Solar Air Conditioning and Cooling - IEA SHC Solar Academy Task 53

ELISA "Environmental Life-cycle Impacts of Solar Air-conditioning systems"

ENVIRONMENTAL LIFE-CYCLE IMPACTS OF SOLAR AIR-CONDITIONING SYSTEMS

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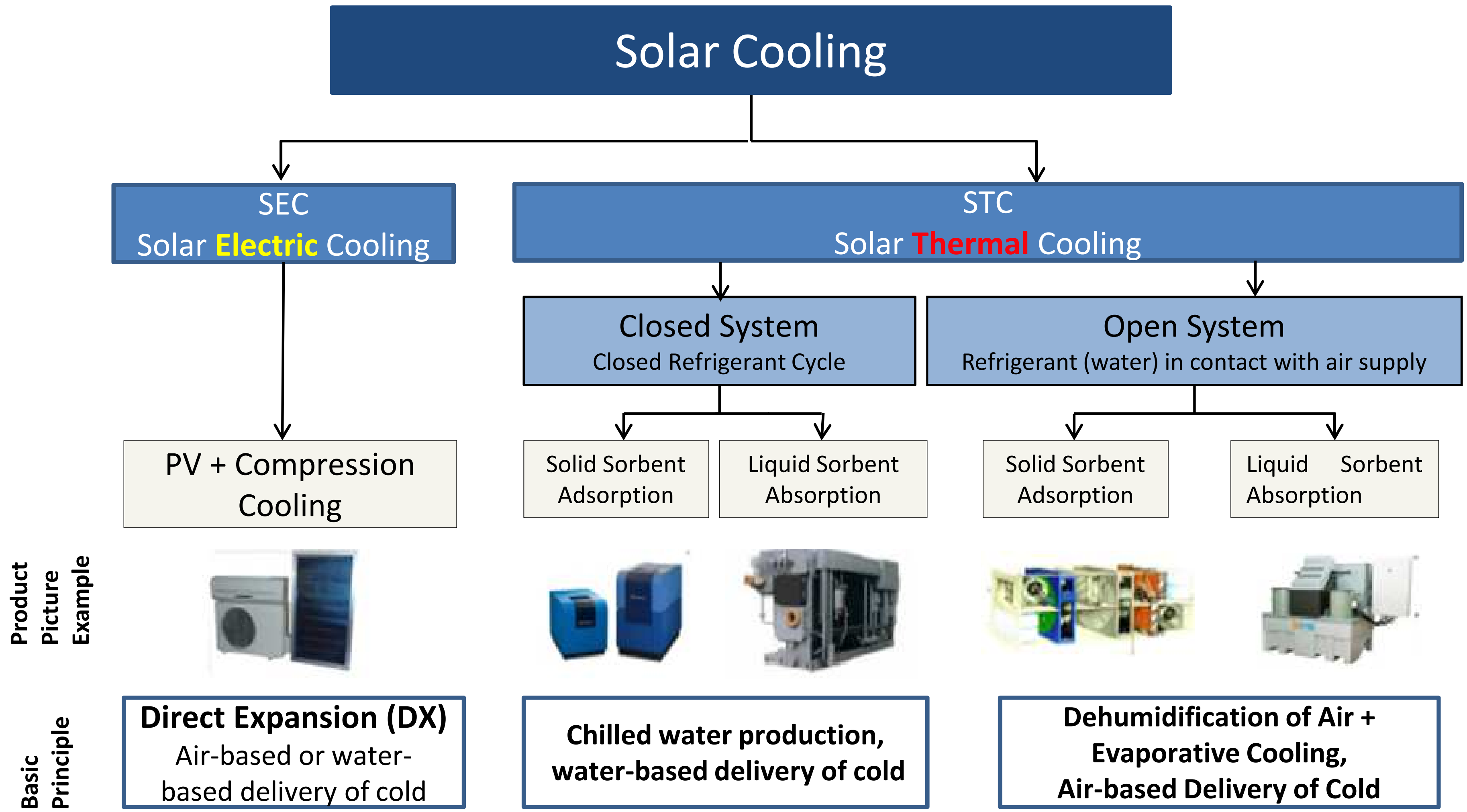
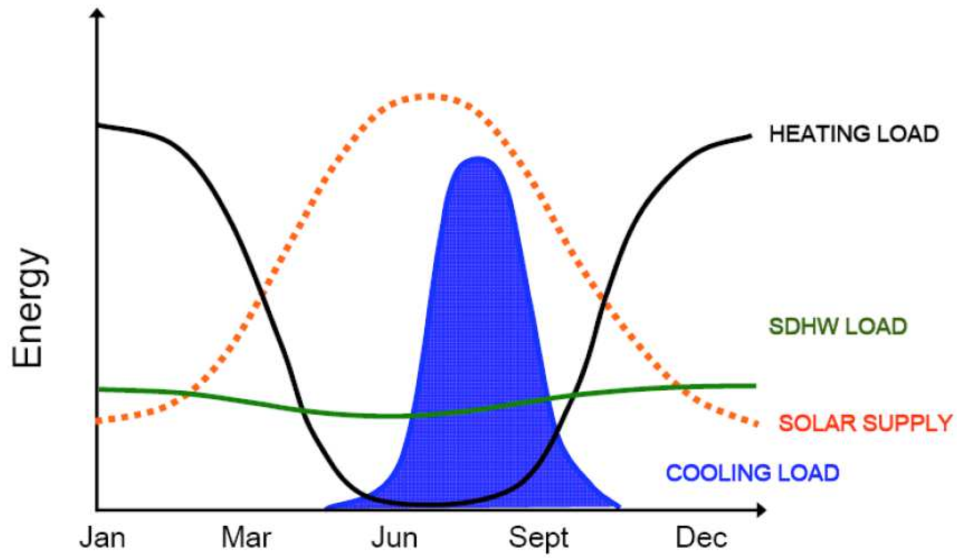
SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

