1st Saudi Renewable Energy Conference & Exhibition

Solar Thermal Energy For Cooling and Refrigeration : Status and Perspectives

Dahran, Saudi Arabia, 20/02/2012

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TECSOL

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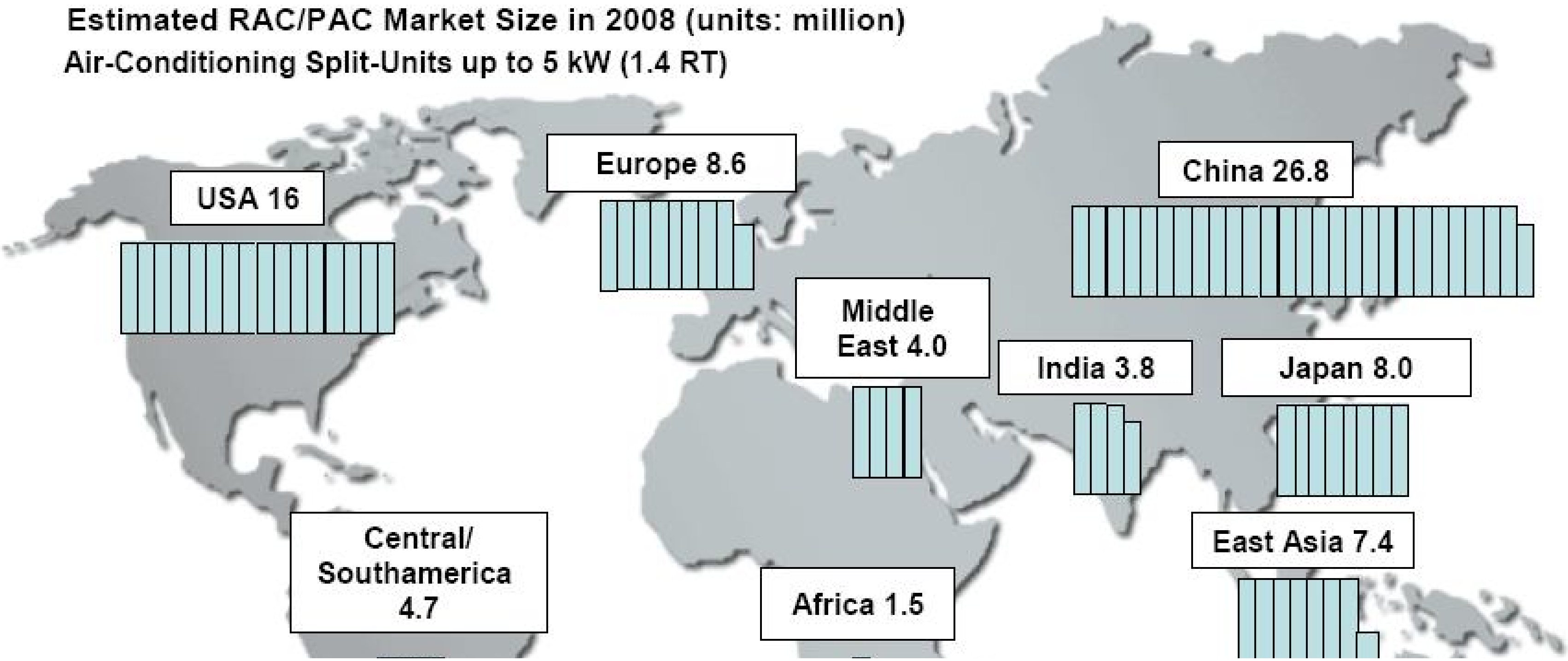
Introduction



Even now with a –10% market decrease market in 2009 and stagnation in 2010 and 2011

The World market is representing… 70 000 000 000 US$

Source: JARN

World total 2008: 82.3 million units

Source : Uli Jakob, SOLARNEXT 2009

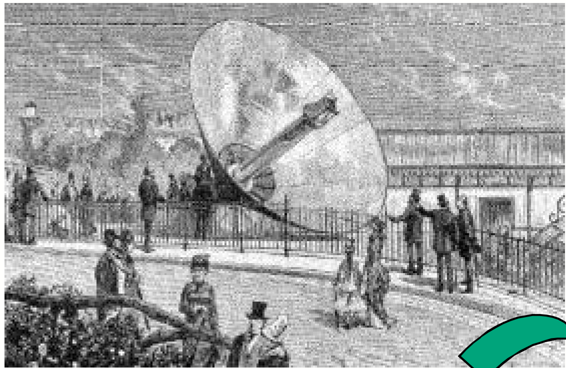
Introduction

Overall approach to energy efficient buildings in Europe

- Assure indoor comfort with a minimum energy demand

1. *Reduction of energy demand*	Building envelope; ventilation
2. *Use of heat sinks (sources) in the environment*	Ground; outside air (T, x) directly or indirectly; storage mass
3. *Efficient conversion chains (minimize exergy losses)*	HVAC; combined heat, (cooling) & power (CH(C)P); networks; auxiliary energy
4. *(Fractional) covering of the remaining demand using renewable energies*	Solar thermal; PV; (biomass)

Introduction on Solar Cooling Evolution



From World exhibition in Paris : First ice block through solar energy (1878)

Source : Olynthus Verlag

SCIENCE

To Banyuls sur Mer ... (1991)
<u>Europe</u>
52 kW – 130 m²
Still running nominally

Source: TECSOL

TECHNOLOGY

<u>MARKET</u>

To UWCSEA in Singapore ... (2011)
1500 kW – 4 000 m²
<u>Asia</u>

Source : SOLID

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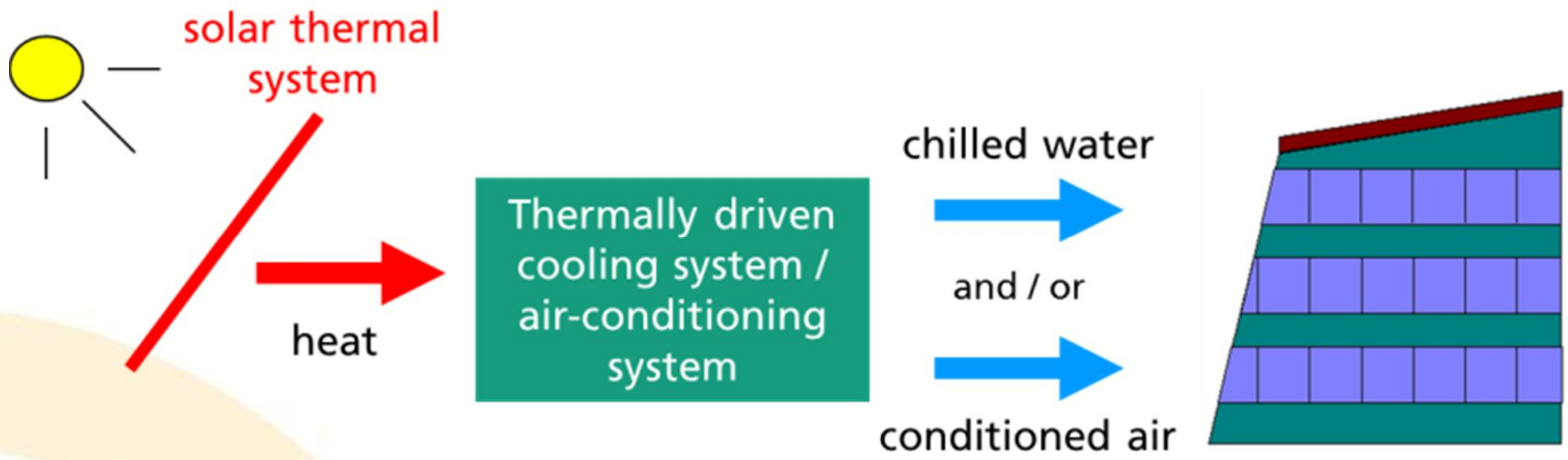
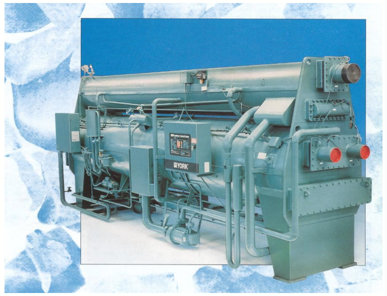
Solar thermal cooling - basic principle



