Keynote zur solaren Kühlung und SHC Task 53

... in English

ISEC Conference

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Content

- Background
- Solutions & trends
- Best practice examples
- Summary

Kigali Cooling Efficiency Program:

"Cooling is essential to health and prosperity and is becoming more important as world urbanizes, economies grow and the planet heats up…".

- K-CEP: a philanthropic program to support the Kigali Amendment of the Montreal Protocol.

Background

- Global **cooling demand** is **growing** due to
  - Global economy, population growth
  - Climate change
  - OECD/IEA (2018): The Future of Cooling….

- Several **initiatives** and **policies** on cooling
  - F-gas regulation
  - COP 21 (Paris Agreements)
  - Sustainable Development Goal #7
  - Mission innovation: challenge #7
  - Chinese government …**2% goal for solar thermal cooling within 2020**

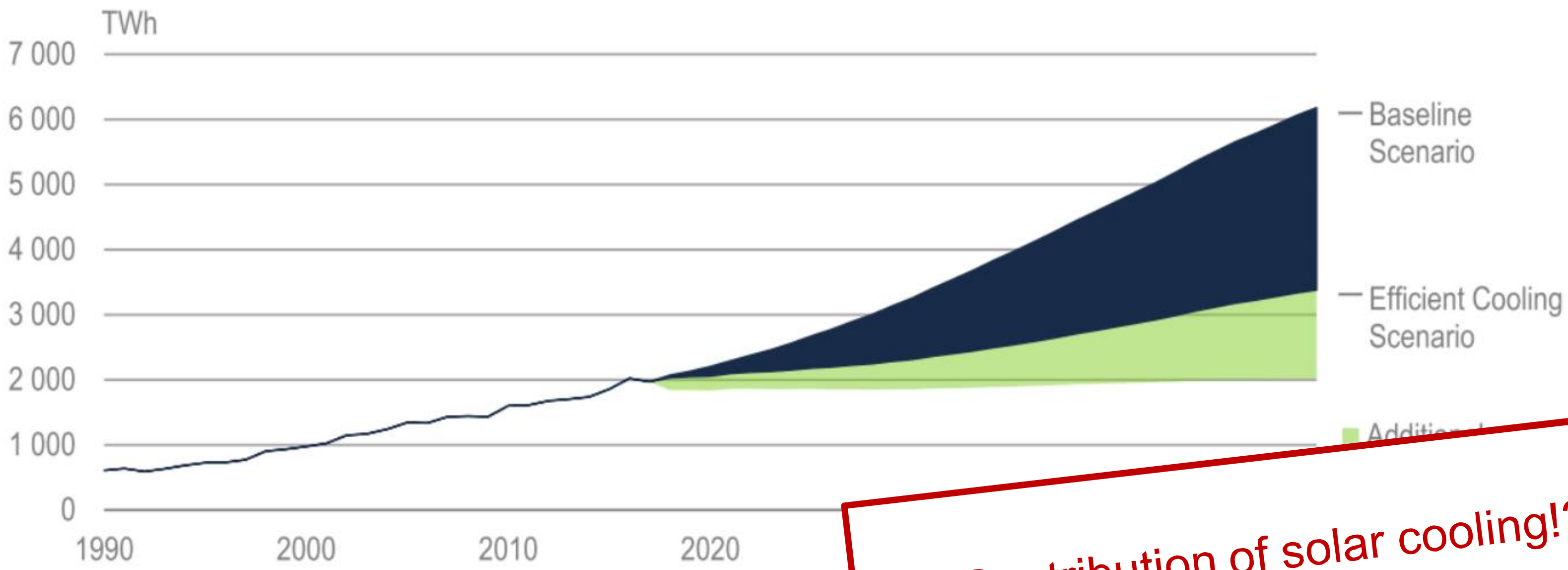
The Future of Cooling - Implications & opportunities energy efficiency (IEA)

Reference scenario

- On current trends, energy needs for space cooling – almost entirely in the form of electricity – will more **than triple between 2016 and 2050, driven mainly by the residential sector (2 000 TWh => 6 000 TWh)**
- Most of the **projected growth in energy use for cooling is set to come from India, China and other emerging economies.**
- Space cooling is set to overtake appliances and plug loads **to become the single largest user of electricity in buildings (2015:10% ; 2050 : 30%)** and the second largest electrical end use after industrial motors.
- The **share of cooling in electricity demand increases everywhere bar China and most notably in India and Brazil,** where the potential for increased use of air conditioners is greatest.

