhofer -ISE

DEC Example

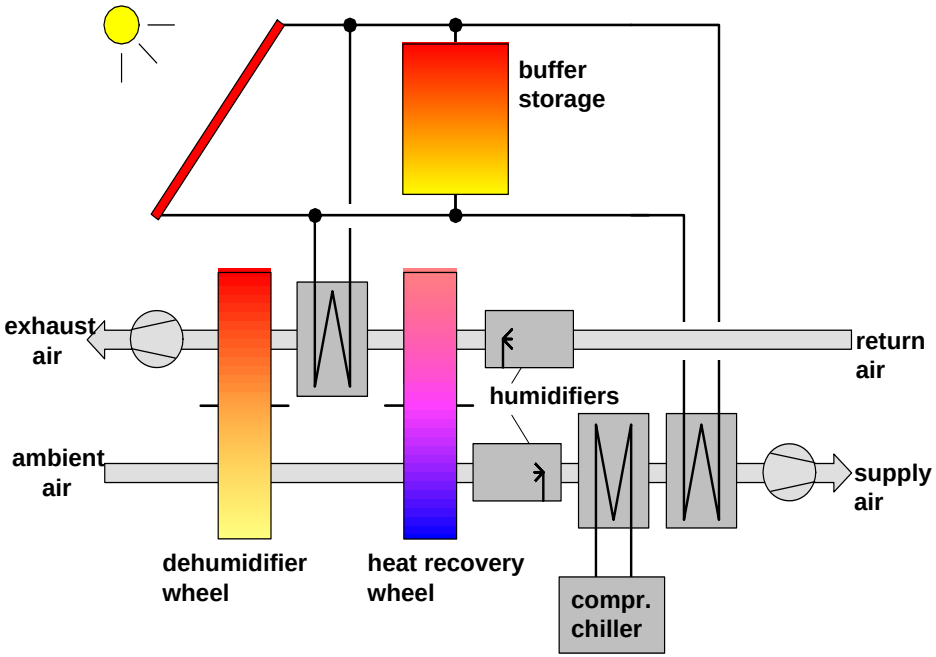
- Mataro/Spain
- Public Library
- DEC system (12.000 m^3/h) with air collectos 105m^2