Basic systems categories

- Closed cycles (chillers): chilled water production
- Open sorption cycles: direct treatment of fresh air (temperature, humidity)

Closed cycles – water chillers or ice production



- Liquid sorption: Ammonia-water or Water-LiBr (single-effect, double-effect, future triple-effect)
- Solid sorption: silica gel – water, zeolite-water
- Ejector systems
- Thermo-mechanical systems

Turbo Expander/Compressor AC-Sun, Denmark in TASK 38

source: website Kawasaki Heavy Industries Pte Ltd

Open sorptive cycles – desiccant air handling units

Air treatment in an open cycle

- Solid sorption
- Desiccant wheels
- Coated heat exchangers
- Silica gel or LiCl-matrix, future zeolite

- Liquid sorption
- Packed bed
- Plate heat exchanger
- LiCl-solution: thermochemical storage possible


ECOS (Fraunhofer ISE) in TASK 38

Technical status

- **Mature components available** (both solar and refrigeration, A/C)

Driving temperature	Collector type	System type
Low (60-90°C)		Open cycle: direct air treatment
		Closed cycle: high temperature cooling system (e.g. chilled ceiling)
Medium (80-110°C)		Closed cycle: chilled water for cooling and dehumidification
		Closed cycle: refrigeration, air-conditioning with ice storage
High (130-200°C)		Closed cycle: double-effect system with high overall efficiency
		Closed cycle: system with high temperature lift (e.g. ice production with air-cooled cooling tower)

Sorption cooling

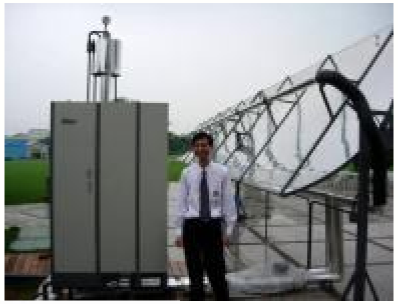
Type of system	Water chillers (closed thermodynamic cycles)							Direct air treatment (open thermodynamic cycles	
Physical phase of sorption material	Liquid				Solid			Liquid	Solid
Sorption material	Water	Lithium-bromide			Zeolite	Silica gel	Lithium-chloride	Lithium-chloride	Silica gel, zeolite, cellulose / lithium-chloride
Refrigerant	Ammonia	Water			Water	Water	Water	Water	Water
Type of cycle	1-effect	1-effect	2-effect	3-effect	1-effect	1-effect	1-effect	Cooled sorption process	Desiccant rotor
COP range	0.5 - 0.75	0.65 - 0.8	1.1 - 1.4	1.6 - 1.8	0.5 - 0.75	0.5 - 0.75	0.5 - 0.75	0.7 - 1.1	0.6 - 0.8
Driving temperature range, °C	70 … 100 120 …180(1)	70 … 100	140 … 180	200 … 250	65 … 90	65 … 90	65 … 90	60 … 85	60 … 80
Solar collector technology(2)	FPC, ETC SAT(1)	FPC, ETC	SAT	SAT	FPC, ETC	FPC, ETC	FPC, ETC	FPC, ETC, SAHC	FPC, ETC, SAHC

1: high temperature lift
2: FPC = flat plate collector; ETC = evacuated tube collector; SAT = single axis tracking collector; SAHC = solar air heating collector

Technical status

- **Mature components available** (both solar and refrigeration, A/C)

BROAD AIR CONDITIONING
远大空调有限公司



DB

Dunham Bush
(Russia) 85 RT

Thermax
(India)
THERMAX

YAZAKI

YAZAKI (Japan)

Nishyodo (20-140 RT) (Japan)
Maekawa (14-100 RT)

no claim on completeness

Technical status

- **Mature components available** (both solar and refrigeration, A/C)
- **Main progress made in last decade**
  - *Small scale heat driven chillers*
  - *Increasing number of high efficient double and – recently – triple effect absorption chillers*
  - *Development of systems using single-axis tracking solar collectors*

New developments of small capacity water chillers

~3.28 ft

SAKURA Air Conditioner

PINK ENERGIE- & SPEICHERTECHNIK

invensor

(2.5 RT)

SorTech AG

YAZAKI

EAW Energieanlagenbau Westenfeld GmbH

ClimateWell

no claim on completeness

High-temperature applications

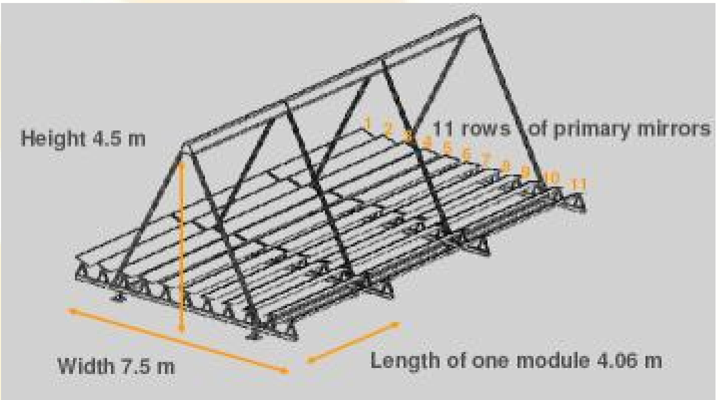

Wine cooling in Tunisia (MEDISCO)

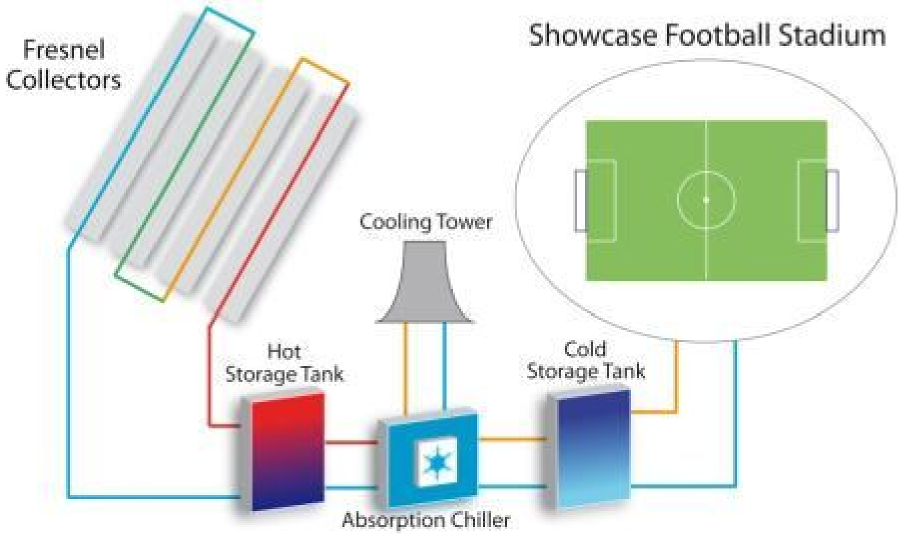

Solar cooling for a hotel in Turkey (SOLITEM)