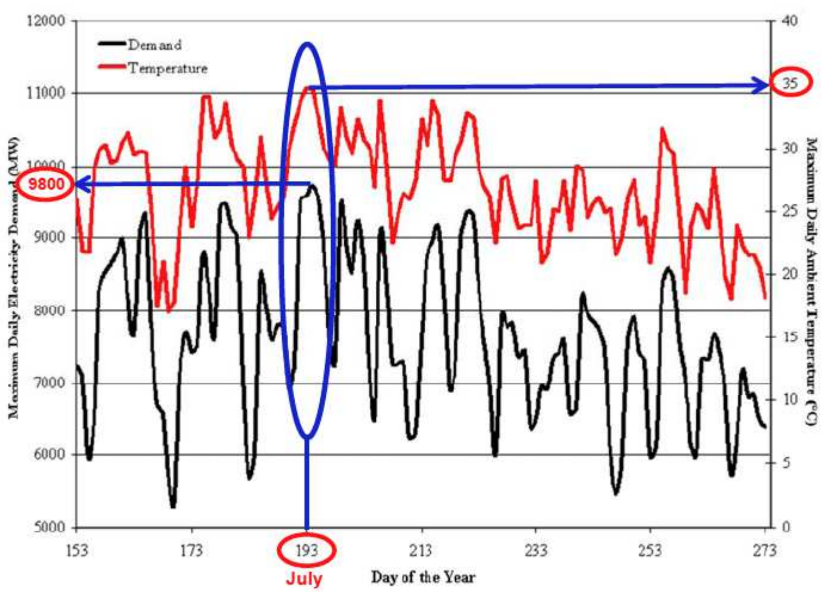
Task 53

SOLAR COOLING TECHNOLOGICAL OPTIONS



WHY CHOOSE SOLAR COOLING?