Future cooling demand

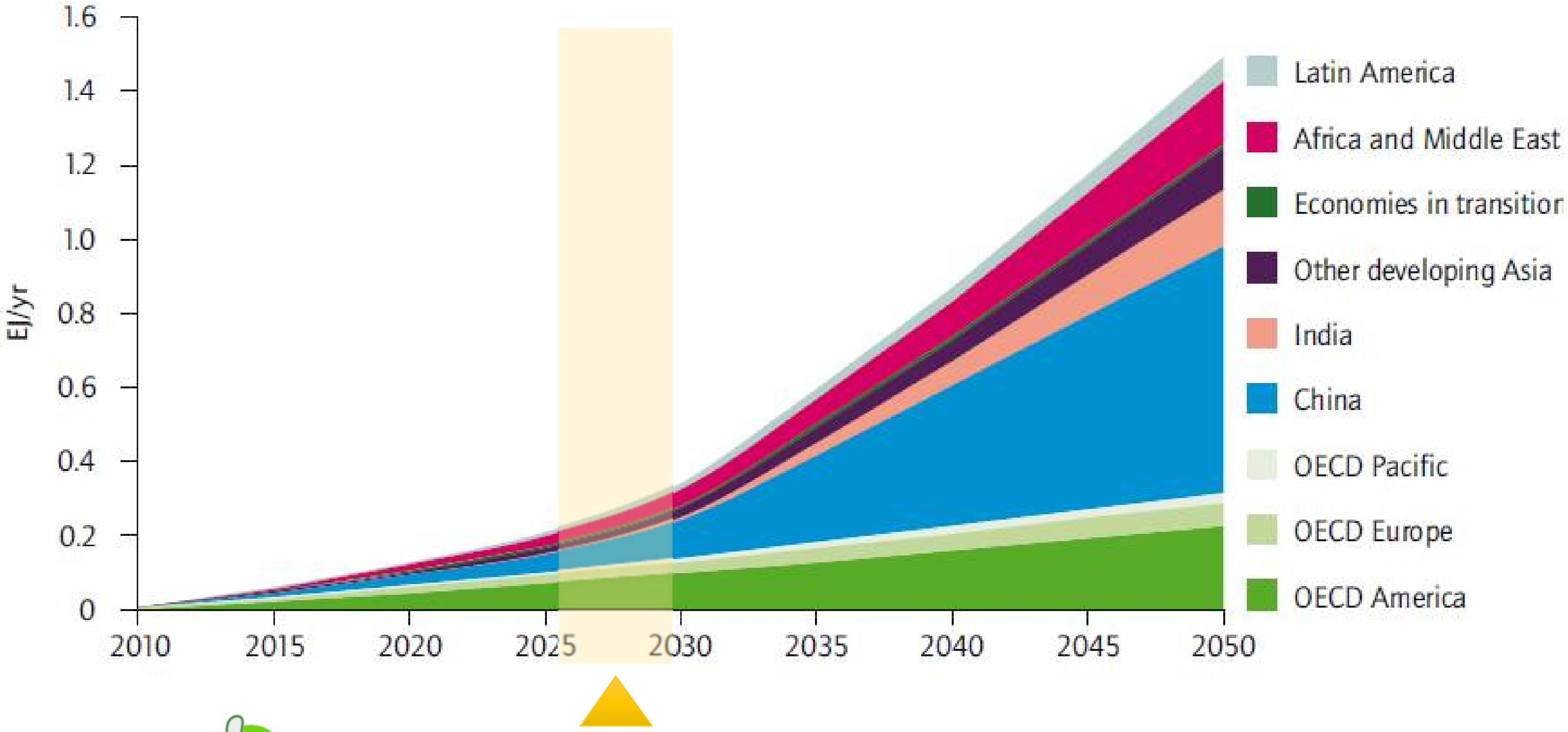
- OECD/IEA efficiency scenario
  - Component level: SEER 8.5 by 2050
  - Measures on building level are possible but limited…



Source: OECD/IEA (2018) The Future of Cooling

→ Contribution of solar cooling!?

Vision for solar cooling – Roadmap until 2050



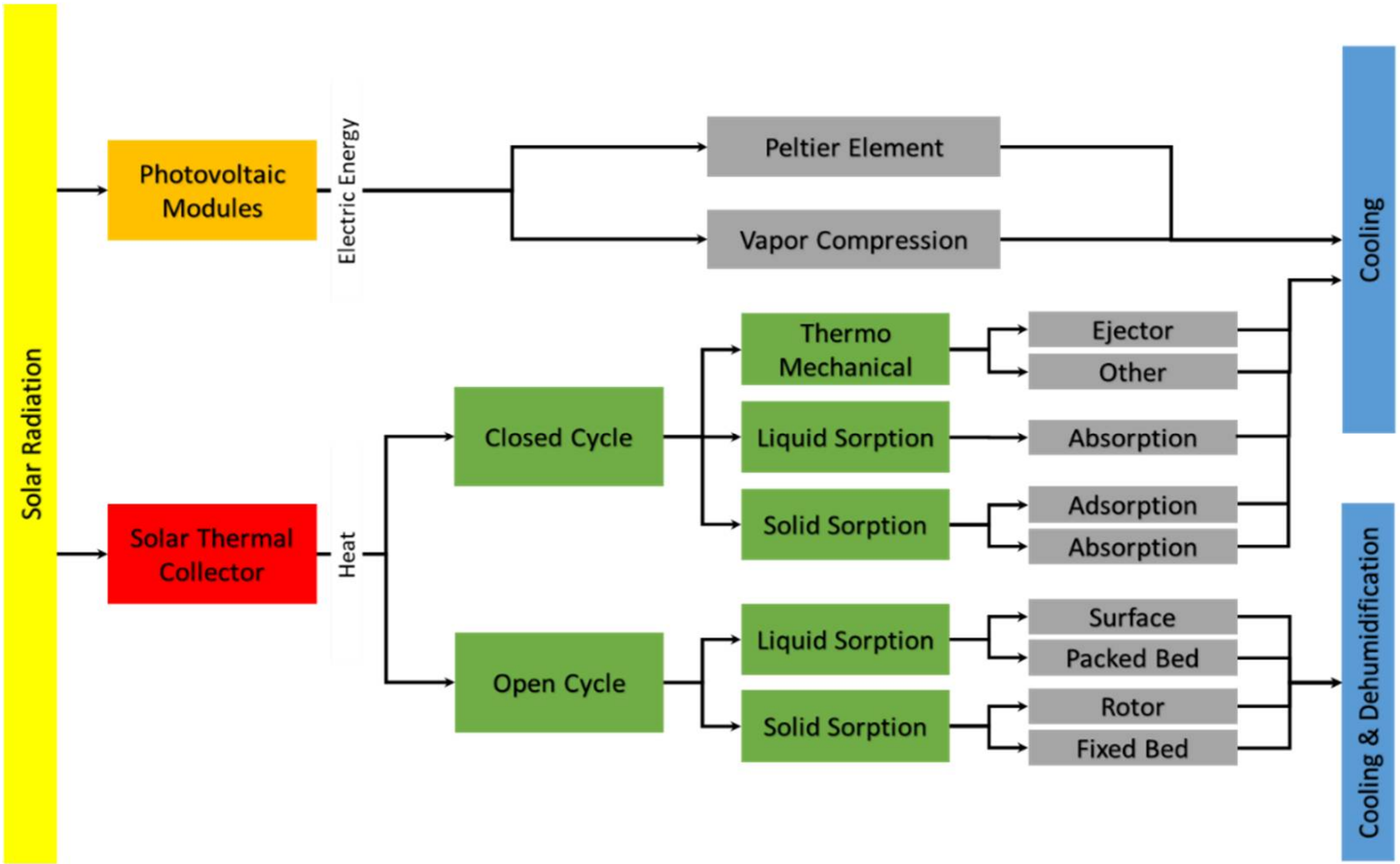
Cost of solar cooling technology is expected to reduce