- **Increasing number of systems using single-axis concentrating collectors** (parabolic trough, Fresnel) in combination with thermally driven chillers (150°C ... 200°C)
  - *Double-effect chiller with high conversion efficiency (Coefficient of Performance COP 1.1...1.3)*
  - *Single-effect chiller with high temperature lift for low cooling temperatures (e.g. ice production) and high heat rejection temperatures (dry cooling towers)*
- **Application in sunny regions for buildings** (e.g. hotels) or industrial application (e.g. cooling of food, ice production)

High-temperature applications

Example : Footbal Stadium
in Dubai





INDUSTRIAL SOLAR thermal solutions

Technical status

- **Mature components available** (both solar and refrigeration, A/C)
- **Main progress made in last decade**
  - *Small scale heat driven chillers*
  - *Increasing number of high efficient double and – recently – triple effect absorption chillers*
  - *Development of systems using single-axis tracking solar collectors*
- **Main technical shortcomings are still on system level**
  - *Energy efficient heat rejection system*
  - *Energy management*
  - *Bottleneck: good trained technical staff almost not available*

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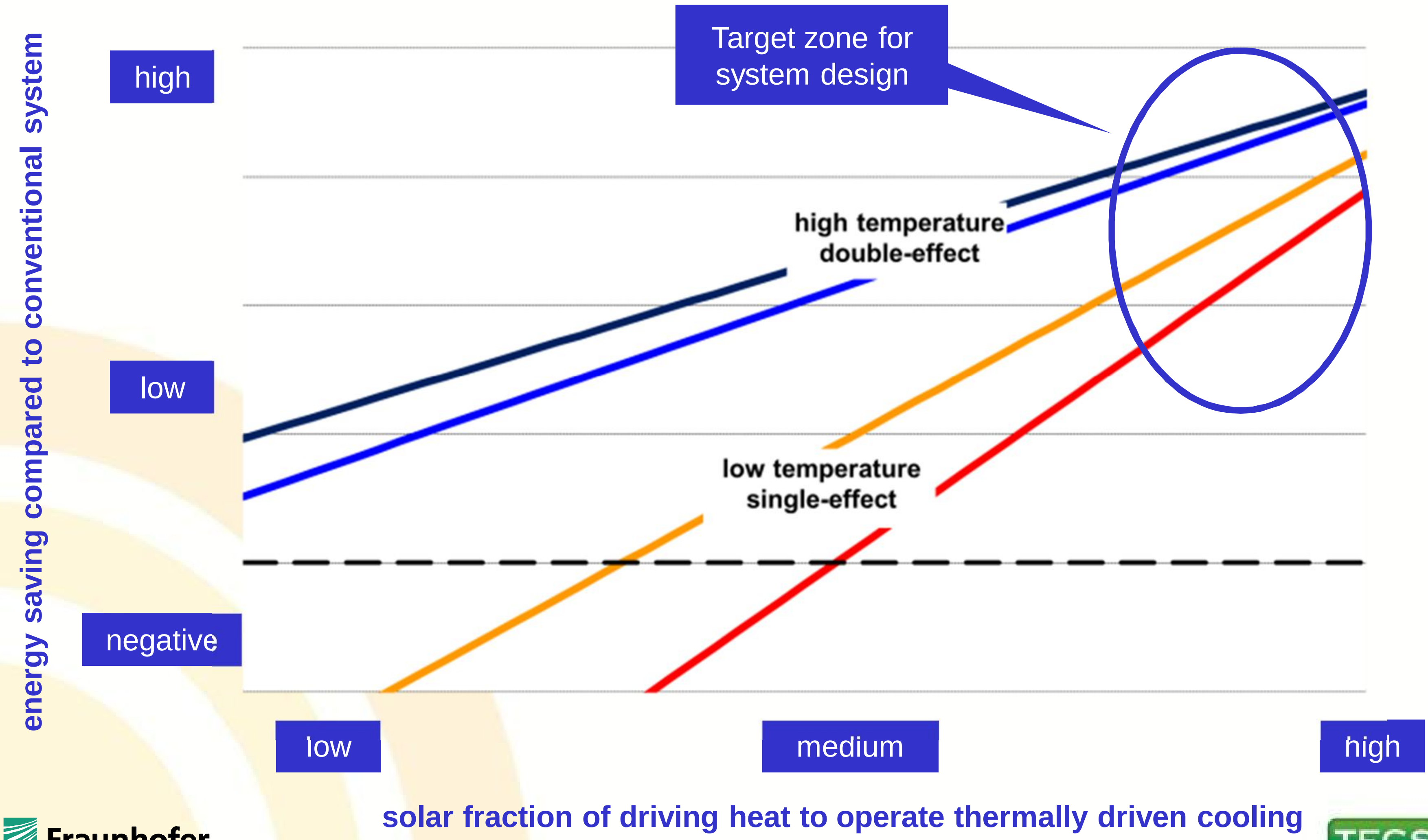
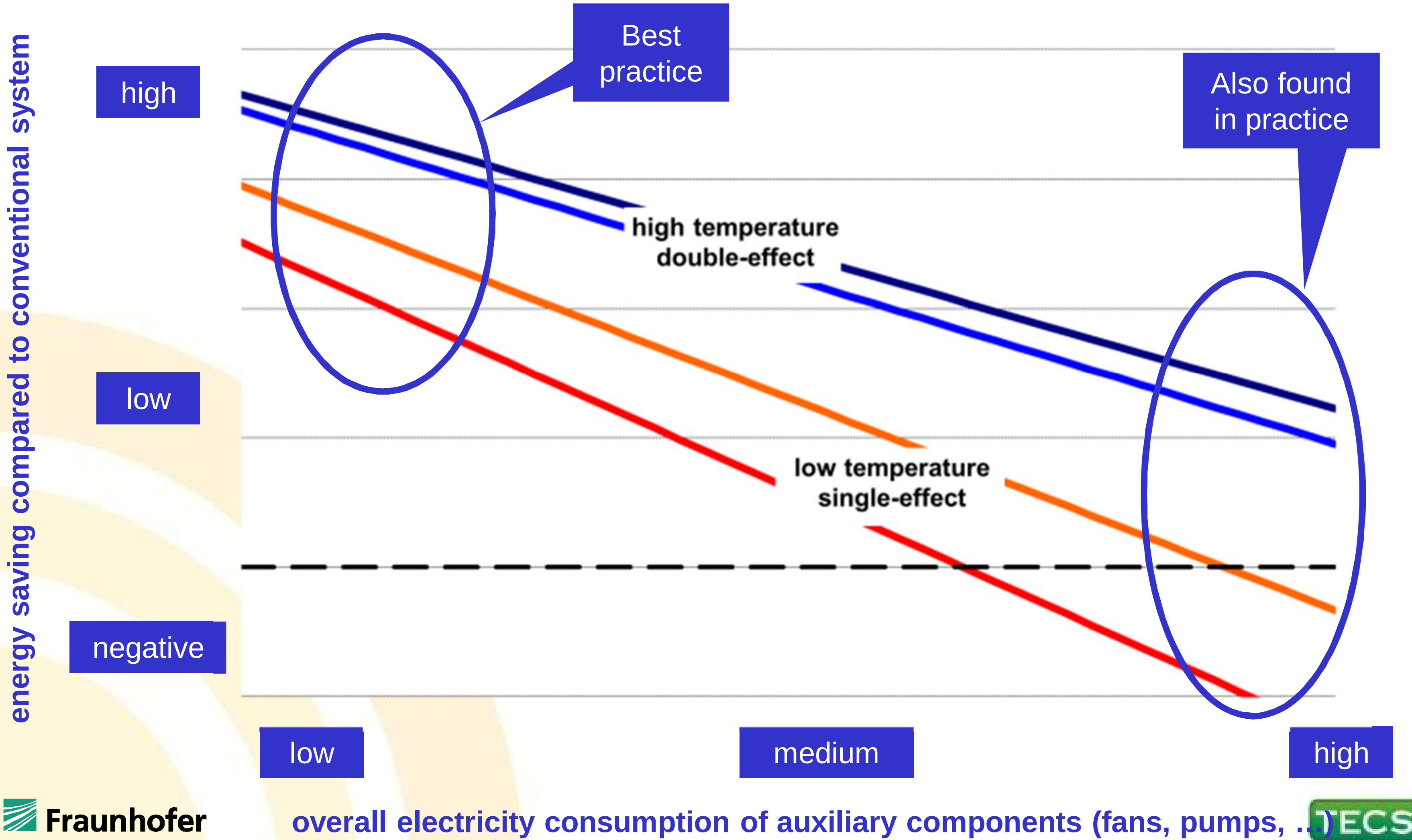
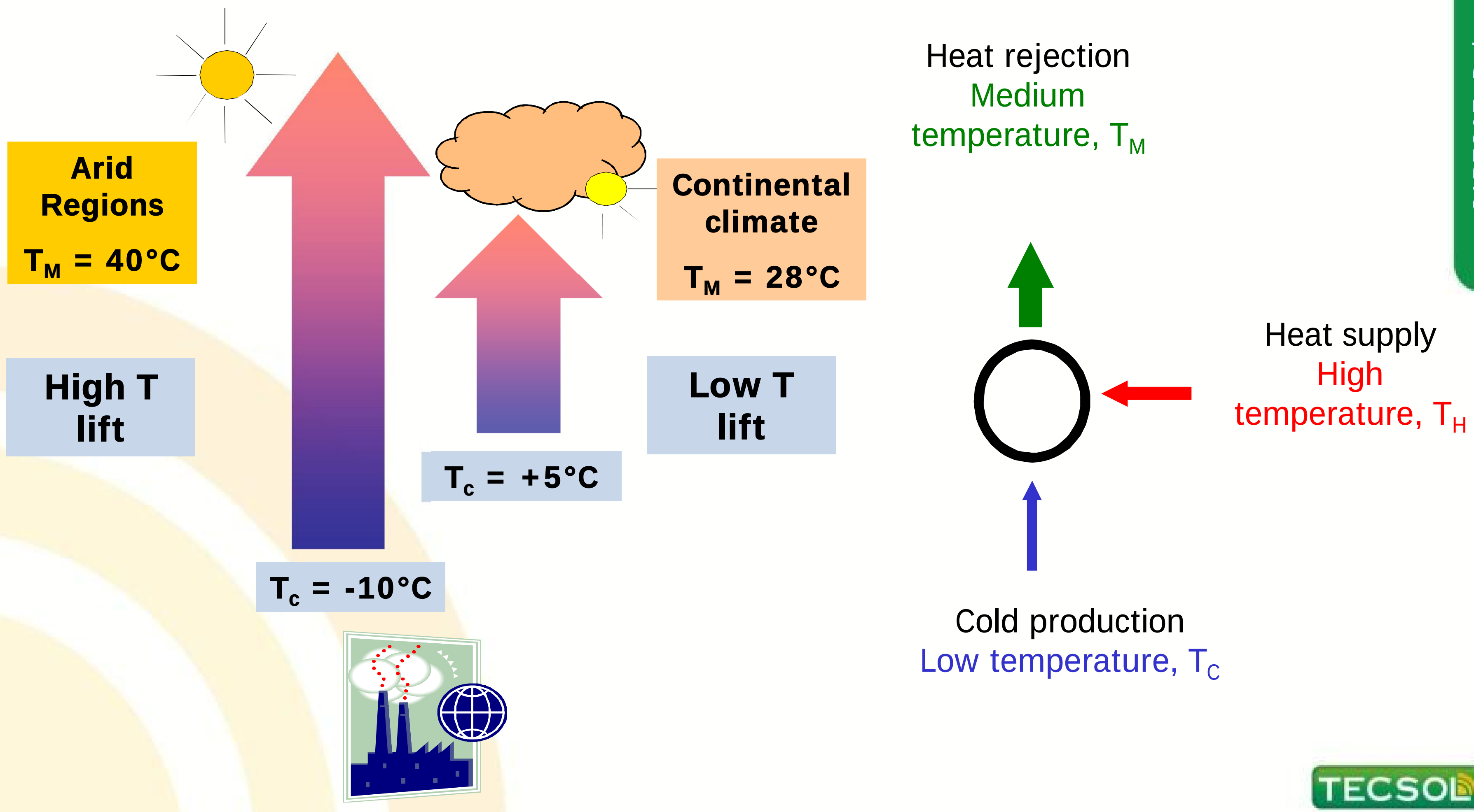
Influence of solar fraction of driving heat