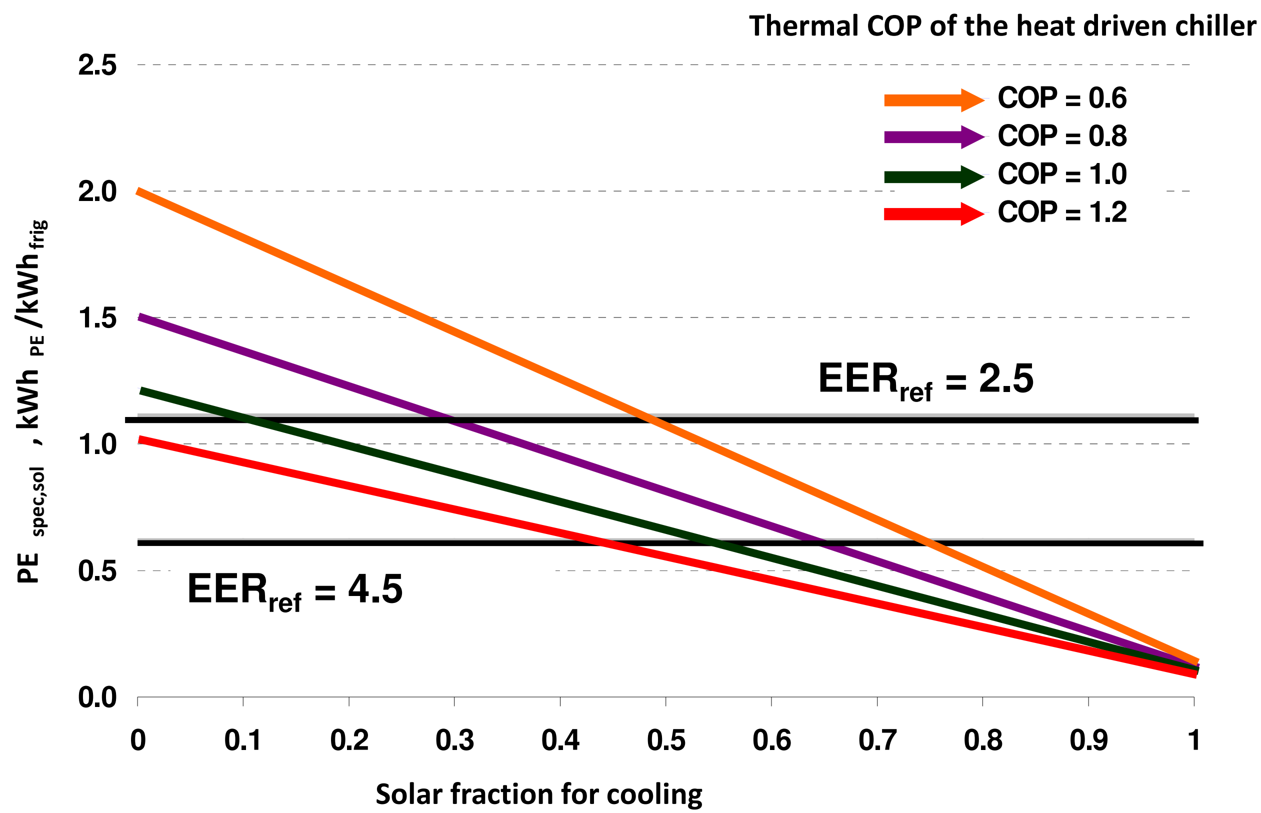


- Very good correspondece between solar radiation and demand during the year and during the days
- Opportunity to avoid the overload of the electric grid
- Give more added values to solar heating system aiming to an all-year-long operation and better economic features
- Introduce storage/load shifting (short, mid, long term)

Primary energy required for a kWh of cooling

ASSUMPTIONS:

- **Solar thermal driven with back up (gas boiler)**
- **Electricity to primary energy factor: 0.36**
- **Heat to primary energy factor: 0.9**
- **Reference System: Electric Compression Chiller**