Electricity cost is expected to continuously increase

Source: OECD/IEA (2013) Solar heating Roadmap

Possible Solutions

- Several **solar supported** solutions are available

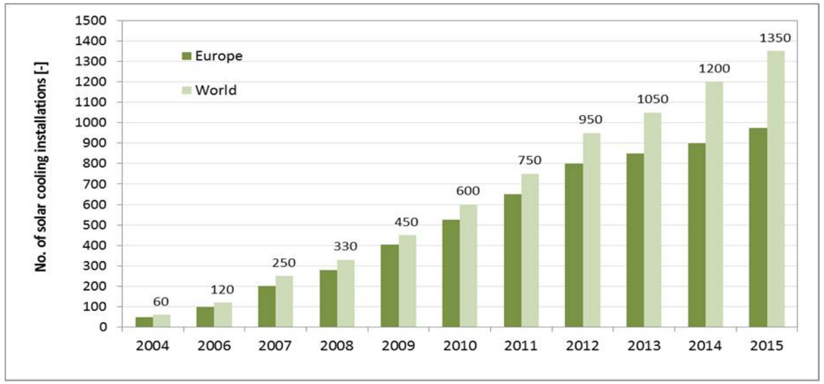


Source: Henning et al. (2013) Solar Cooling Handbook

Status of solar cooling

- Components are available but

  Still a niche market :
  ≈ 1,350 systems installed worldwide (2015)



Source: Solem Consulting / TECSOL

- On system level there is still **lack of**
  - efficient, reliable and **cost competitive** SHC solutions
  - **Technical** : Limit on adaptability due to hydraulics, complexity
  - **Economical** : High initial investment cost, especially for small systems
- **Huge potential** for innovation
  - Heat rejection / electric consumption / costs

  → new generation of PV and ST SHC

Current trends

- **Compact** (small scale) solar air conditioning units with **air- cooled** ab- and adsorption **chillers**
- **x.N stage chillers** (half, single, 1.N, double, triple) with (new) middle temperature collectors
- Small scale and large multi stage **desiccant systems** with solar thermal collectors or desiccant coated components
- Thermal driven **heat pump systems for heating and cooling**, also in **hybrid** operation with vapor compression chillers
- PV & inverter controlled **split units**
- (Small size) PV driven components with **new HP/chillers** with **natural refrigerants**

Innovative companies

- **Overview** by IEA SHC Task 53

Logo	Manufacturer, country	Market status	Service	Solar input type	Nominal cooling capacity (kW or m^3/h)	Nominal heating capacity (kW)	Nominal solar input (Wp for PV and m^2 for ST
	ATISYS, France	R&D	Cooling/ heating	PV	4 kW	5.1 kW	4.6 kW
	CLIMATEWELL, Sweden	R&D	Cooling/ heating/DHW	ST	40 kW	108 kW	180 m^2
	FREECOLD, France	Commercial	Cooling	PV	2.5 kW	No heating	1.5 kW
	FREESCOO, Italy	R&D	Cooling/ heating	ST/PV	500 m^3/h	1.44 kW	2.4 kW
	GREE, China	R&D	Cooling/ heating	PV	33.5 kW	37.5 kW	12.2 kW
	KAYSUN, Spain	Commercial	Cooling/ heating	PV	3.5 kW	3.5 kW	0.7 kW
	PURIX, Denmark	Commercial	Cooling/ heating	ST	2.5 kW	3.6 kW	4.8 m^2
	SENR, France	Commercial	Cooling/ heating	PV	3.6 kW (split) 45 kW (VRF)	3.6 kW (split) 50 kW (VRF)	0.65 kW (split) 20 kW (VRF)
	SOLABCOOL, Netherlands	R&D	Cooling/ heating	ST	4.5 kW	8 kW	13.3 m^2
	YAZAKI, Japan	R&D	Cooling/ heating	ST	35 kW	60 kW	0.1 kW