Influence of electricity consumption of auxiliary components



Cold production and Temperature “lift”: arid regions



Energy performance

- **Many systems lead to measurable energy savings** when compared to a best practice conventional reference solution
- **Best values of overall electric COP range up to 6-8**, which means that
  6-8 kWh of useful cooling are produced with 1 kWh of invested electricity
- **Target value for electric COP > 10**
- **However**: also many systems do not achieve these values in practice due to
  - *Non-optimal design*
  - *Non-optimal operation (e.g. control, part load)*

Example of performing concept in 2011

Building block in Montpellier, France

2 parts : building A & B (mini district)

Building A : 11 000 m² for offices and shops

Building B : 10 600 m² with 167 dwellings

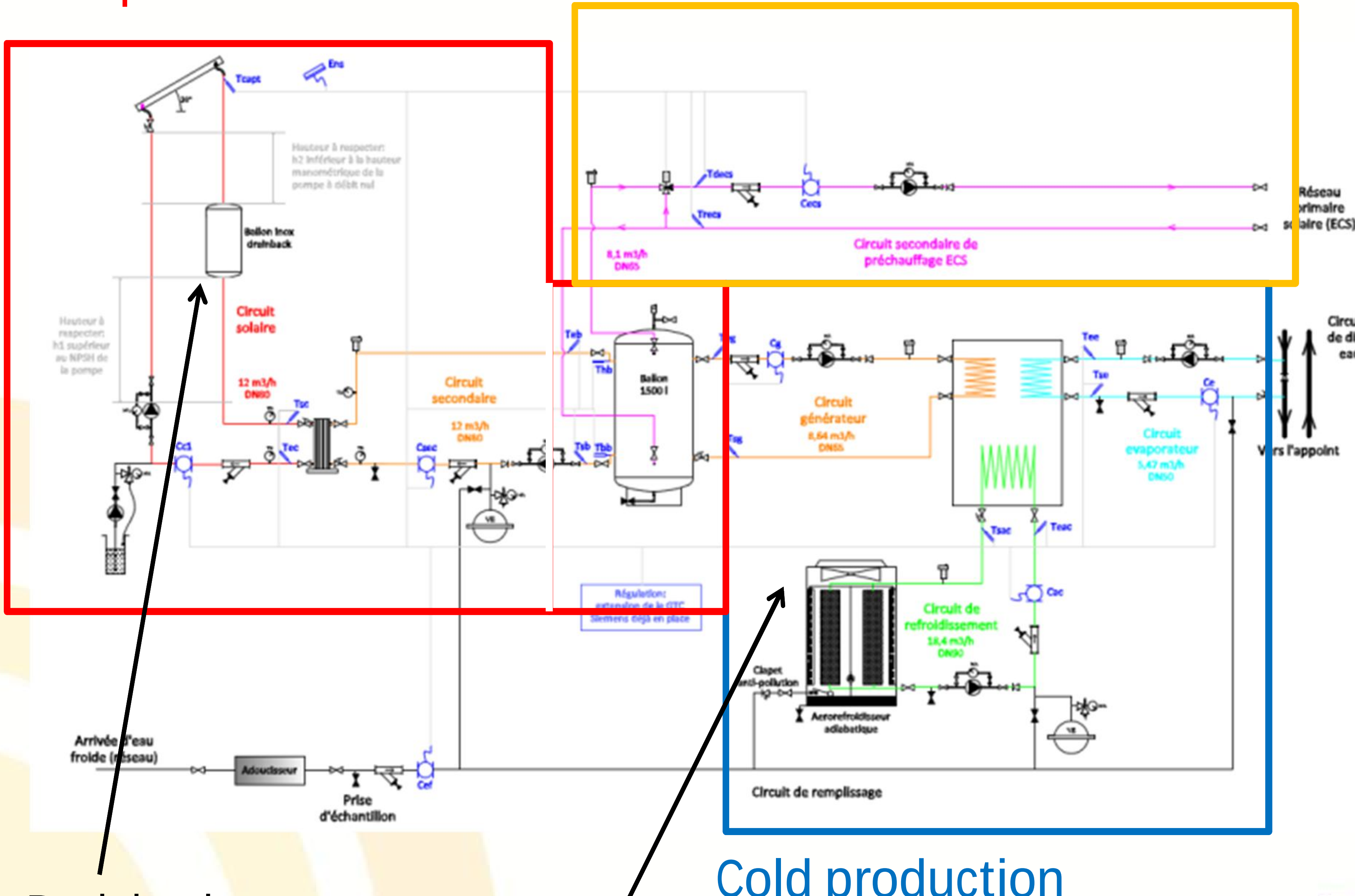
Both production of Domestic Hot Water and Cooling

Safe solar production : drainback strategy (freeze & overheating protections)

Energy performance : Electrical COP of… 17 !

Solar production

DHW distribution



Drainback system

Cold production

Anti legionnella adiabatique cooling tower

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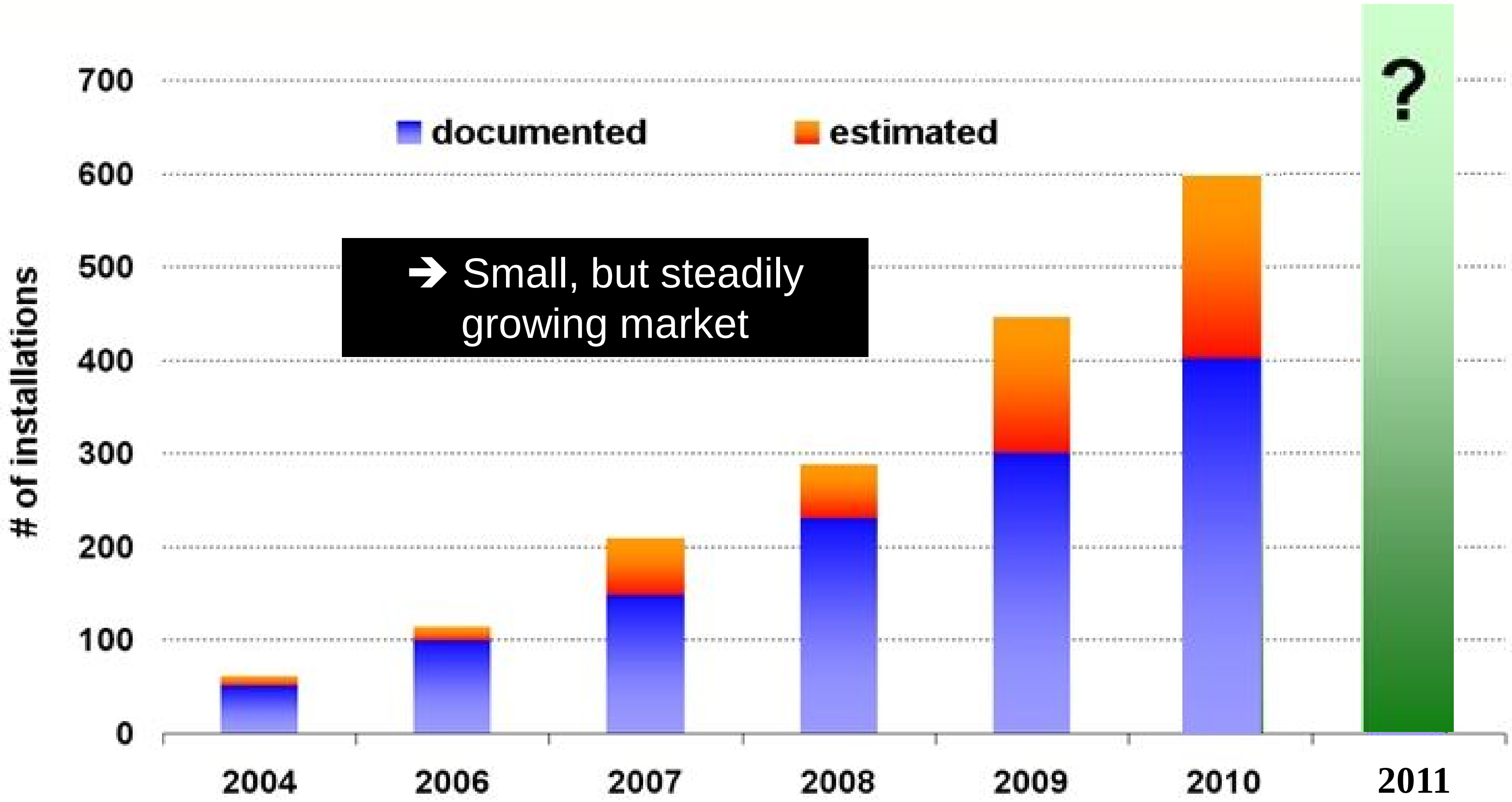
Market – estimated > 800 systems worldwide



About 150 new installations in 2010 and 2011 (+30%)