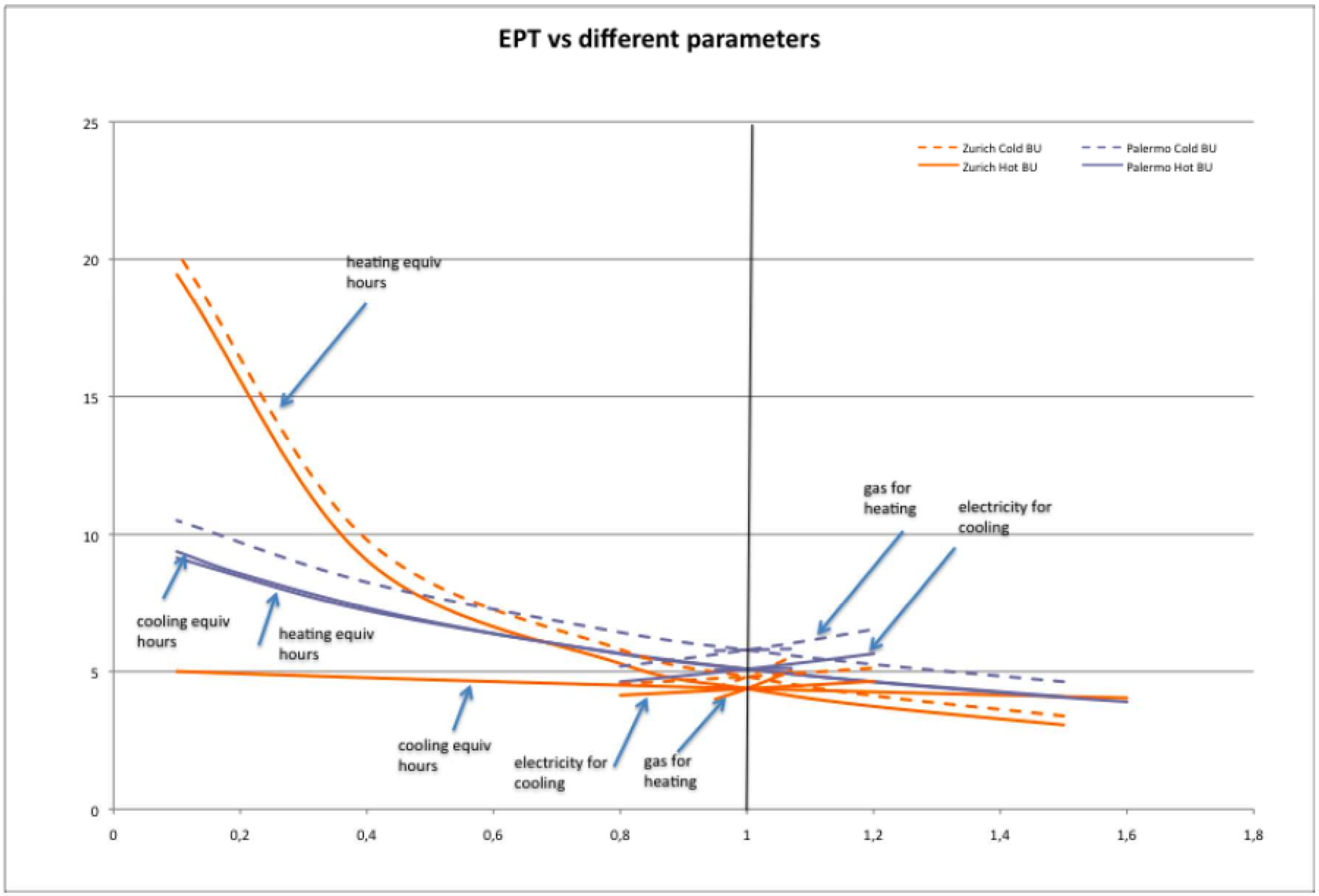
Source: H.M Henning, Fraunhofer ISE

- Using solar radiation to drive a cooling process it's not sufficient to achieve primary energy saving during the operation of the systems
- As far as green electricity share is rising up, "quantitative" benefits related to its substitution with heat carriers become lower
- This kind of balances do not take into account:

  -Energy used for the construction, maintainance and disposal of the systems

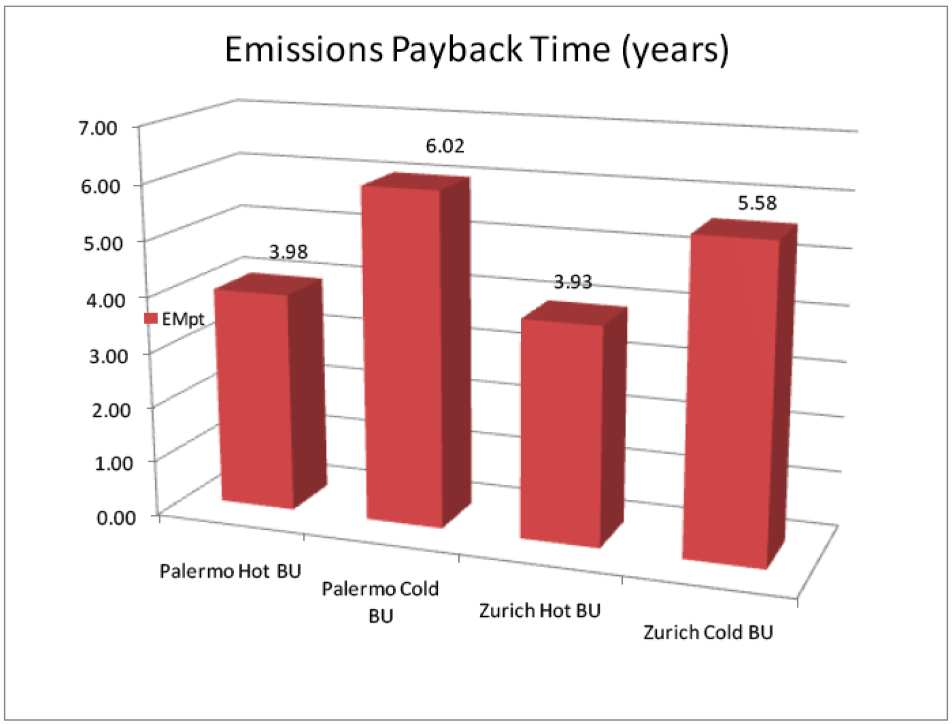
  -Impacts related to emissions by the solar and the reference system

Energy Payback Time (EPT):
the time during which the system must work to harvest as much energy as it required for its production and disposal



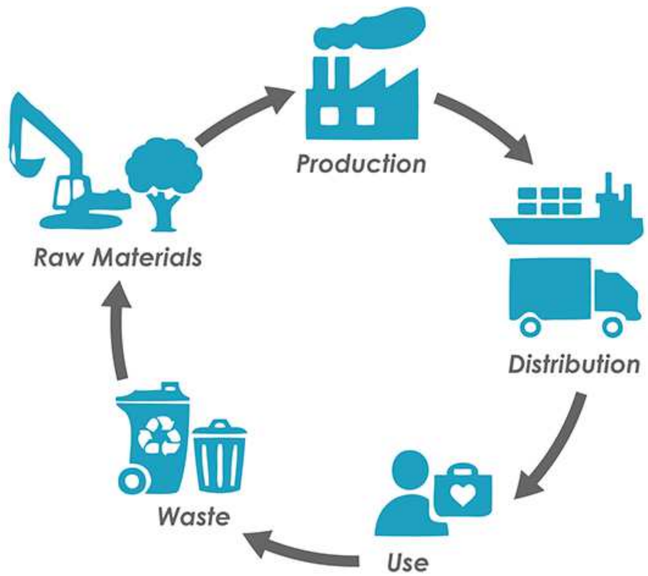
Source: Beccali et.al , IEA SHC Task 38

Energy balances are not enough to assess the real impact of a technology: environmental issues must be considered a proper way



THE LIFE CYCLE ASSESSMENT (LCA) METHODOLOGY

The LCA is a “compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle”.
Source: International standards of the ISO 14040 series (ISO 14040, 2006; ISO 14044, 2006).