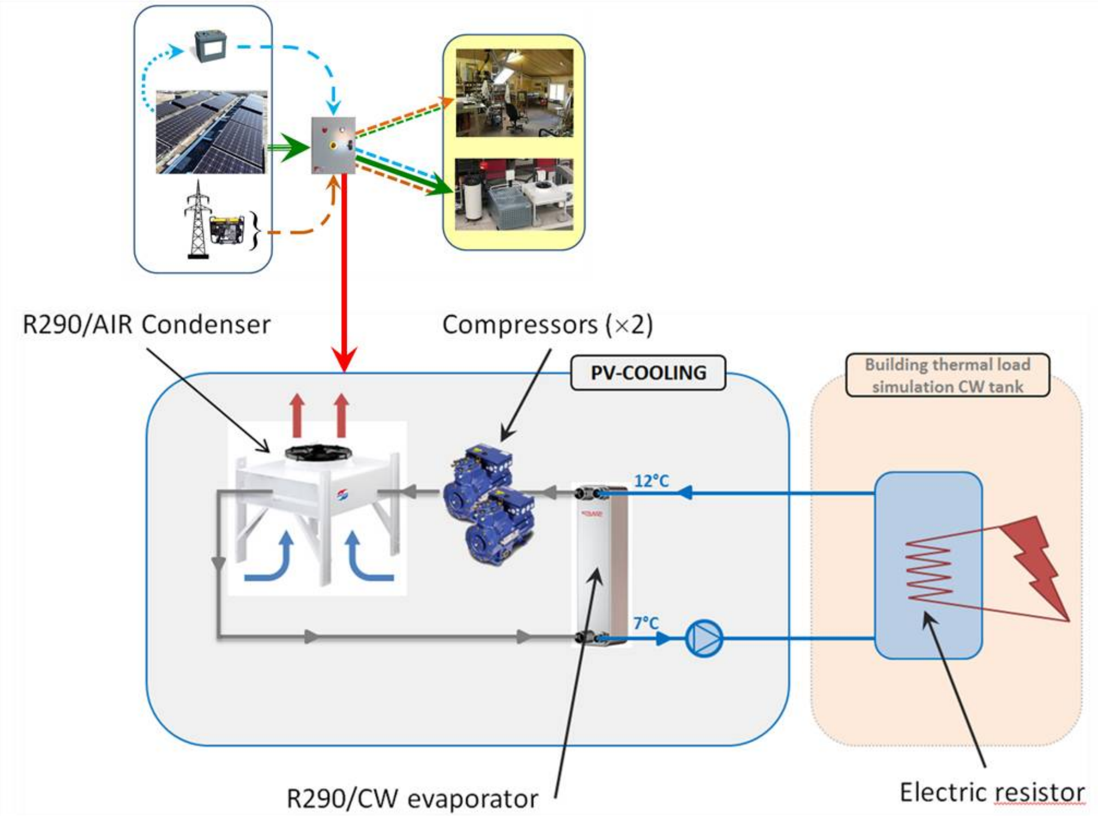
SOLABCOOL (NL)
4,5 kWc

SunOyster

no claim for completeness!

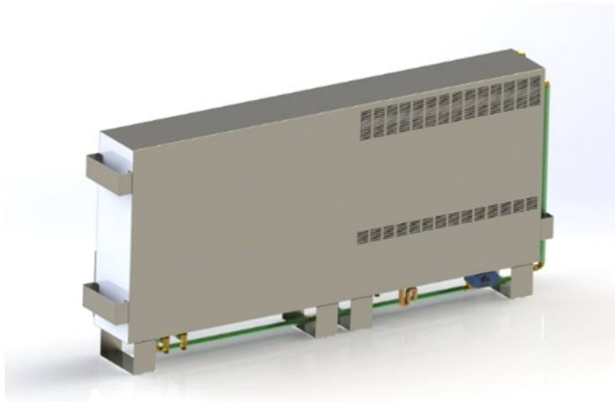
PV COOLING project

- PV + INVERTER
  + R290 chiller
- Self consumption > 80%
- fully autonomous systems possible
- EERsol 25-100
- Ready for the market via demos..



Compact DEC-system

Freescoo is an innovative solar DEC air conditioning concept designed for **ventilation**, **cooling**, **dehumidification** and **heating** of buildings in residential and tertiary sectors



- Use of the Cooled Packed Bed (CPB) technology and high efficiency evaporative cooling concepts
- Low grade solar heat (50-60°C) to drive the cooling process
- High global electrical efficiency (**Typical EER >10**)
- Preassembled and ready to be installed
- Cooling capacity 2,5 kW, scalability possible
- Selected for the Brochure 2018 of the **EeB PPP Promising Technologies**

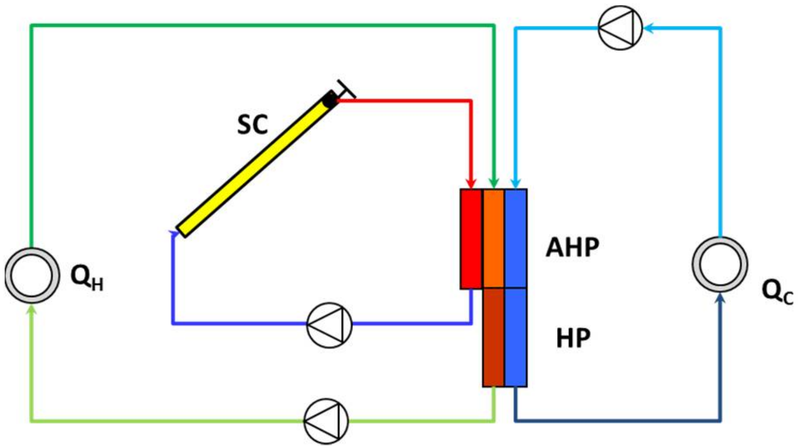
Freescoo is a patented solution by the startup company

SOLARINVENT

Hybrid concepts

- SolarHybrid by

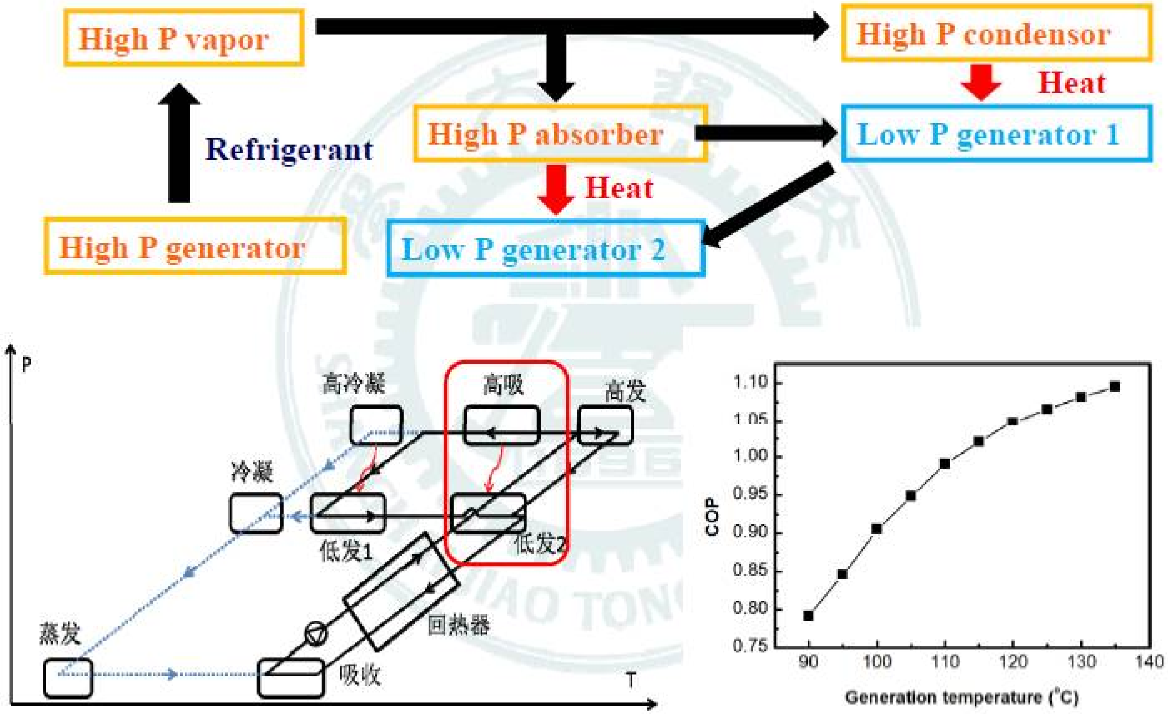
- Prototypes in Hardware-in-the-Loop & simulation study
  - 20 kW NH3/H20 absorber
  - 20 kW NH3 vapor compression
- Solar direct driven absorber + complementing compressor
  - Primary Energy Savings up to 80 %
  - CR < 1 possible