Task 48 : Quality assurance
& support measures for Solar Cooling

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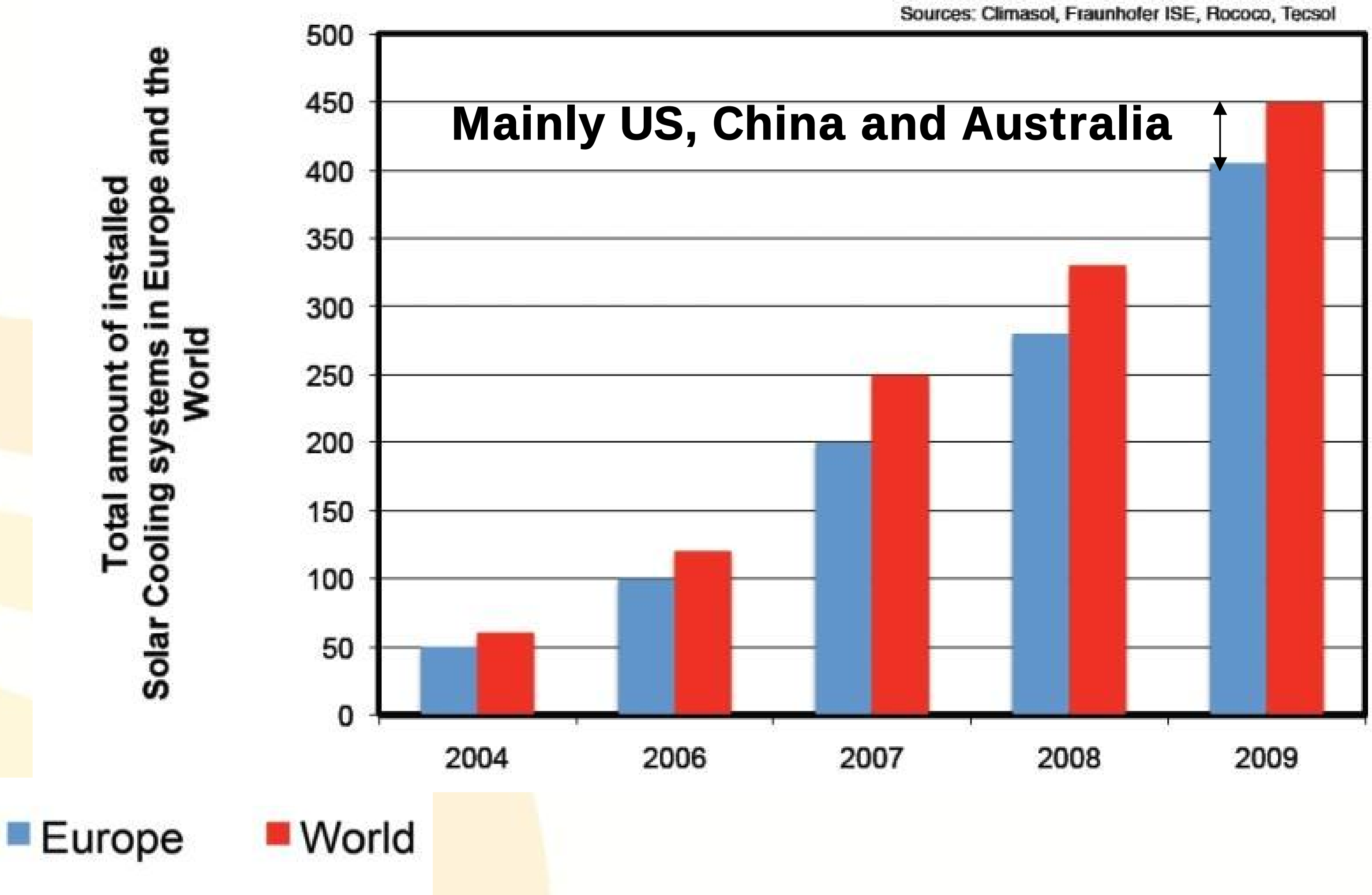
Market analysis : Europe / World



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Task 48 : Quality assurance
& support measures for Solar Cooling

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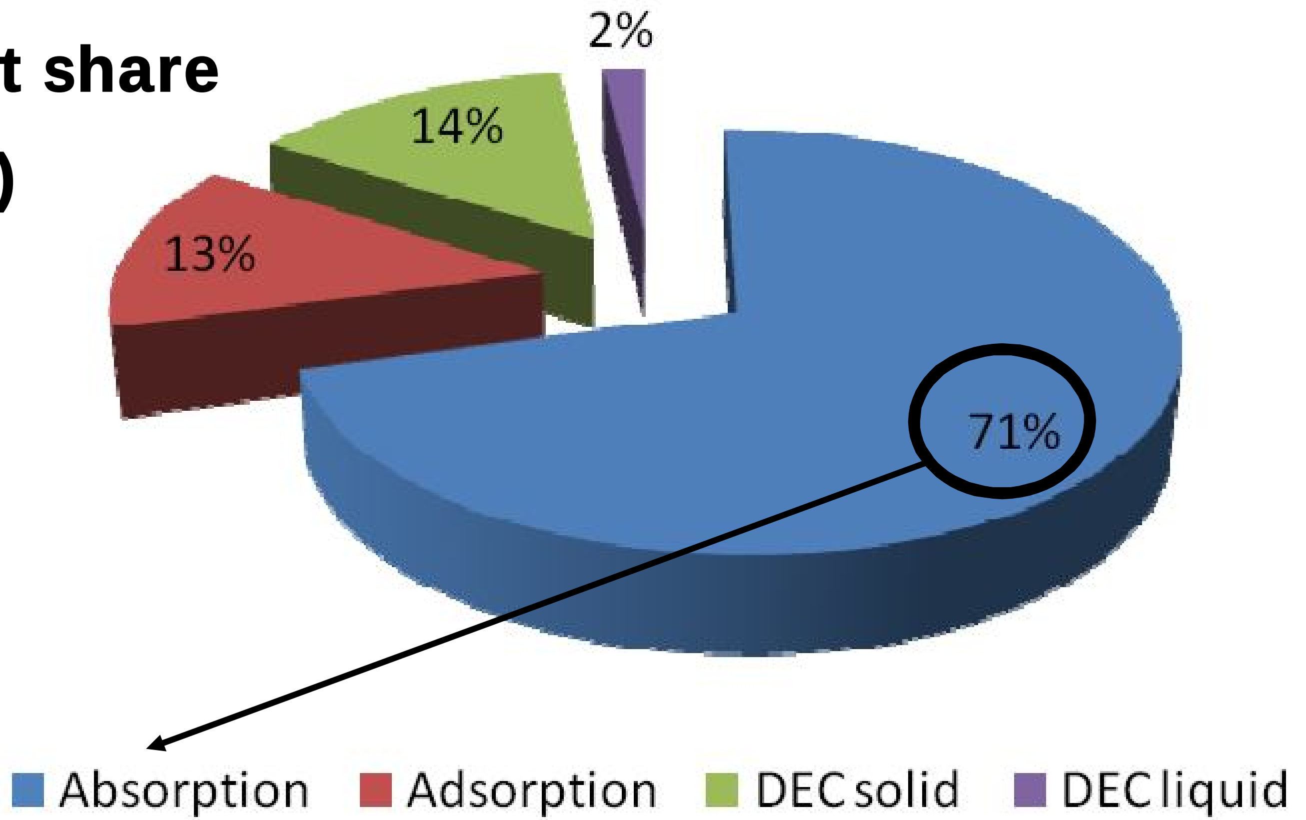
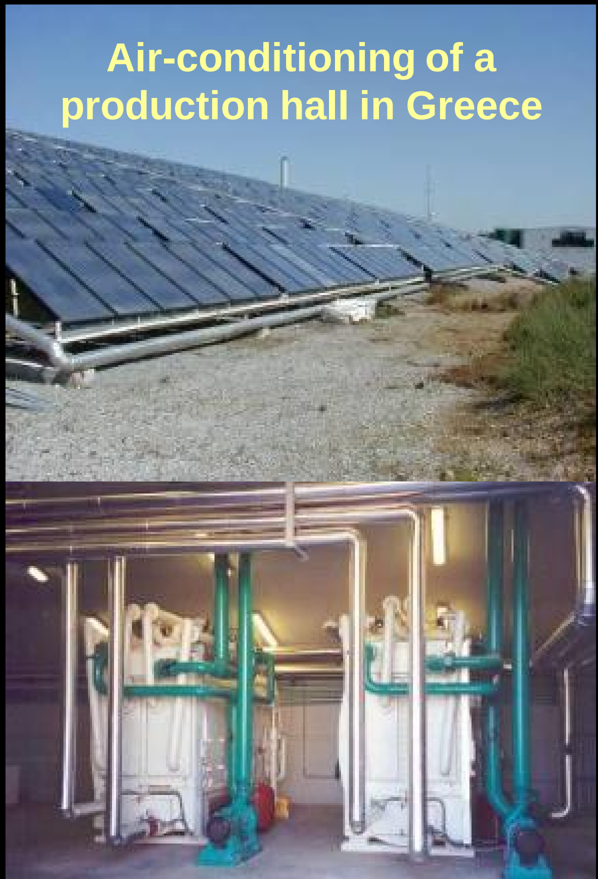
Market share (2009)



- Percentage of use of different technologies for thermally driven chillers within 113 large scale systems.