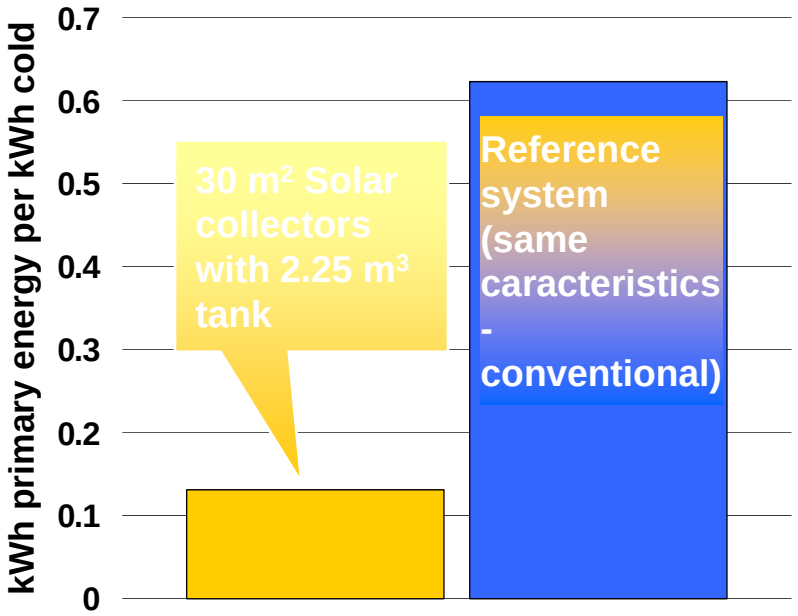
Source: Fraunhofer -ISE

Fraunhofer ISE – Liquid DEC office cooling

Source: Fraunhofer -ISE

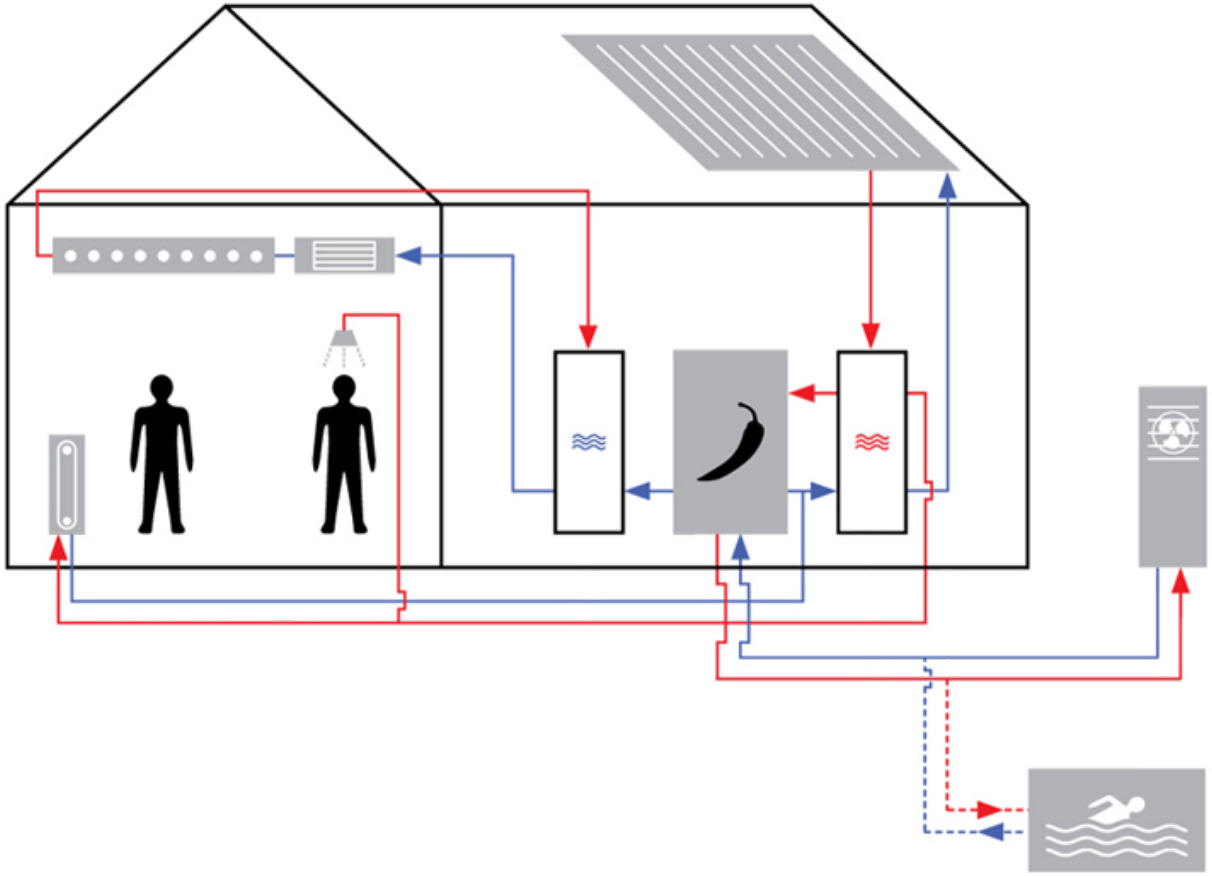
Hybrid Systems





- „DEC“ system with integrated compression chiller in Palermo, Italy (240 m²)