x.N Chillers

Fresnel Solar Collector + 1.N effect absorption chiller

@ Shanghai Jiao Tong University, Prof Dai



Large Scale SHC

SOLID
solarinstallation+design

	United World Collage (UWC)	Desert Mountain High School (DMHS)	Hospital Managua (MANAGUA)
Commissioned	2011	2014	2017
Location	Singapore	USA, Arizona	Nicaragua
Collector Area	3872 m²	4935 m²	4450 m²
Cooling Capacity	1475 kW	1750 kW	1023 kW
Domestic Hot Water	Yes	No	Yes
Climate	Tropical Rainforest Climate	Desert Climate	Tropical Wet and Dry Climate

Solar conversion factor	2011 to 2017	+ 36%
Specific cost	2011 to 2017	- 71%

Successful design

Task 48

- Summary of **experiences / lesson's learned**
  - General findings → **10 key principles**
- The **Solar Cooling Design Guide**,
  - Case Studies of Successful Design
  - **3 examples**
- **Scientific background**
  - Solar Energy Paper
  - Literature in context of Task48
  - Recent literature review
  - Expert survey

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10 key principles for successful solar air conditioning design – A compendium of IEA SHC Task 48 experiences

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Technical and economic solutions

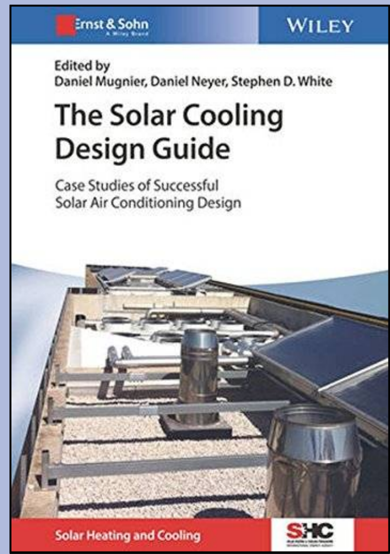
ABSTRACT

The results of past and ongoing activities, in successive IEA SHC (solar heating and cooling) Tasks, suggest enormous potential for solar cooling technologies to reduce greenhouse gas emissions. However, solar thermal cooling still faces barriers to emerge as an economically competitive solution. IEA SHC Task 48 was introduced to gather learnings from existing installations, and to find technological and market solutions, which could enable industry to deliver solar thermal driven heating and cooling systems that are efficient, reliable and cost competitive.

The selected experiences of these research activities were clustered into 10 qualitative key principles for successful design and operation of SHC systems. Three existing systems are fully discussed in a solar cooling design guide (Mugnier et al., 2017). This paper aims to introduce these key principles in its general format. The background to the qualitative statements is explained, supplemented with examples from the context of Task 48 and compared with recent literature. Furthermore, a survey was conducted among SHC experts, who provide an assessment of the importance of the principles.

The result shows that all principles have their eligibility. However, it turns out that there are three main categories of principles: (i) essential, (ii) important and (iii) controversial. Following the key principles is not a guarantee, but they can support researchers, designers and contractors to implement solar heating and cooling systems successfully.

https://doi.org/10.1016/j.solener.2018.03.086



https://doi.org/10.1002/9783433606841

Task 53

TECSOL

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

Assessment

- Solar cooling and heating can be **complex**
  - Solar Thermal or Photovoltaic driven
  - System design & configurations (backups, storages,…)
  - Demands (domestic hot water, space cooling, …)

→ Assessment in a **common comparable format**

- energetic, ecological, economic, evaluation

  → **T53E4 Assessment Tool**
- Assessment based on (monthly) energy balances
- Measured or simulated (sub) system
- Data base for Technical and Economic assessment

Main driving future for solar cooling...

MISSION INNOVATION
Accelerating the Clean Energy Revolution
www.mission-innovation.net

Linked with Mission Innovation Challenge #7
Affordable Heating & Cooling for Building Innovation

Statement : Cooling is one of the major energy need increase worldwide and except solar, no renewables are really competing

The future market is essentially in the Sunbelt : MENA, India, Asia, Africa, America, Oceania

IEA SHC Countries own a real knowhow on solar cooling but the "mistake" was to imagine to develop solutions for IEA SHC countries

A "technology-transfer" collaborative Work/Task is more than ever needed

Study on solar cooling potential

Clients :