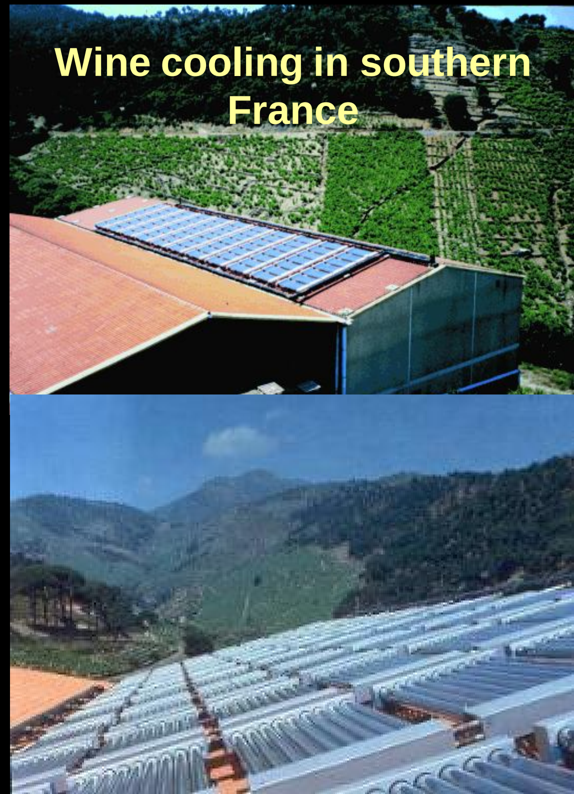
Ab / Adsorption representing nearly 85 %...

Source : EURAC, Sparber & Napolitano, 2009



Air-conditioning of a production hall in Greece

Air-conditioning of a meeting room and cafeteria in Freiburg/Germany



Wine cooling in southern France

Air-conditioning and process heat production for a hotel in Turkey

Wine cooling in Tunisia

Recently large and very large installations (examples)

CGD Bank Headquarter

Lisbon, Portugal

1560 m^2 collector area

400 kW absorption chiller

Source: SOLID, Graz/Austria

FESTO Factory

Berkheim, Germany

1218 m^2 collector area

1.05 MW (3 adsorption chillers)

Source: Paradigma, Festo

United World College (UWC)

Singapore

3900 m^2 collector area

1.47 MW absorption chiller

Source: SOLID, Graz/Austria

Examples of Custom made system manufacturers

NEPSOLAR	(Australia, Europe)
MILLENNIUM	(Middle East, North Africa)
SOLARAIRE	(USA)
SOLAR PANELS PLUS	(USA)
SOLEL	(Middle East, Europe, USA)
SOLID solarinstallation+design	(Europe, USA, Caribbean, Asia)
	(Europe, Middle East)
Optimal Solutions GROUPE EDF	(Europe, North Africa, Middle East)

no claim on completeness

Source : GreenChiller, TECSOL

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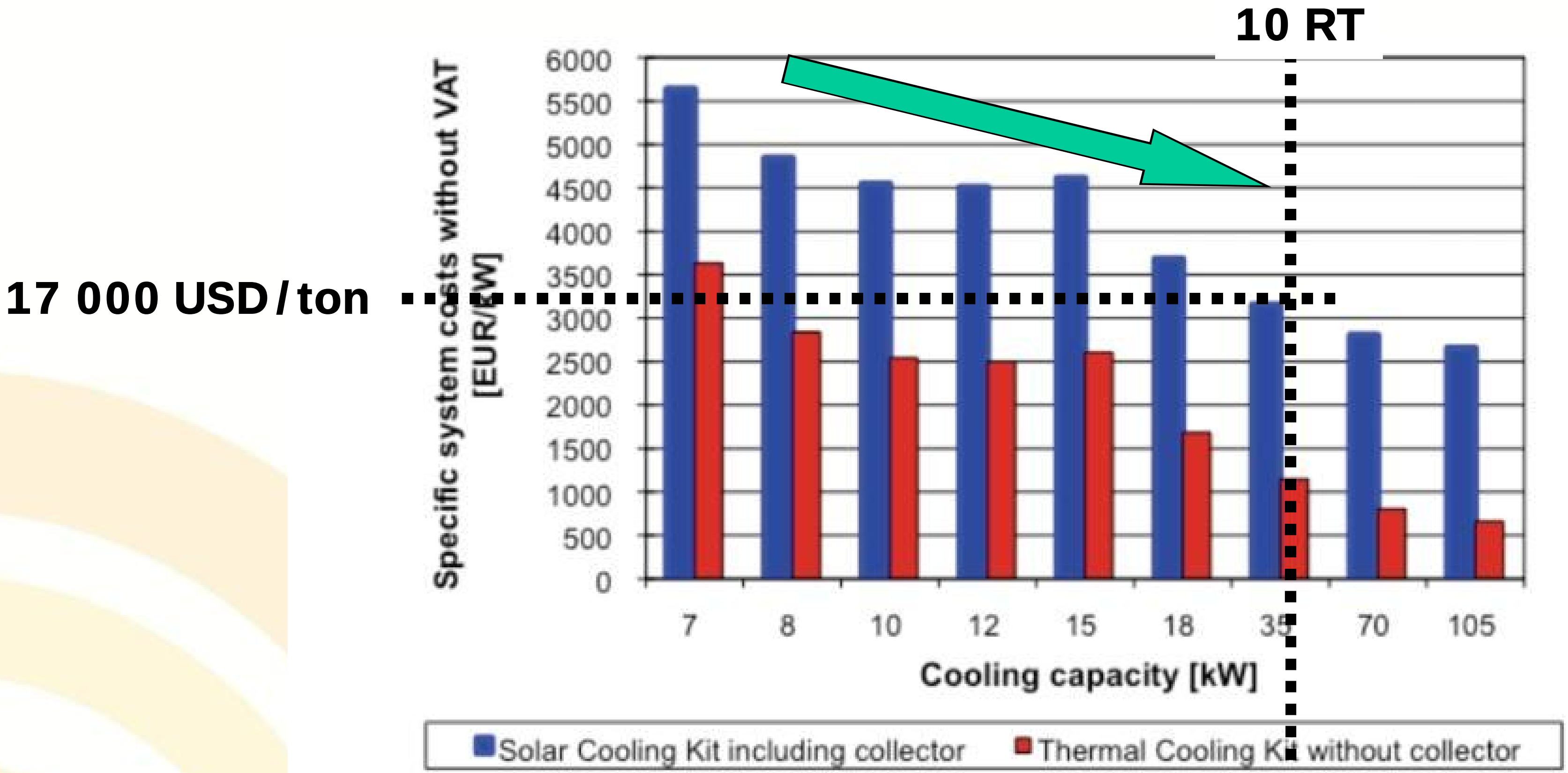
Economic viability