House Chilling



Source: SolarNext

Small Scale Solar Chillers

aosol energias renováveis

EAW

rotartica

SorTech AG

PINK

ClimateWell

SK SonnenKlima GmbH

House with small chiller 4.5kW

Source: Rotartica

Heat Rejection
Dry Cooling Tower

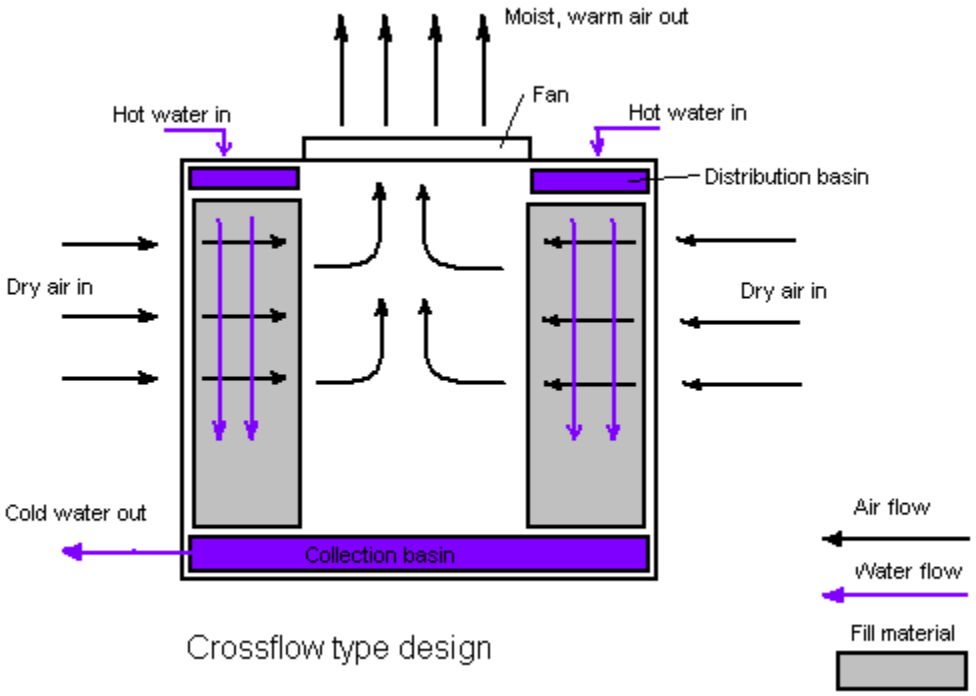
The heat is dissipated thought a heat exchanger with the use of fans

Problems:

Big construction, problem with rejection in summer high temperatures (above 32°C)