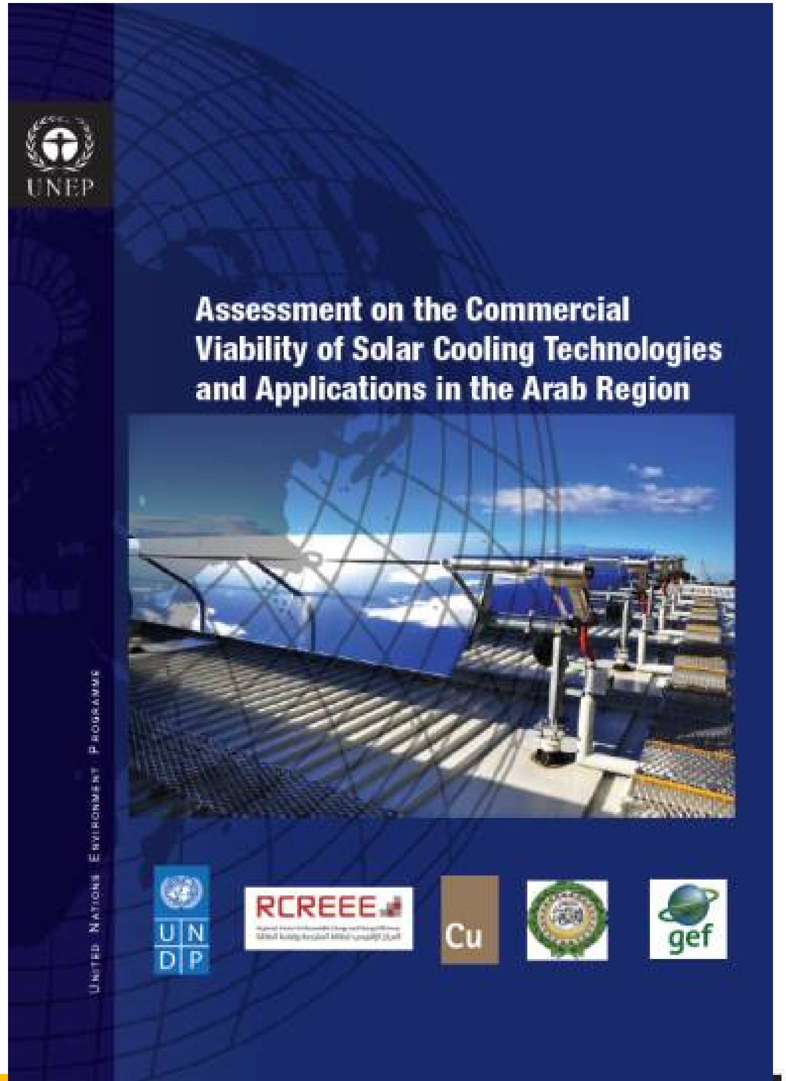
RCREEE
Regional Center for Renewable Energy and Energy Efficiency
المركز الإقليمي للطاقة المتجددة وكفاءة الطاقة

UNEP

Consultants :

SOLEM CONSULTING

TECSOL



Qualitative assessment

* Target buildings in Arab region where solar cooling accurate
⇒**a predominant daily cooling load.**

* For large spectrum of markets in the Arab region
Solar cooling to be **very robust & simple to maintain in harsh hot & arid conditions**.

* As solar cooling technology is having high upfront costs,
each produced kWh of cooling to be used in the best efficiency.

* Study **on developing the analysis of 2 driving technologies**:

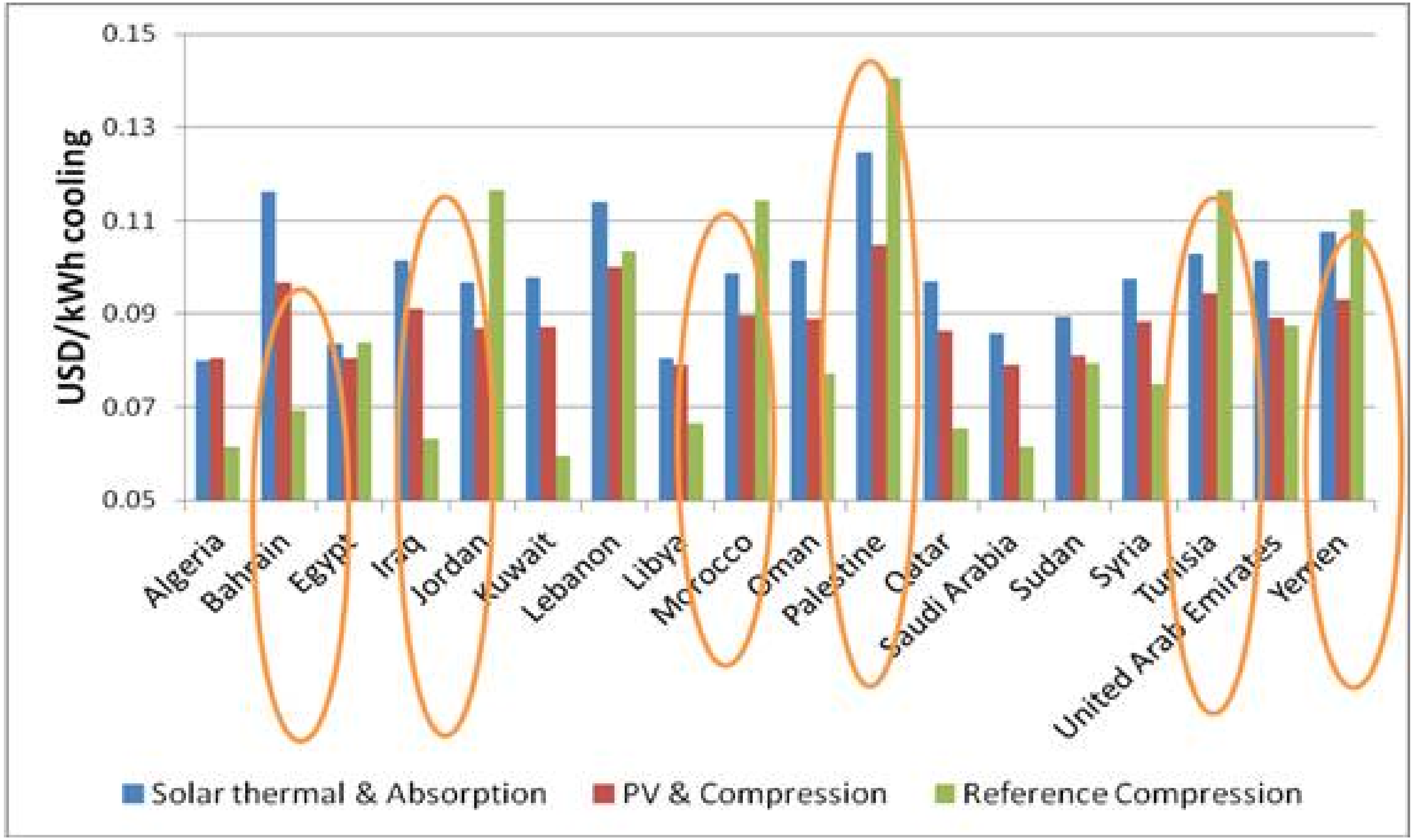
- Solar thermal absorption cooling
- Vapour compression scroll chiller and PV modules