Why the Life Cycle Assessment?

•It prevents to move the problems from one life-cycle step to another;
• It prevents to move the problems from an impact category to another;
•It captures the complexity hidden behind a product;
•It is a useful tool to compare products and services on a scientific basis.

IEA SHC Task 38 “Solar Air-Conditioning and Refrigeration”
Subtask D “Market transfer activities” - Activity D3 “Life cycle assessment”

IEA SHC Task 48 “Quality Assurance & Support Measures for Solar Cooling Systems”
Subtask A “Quality Procedure on Component Level” - Activity A2 “Life cycle analysis at component level”
Subtask B “Quality procedure on system level” - Activity B3 “Life cycle analysis at system level”

IEA SHC Task 53 "New Generation Solar Cooling & Heating Systems (PV or solar thermally driven systems)“
Subtask A “Components, systems and quality” - Activity A5 “LCA and techno-eco comparison between reference and new systems”

THE LCA AND THE SHC SYSTEMS

IEA SHC Task 53 "New Generation Solar Cooling & Heating Systems (PV or solar thermally driven systems)"-

Researchers often analyze only the SHC systems behavior during the operation stage, neglecting the other life cycle steps.

Needs of a life cycle approach

Development of a complete LCA

LCA is difficult to apply

LCA is time-consuming

No confidence with LCA

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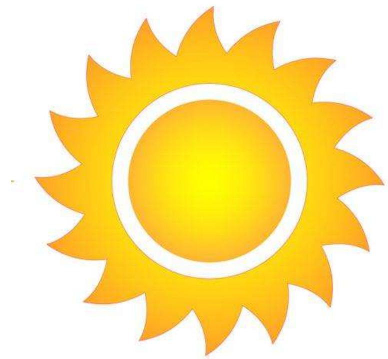

ENVIRONMENTAL LIFE-CYCLE IMPACTS OF SOLAR AIR-CONDITIONING SYSTEMS

A user-friendly LCA tool to evaluate the life cycle energy and environmental advantages related to the use of SHC systems in substitution of conventional ones, considering specific climatic conditions and building loads.

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Comparison of four typologies of heating and cooling systems:

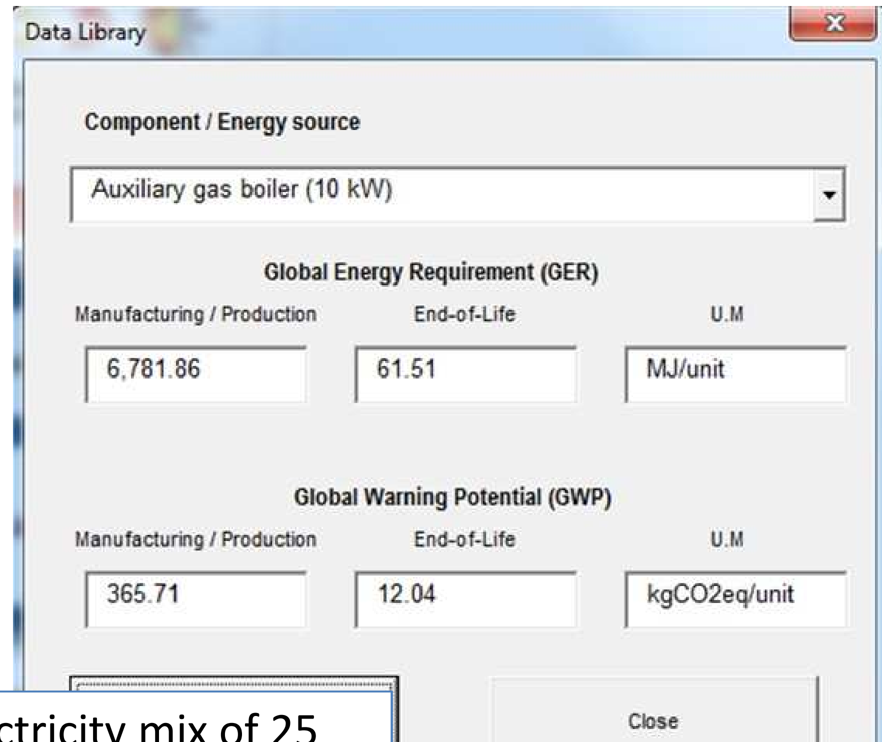
SHC | SHC with PV | Conventional | Conventional with PV (PV cooling)

Calculation of:

- Global energy requirement (GER);
- Global warming potential (GWP);
- Energy payback time (EPT);
- GWP payback time (GWP-PT);
- Energy return ratio (ERR).