Heat Rejection

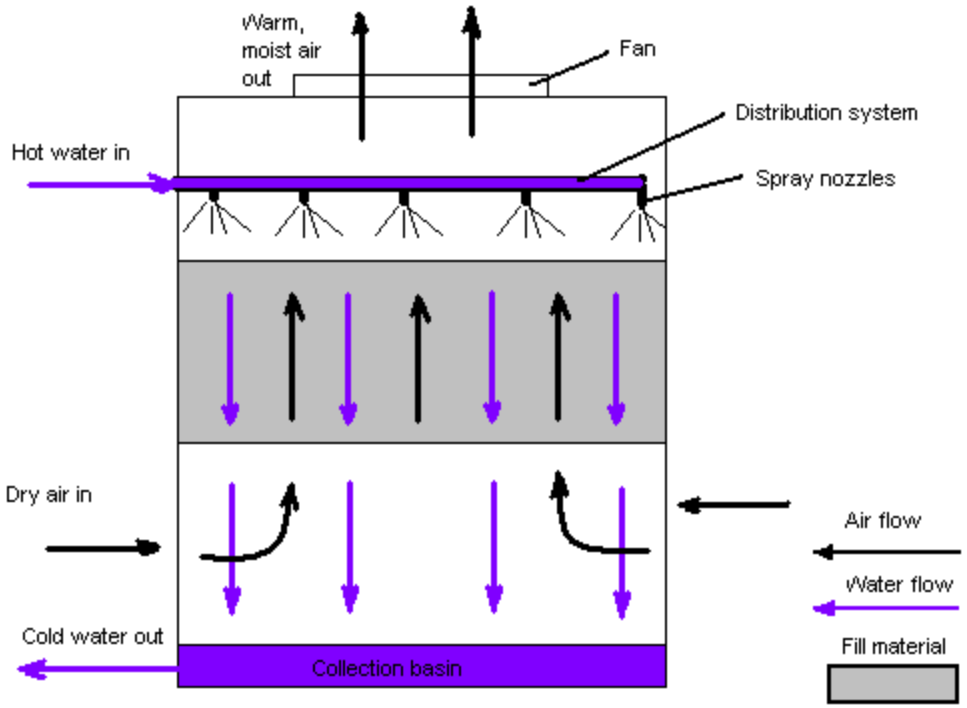
Crossflow wet cooling tower



Crossflow type design

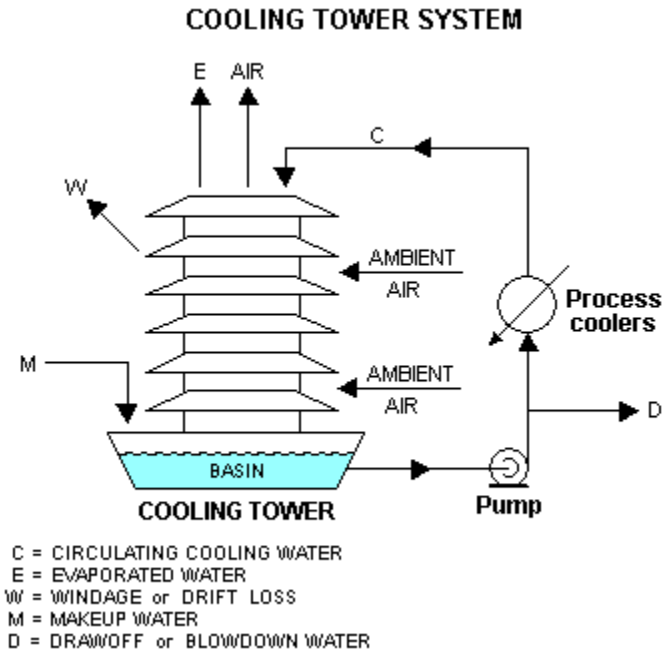
Heat Rejection

Counterflow wet cooling tower



Counterflow type design

Heat Rejection
Wet Cooling Towers



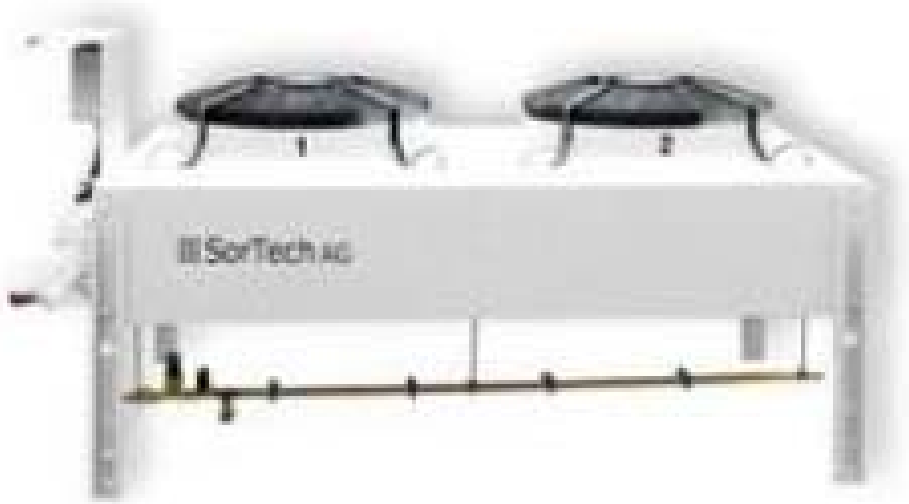
Problems:

-Water Consumption

-Formation of Legionela Bacteria

Heat Rejection

Hybrid cooling tower



Solar Cooling, Technical aspects

SAC = solar air coll.