Economic analysis : hypothesis

	Global Horizontal Irradiation	Direct normal Irradiation	PV yield, (°20 tilt ; South)	Electricity cost for commercial	% of subsidy on electricity tariff for commercial	Water cost
	kWh/m².y	kWh/m².y	(kWh/ kWp.y)	(cUSD/ kWh)		(USD/m³)
Algeria	1,970	2,700	1,600	4.2	78%	0.5
Bahrain	2,160	2,050	1,900	0.8	96%	8
Egypt	2,450	2,800	1,730	9.9	49%	0.4
Iraq	2,050	2,000	1,800	1.1	94%	0.05
Jordan	2,320	2,700	1,800	17	12%	1.47
Kuwait	1,900	2,100	1,900	0.7	96%	0.75
Lebanon	1,920	2,000	1,700	10.4	46%	1
Libya	1,940	2,700	1,700	5.5	71%	0.05
Morocco	2,000	2,600	1,700	16.1	16%	1.5
Oman	2,050	2,200	1,900	5.2	73%	2
Palestine	1,920	2,000	1,800	19.2	0%	1.2
Qatar	2,140	2,200	1,900	2.5	87%	1.4
Saudi Arabia	2,130	2,500	1,930	3.2	83%	1
Sudan	2,130	2,500	1,950	7.7	60%	0.3
Syria	2,360	2,200	1,800	5.1	74%	0.3
Tunisia	1,980	2,400	1,600	16	17%	0.6
United Arab Emirates	2,120	2,200	1,900	8	58%	0.6
Yemen	2,250	2,200	1,900	14	27%	0.3

Economical analysis of the 100 kW cooling segment

Levelized cost of cooling energy over 20 years & reference cooling cost for specific 12 countries



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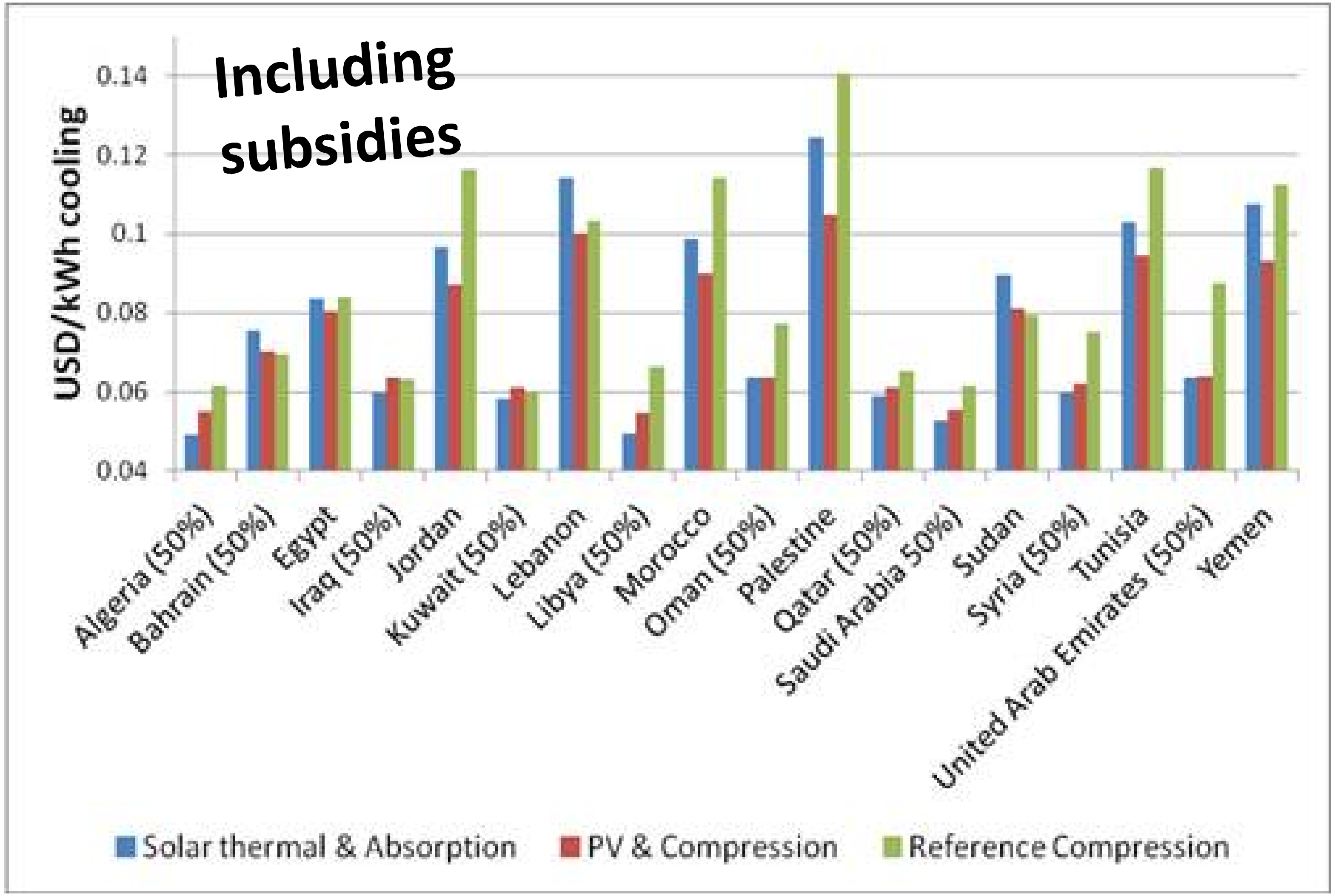
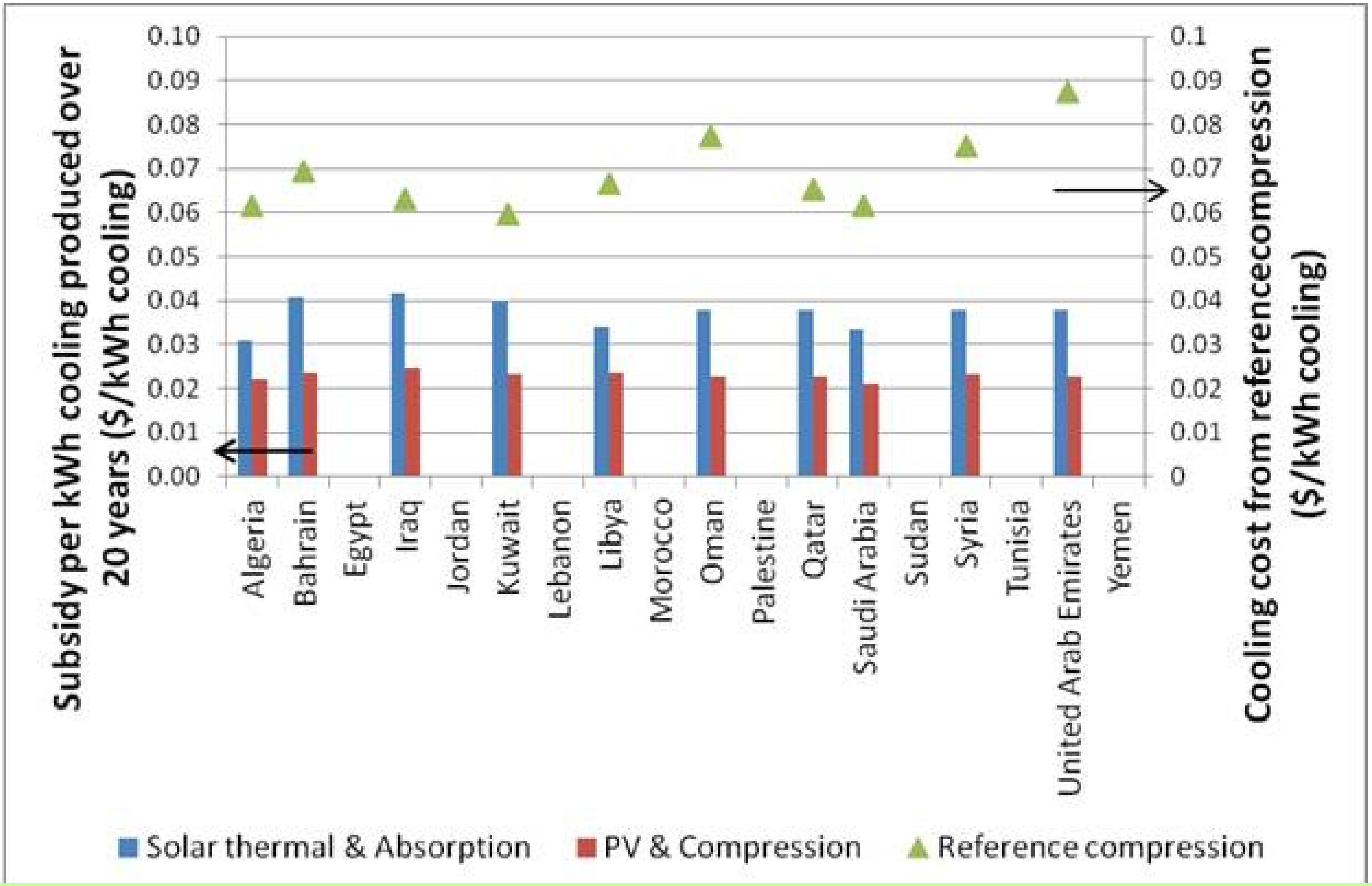