Step 1: Input data

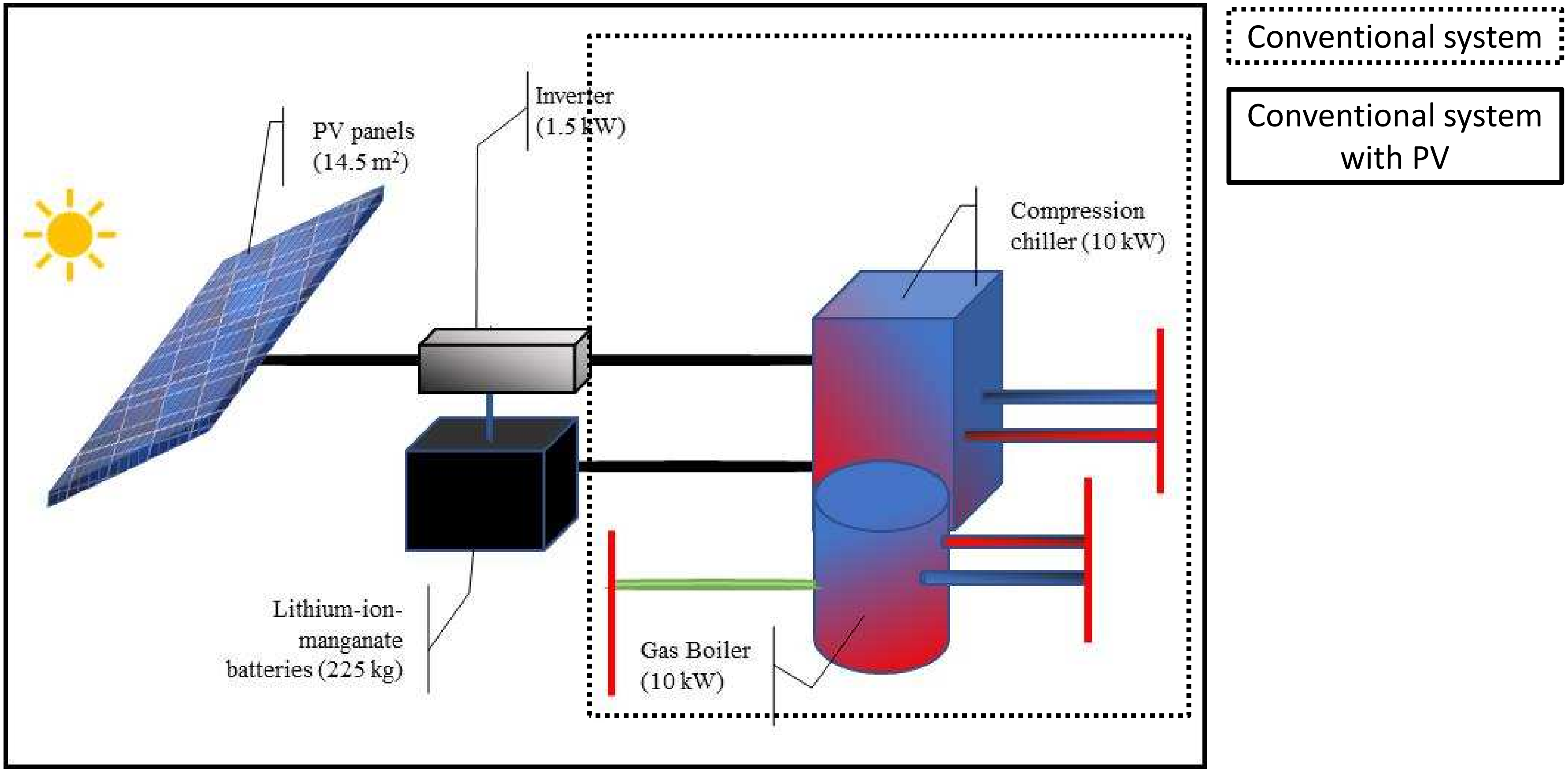
Step 2: Analysis of the results



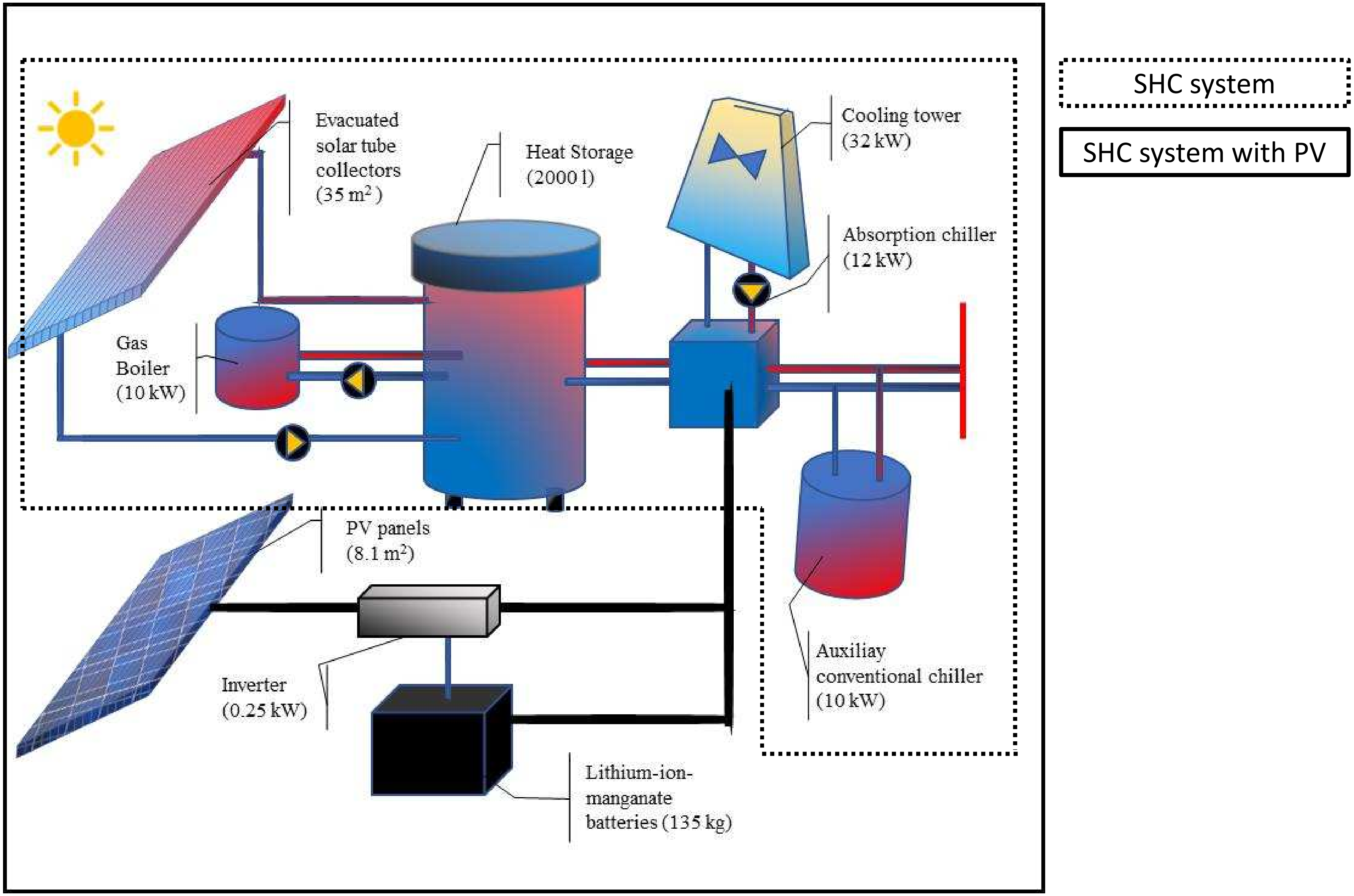
Electricity mix of 25 localities (23 European countries, Switzerland and Europe)

Natural gas burned in 10 different systems in the European context

THE EXAMINED SYSTEMS



THE EXAMINED SYSTEMS



Step 1: Input data

COMPONENTS OF THE SHC SYSTEM

Category	U.M.	Quantity	n° REPLACEMENT
Ammonia	kg	15.00	
Auxiliary conventional chiller (10 kW)	unit	1.00	
Auxiliary gas boiler (10 kW)	unit	1.00	
Absorption chiller (12 kW)	unit	1.00	
Cooling tower (32 kW)	unit	1.00	
<Glycol>	kg		
<Heat rejection system>	unit		
Heat storage (2000 l)	unit	1.00	
<Heat-pump>	unit		
Pipes	m	60.00	
Pump (40 W)	unit	8.25	
Evacuated tube collector	m^2	35.00	
Water	kg	10.00	

ENERGY SOURCES

Category	U.M.	Quantity
Electricity, low voltage, Italy (including import)	kWh/year	1,117.00
Natural gas, burned in boiler atmosferic low-NOx condensing non-modulating, <100 kW, Europe	kWh/year	414.00

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Step 2: Analysis of the results