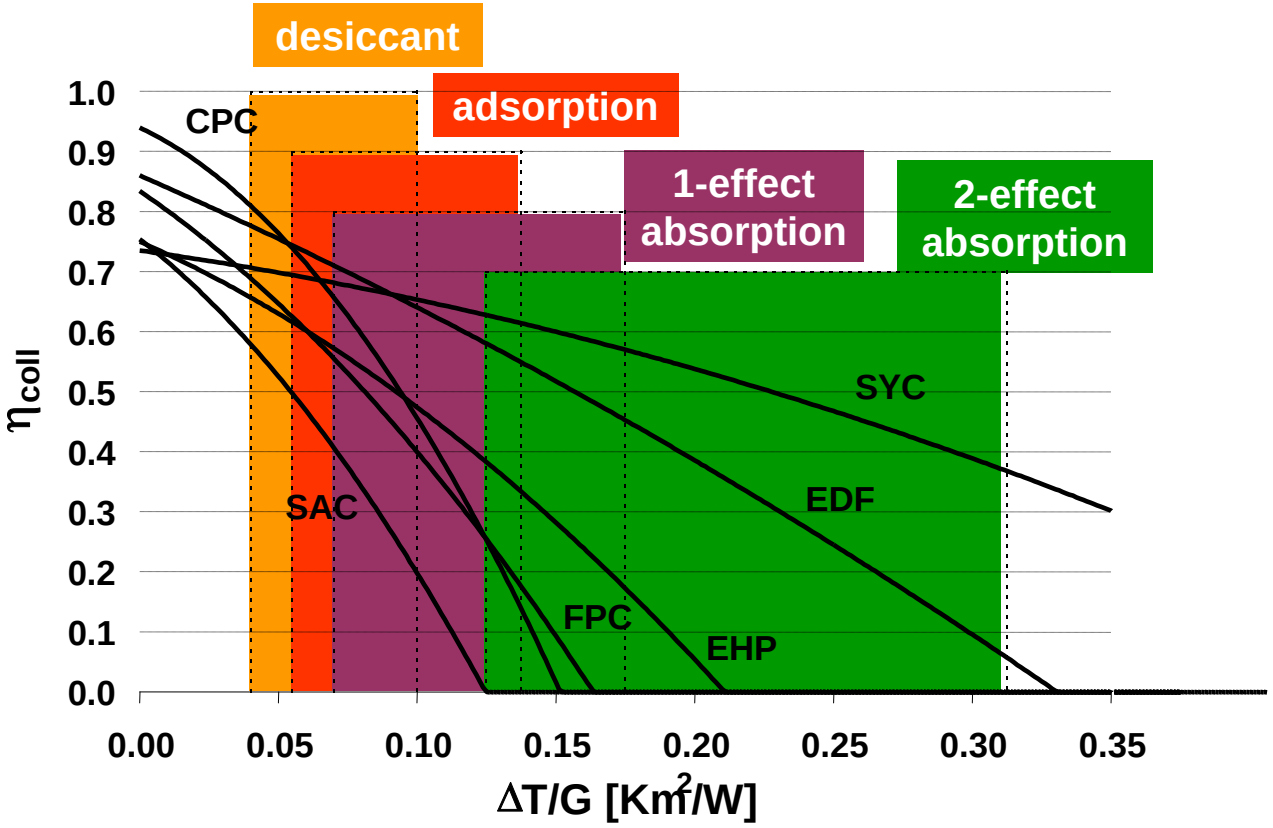
CPC = stationary CPC

FPC = selectively coated flat plate

EHP = evacuated heat-pipe

EDF = evacuated, direct flow

SYC = stationary concentrated, Sydney-type



Solar Cooling
Technical Aspects

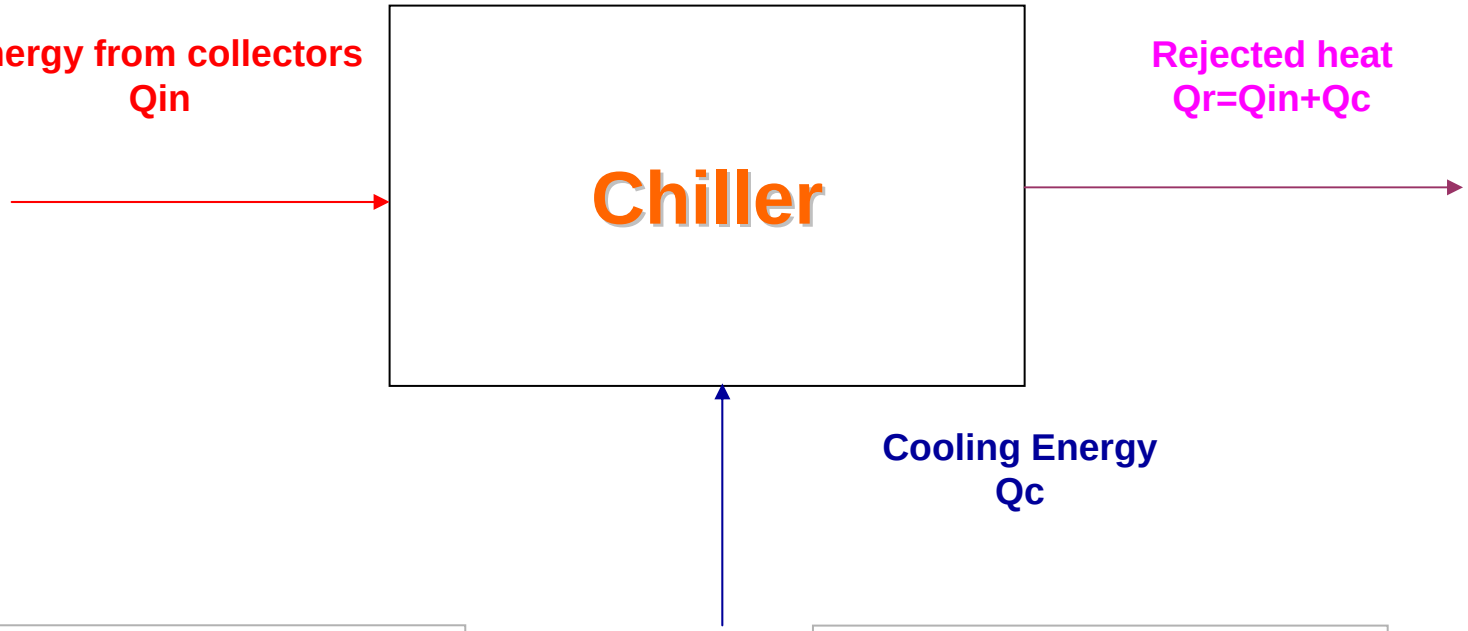
Chillers have 2 COP:

Thermal COP = Qc/Qinth

Electrical COP = Qc/Qelectical

	Split unit	Geothermal Heat pump	Adsorption	Absorption	DEC
COPel	2-4	4-5	60-80	60-80	4-5
COPth	-	0.2	0.5-0.6	0.6-1	0.3-1

Solar Cooling
Technical Aspects



- Required Power from Collector Field

$$Q_{in} = Q_c / COP_{th}$$

- Rejected power

$$Q_r = Q_{in} + Q_c$$

- For 10kW chiller with COP_{th}= 0.6:

Q_c = 10kW

Q_{in} = 10kW / 0.6 = 16.67kW

Q_r = 10 + 16.67 = 26.67kW

- Electrical consumption For 10kW chiller with COP_{th}= 60:

Q_c = 10kW

Q_{el} = 10kW / 80 = 166.7W

Solar Cooling
System Dimensioning

- Cooling Load Calculation (from EM calculations)
- Definition of coverage percentage
- Available space for:
  - Solar collectors (about 1.5 x collector area)
  - Storage tanks
  - Chiller
  - Cooling tower
- Connection with existing distribution system
- Connection with back-up chiller

- Calculation of Cooling Power (according to load and % of coverage)
- Calculation of Solar Collector Field Power
- Calculation of Cooling Tower
- Dimensioning of collector filed according to Solar Combi systems

Solar Cooling
Component Dimensioning

Component dimensioning follows the rules of general hydraulic dimensioning but required flow is given by the manufacturer

CLEAN ENERGY FOR YOU

Technical Data

			Cooling ceiling (nominal)
Adsorber:	SorTech AG, Germany	**Cold water cycle:**	
		Cooling capacity:	15 kW
Working pair:	Water / Silica Gel	Temperature in/out:	18 / 15°C
		Flow rate	4.3 m³/h
Dimensions (LxDxH):	0.79 x 1.35 x 1.45 m	Connection:	1¼" external thread
Operating weight:	approx. 510 kg	**Hot water cycle:**	
		Capacity:	26.8 kW
Electrical input:		Temperature in/out:	75 / 69°C
Voltage:	230 V ~ 50 Hz	Flow rate	3.8 m³/h
Power:	30 W	Connection:	1¼" external thread
		Recooling cycle:	Dry cooler
		Capacity:	41.8 kW
		Temperature in/out:	27 / 32°C
		Flow rate	7.0 m³/h
		Connection:	1¼" external thread

SolarNext AG
Nordstraße 10

Solar Cooling
System Design

Hot Storage:

- Maximize the efficiency of the collectors

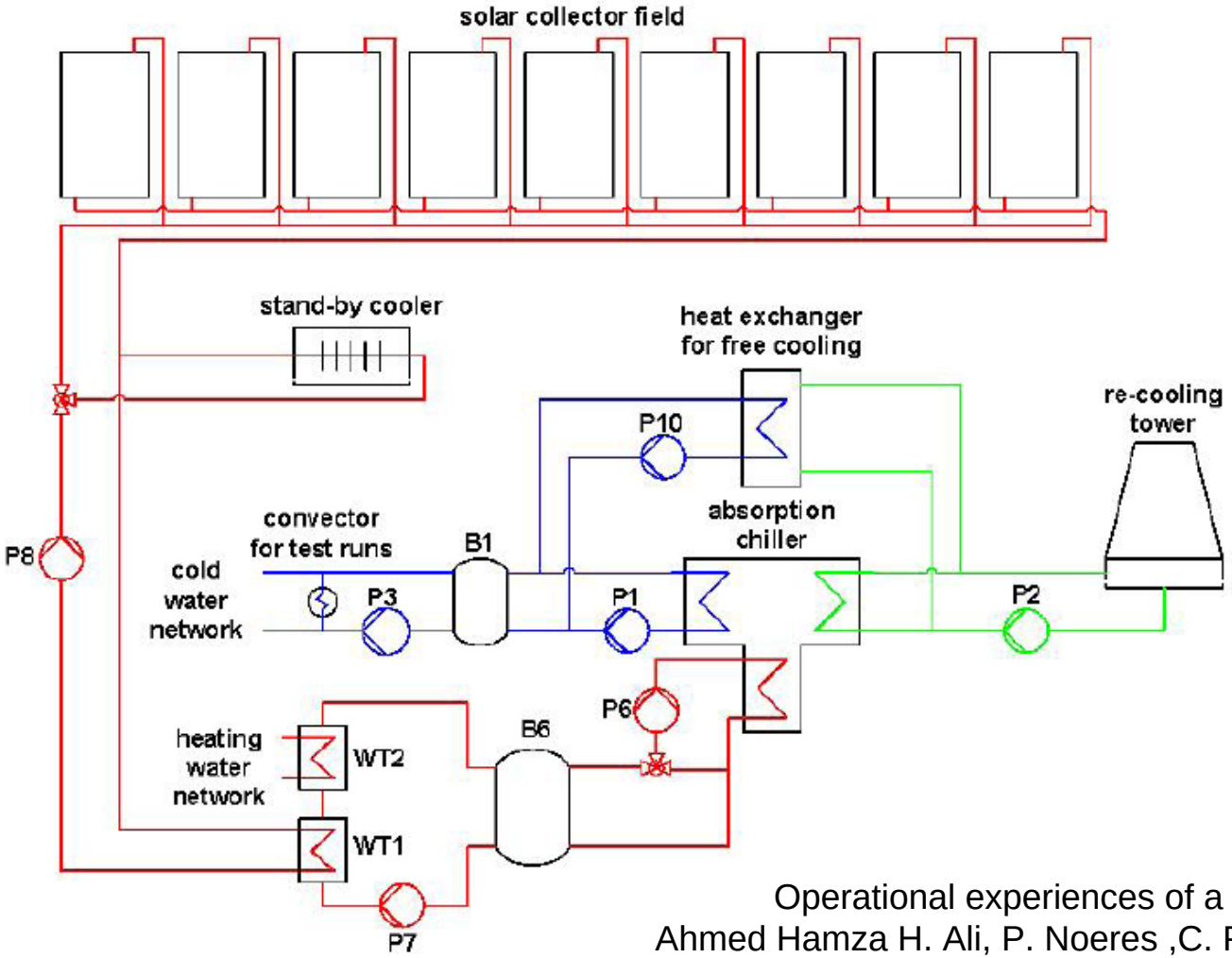
- Energy Storage (about 40lt/m²)

Cold Storage:

-Maximize efficiency of Chiller (operation at maximum COP conditions)

-Energy Storage (about 15lt/m²)

Solar Cooling
Detailed System Design



Operational experiences of a solar cooling plant
Ahmed Hamza H. Ali, P. Noeres ,C. Pollerberg and C. Doetsch

General Information

- ✓ Seasonal coinherance of load and energy supply
- ✘ Small scale solar chiller industry still under developement
- ✘ High chiller cost for chillers of less than 30kW (1000€/kW)
- ✓ Integration on existing systems (use of Fan coils – underfloor heating)
- ✓ Solar Chillers in split unit format expected soon

General Solar Field dimensioning:

- $3m^2/kW_c$ for closed circuit chillers
- $10m^2$ per $1000m^3/h$ for open circuit chillers