Economical analysis of the 100 kW cooling segment

Level of subsidy per unit of cooling production over 20 years & reference cooling cost for specific 12 countries



It is far cheaper to subsidized solar cooling than oil or gas cooling !

Conclusion for 100 kW cooling segment

Compensation of the **important implied subsidy** by a

≈ equivalent subsidy on the upfront cost of solar cooling.

If **50% grant** on the capital cost **to increase the attractiveness** of the solar cooling systems

⇒ **In all the countries of Arab Region the kWh cooling is lower over 20 years with solar cooling than with a conventional system.**

Conclusion for 100 kW cooling segment

Egypt, Jordan, Morocco, Palestine, Tunisia and Yemen, where **the cost of solar cooling energy** is **lower over 20 years than for conventional cooling.**

In all cases, **the PV Cooling solution is more competitive than the solar thermal one**

Cost reduction potentials on solar cooling

(by 2020-2025)

Factor	**Key indicator evolution** *(difference between initial situation and new one)*	**Cost reduction ratio** *(reference : 2015, on investment)*
Sales scaling factor	x10 sales volume	15 to 30%
Size scaling factor	x10 system size from 100 kW_c to 1 MW_c	50 to 70%
Packaging factor	Solar cooling prefabrication (kits of less than 30 kW_c)	30 to 40%
Local company manufacturing factor	Manufacturing of the main components locally	5 to 10%
Technical innovations factor	Arab region adapted solar production	10 to 30%
	Heat rejection	on
	Cooling storage	Net Present Cost

Significant cost reduction potential thanks to R&D !

Summary & findings

- Future **cooling demand** is **rising**
  - Efficiency of conventional components will increase
  - Solar Cooling is needed to complement

- Several **component developments** are ongoing
  - Already some promising solutions
  - ST in **large scale** applications / **hybrid operation**
  - PV in **small scale** with vapor compression chillers & natural refrigerants

Summary & findings

- **System** improvement / **best practice** is needed
  - **quality procedures** for design, commissioning, monitoring and maintaining
  - **pre-engineered** systems for the medium capacity range
  - R&D efforts to further improve solar cooling at **system level for** specific applications / **demands** (cooling, DHW, (pre-)heating)
- **Performance** of SHC examples
  - Non-renewable **Primary Energy S**
  - **Economics** are m ... ated
  - Development w ... **pec costs** are already achieved

→ **Both technologies (PV*ST) can be optimized**

→ **Cost competitiveness can already be reached!**

Final reports of IEA SHC Task 53
to be expected in end of 2018

http://task53.iea-shc.org/

Thank you for your attention!

www.iea-shc.org

SHC

SOLAR HEATING & COOLING PROGRAMME

INTERNATIONAL ENERGY AGENCY