- **First cost 2-5 times higher than for conventional technology**
- **Total first cost found in realized installations**: 2000 – 5000 € per kW of cold production (for entire system including solar collector field)
- **Payback time depends strongly on boundary conditions**
  - *Annual numbers of use (cooling, heating, hot water, ...)*
  - *Conventional energy cost*
  - *Climatic conditions*
- **Best conditions: payback** < 10 years possible

Example of specific total costs of solar cooling kits in Europe



Source: SolarNext

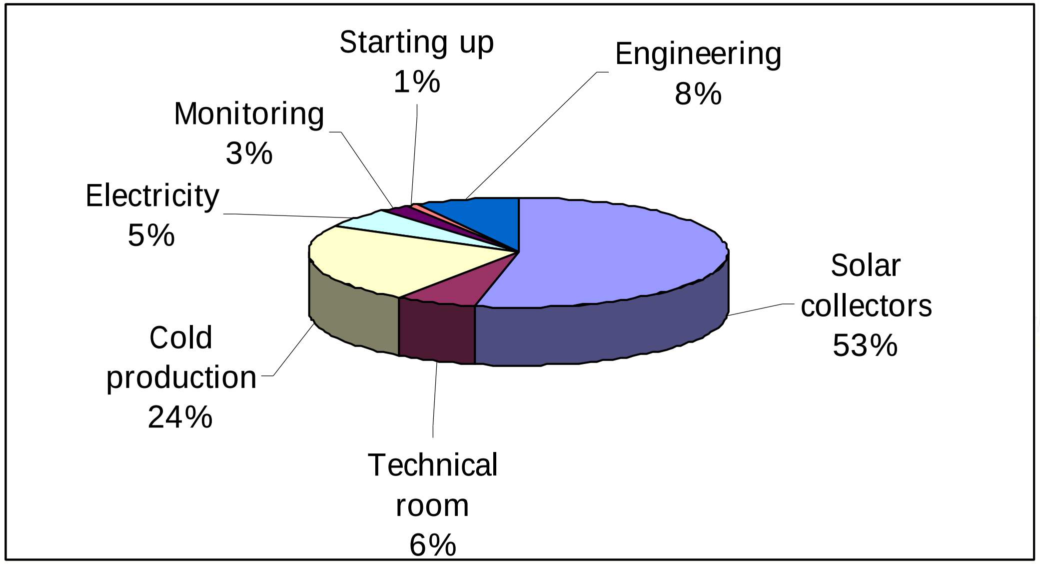
*** Solar cooling kits generally include : solar thermal collectors, hot water storage, pump-set, chiller, re-cooler, cold water storage, system control.**

The specific costs are without cold distribtion and installation costs.

System costs : example

Solar cooling installation – 10 tons abs. – France - 2009

	$ (w/o tax)
Solar collectors	130 000
Technical room	15 080
Cold production	57 200
Electricity	13 000
Monitoring	6 500
Starting up	1 950
Engineering	19 500
TOTAL	**243 230**
$/ton	24 323



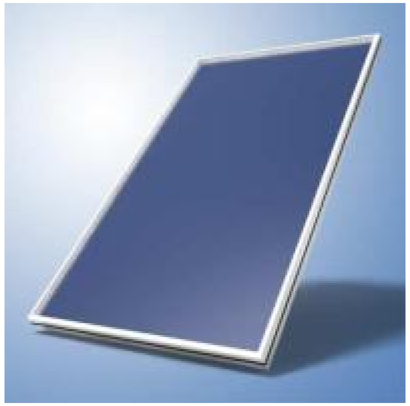
Source : TECSOL

Cost Reduction Potential of Solar Cooling Kits

- **Solar Plant (Collectors and Storage):**
  max. 10% Cost Reduction Potential in the next 2-3 years
- **Small-Scale Sorption Chillers:**
  max. 20% Cost Reduction Potential till 2013, from 2011 up to 50% if Serial Production is started (Production Capacity larger than 500 Units)
- **Recooler:**
  Cost Reduction Potential between 40-50%
- **Control:**
  min. 60% Cost Reduction Potential, Increasing of the System Performance
- **Installation:**
  10-30% Cost Reduction Potential through Standardized Solar Cooling Kits

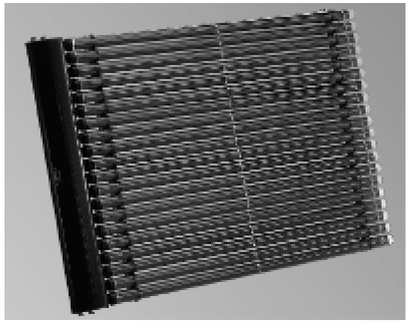
Source : Uli Jakob, SOLARNEXT

How do reduce costs ?



Source : Schüco

High performance flat plate collectors + drainback



Performing, safe and cheap Evacuated Tube collectors

Source : Viessmann

Compact packages solutions

Source : EDF Optimal Solutions

Source : Broad

And above all…

Large scale production

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Perspectives (1/2)

➢**Systems using non-tracking solar collector technology**

- Solar heating & cooling (+ DHW) ➔ summer use of large collector fields
- Application in buildings: residential, tertiary sector
- Significant cost reductions in particular for small scale thermally driven chillers (> 50 % possible)
- Increasing level of standardization
- Pre-fabricated systems for small capacity
- Custom-made systems for commercial buildings
- Desiccant systems in particular for air dehumidification in humid climates

Perspectives (2/2)

➢**Systems using single-axis tracking with optical concentration**

- Medium and large capacity range in regions with high direct solar radiation
- Applications with dominant use of cooling (e.g. industrial refrigeration)
- Installation either on the ground or large flat roofs of industrial buildings
- High efficient cooling cycles using double- or triple-effect
- Applications which require a high temperature-lift (e.g. food conservation with dry cooling tower)

R&D challenges

- **Heat rejection**: full integration, lower O&M costs => application as add-in for residential buildings for 100% solar houses in Southern European countries
- **New and small capacity open cycles** to be integrated in ventilation systems for residential sector
- **Demonstration activities for large solar cooling packaged systems** (more than 100 kW) => cost reduction and guarantee results. Application : industry, cooling networks and large buildings.
- **Quality assurance measures for solar cooling** (T48 SHC-IEA), among others:
  - *Automated failure detection & monitoring*
  - *Systems testing & characterization*
  - *Control strategies optimization*

Quality assurance & support measures for Solar Cooling

Duration : 3,5 years (October 2011 – March 2015)

Subtask A: Quality procedure on component level

Subtask B: Quality procedure on system level

Subtask C: Market support measures

Subtask D: Dissemination and policy advice

PARTICIPATING COUNTRIES : Australia, Austria, Canada, Belgium, France, Germany, Italy, Singapore, South Africa, Spain and USA *(no claim for completness)*

PARTICIPATING MANUFACTURERS AND COMPANIES : Aiguasol, Climatewell, Industrial Solar GmbH, Invensor, Sortech, SOLEM, SOLID, TECSOL, Thermosol *(no claim for completness)*

http://www.iea-shc.org/task48/

Conclusion & outlook

- **Solar heating and cooling (SHC) systems will play a significant role in our future energy system**
- They provide an energy saving solution on the demand side without negative (possibly positive) impact on the electricity grid
- **Main challenge** is to assure **high quality of installations in broad market**
- From **technology** companies toward **sales companies & powerful lobbies…**

Thank you for your attention !!!

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