- Total life cycle impact

COMPONENTS OF THE SHC SYSTEM	GLOBAL ENERGY REQUIREMENT (GER) (MJ)				GLOBAL WARMING POTENTIAL (GWP) (kg CO2eq)			
	Manufacturing	Operation	End-of-Life	Total	Manufacturing	Operation	End-of-Life	Total
Ammonia	629.30			629.30	31.44			31.44
Auxiliary conventional chiller (10 kW)	8,131.10		7.83	8,138.93	1,550.46		25.82	1,576.28
Auxiliary gas boiler (10 kW)	6,781.86		61.51	6,843.37	365.71		12.04	377.75
Absorption chiller (12 kW)	26,005.37		3.13	26,008.50	1,382.34		12.55	1,394.89
Cooling tower (32 kW)	2,950.69		10.74	2,961.43	149.98		3.13	153.11
<Glycol>								
<Heat rejection system>								
Heat storage (2000 l)	14,811.72		21.32	14,833.04	783.31		12.71	796.02
<Heat-pump>								
Pipes	3,928.98		19.92	3,948.90	157.98		5.82	163.80
Pump (40 W)	974.95		3.09	978.04	57.03		0.66	57.69
Evacuated tube collector	55,289.29		454.37	55,743.66	3,043.85		137.94	3,181.78
Water	0.29			0.29	0.01			0.01
Electricity, low voltage, Italy (including import)		299,835.66		299,835.66		17,970.14		17,970.14
Natural gas, burned in boiler atmosferic low-NOx condensing non-modulating, <100 kW, Europe		47,713.35		47,713.35		2,825.69		2,825.69
Total	*119,503.54*	*347,549.01*	*581.90*	*467,634.46*	*7,522.10*	*20,795.83*	*210.67*	*28,528.60*

Step 2: Analysis of the results

- Total life cycle impact
- Total impact for each component/energy source

COMPONENTS OF THE SHC SYSTEM	GLOBAL ENERGY REQUIREMENT (GER) (MJ)				GLOBAL WARMING POTENTIAL (GWP) (kg CO2eq)			
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Step 2: Analysis of the results

- Total life cycle impact
- Total impact for each component/energy source
- Life cycle steps that cause the main energy and environmental impacts

COMPONENTS OF THE SHC SYSTEM	GLOBAL ENERGY REQUIREMENT (GER) (MJ)				GLOBAL WARMING POTENTIAL (GWP) (kg CO2eq)			
	Manufacturing	Operation	End-of-Life	Total	Manufacturing	Operation	End-of-Life	Total
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Water	0.29			0.29	0.01			0.01
Electricity, low voltage, Italy (including import)		299,835.66		299,835.66		17,970.14		17,970.14
Natural gas, burned in boiler atmosferic low-NOx condensing non-modulating, <100 kW, Europe		47,713.35		47,713.35		2,825.69		2,825.69
Total	***119,503.54***	***347,549.01***	***581.90***	***467,634.46***	***7,522.10***	***20,795.83***	***210.67***	***28,528.60***

Step 2: Analysis of the results

- Total life cycle impact
- Total impact for each component/energy source
- Life cycle steps that cause the main energy and environmental impacts
- Components that are responsible of the main impacts in the manufacturing and end-of-life step.

COMPONENTS OF THE SHC SYSTEM	GLOBAL ENERGY REQUIREMENT (GER) (MJ)				GLOBAL WARMING POTENTIAL (GWP) (kg CO2eq)			
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Evacuated tube collector	55,289.29		454.37	55,743.66	3,043.85		137.94	3,181.78
Water	0.29			0.29	0.01			0.01
Electricity, low voltage, Italy (including import)		299,835.66		299,835.66		17,970.14		17,970.14
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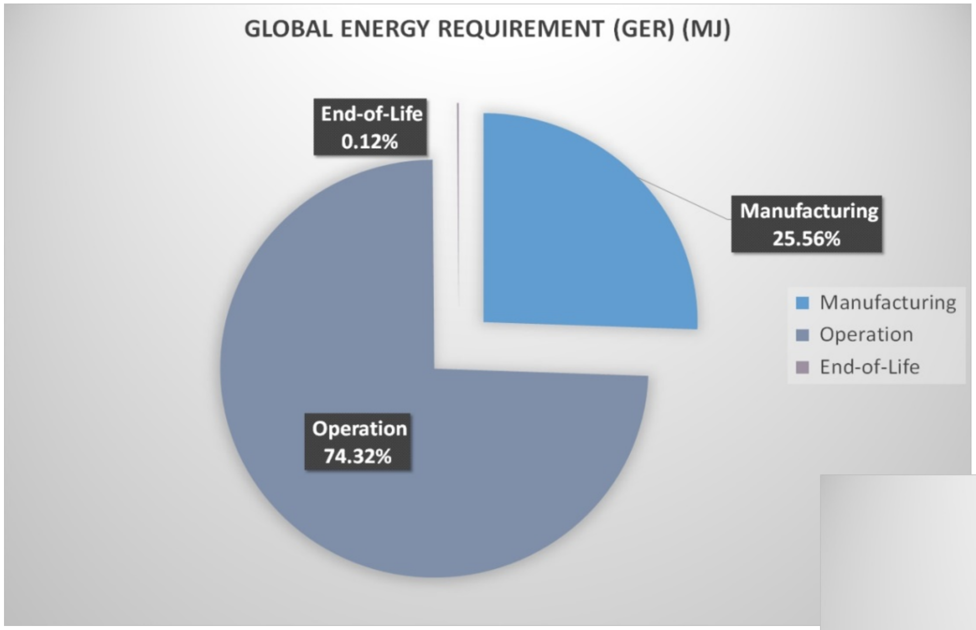
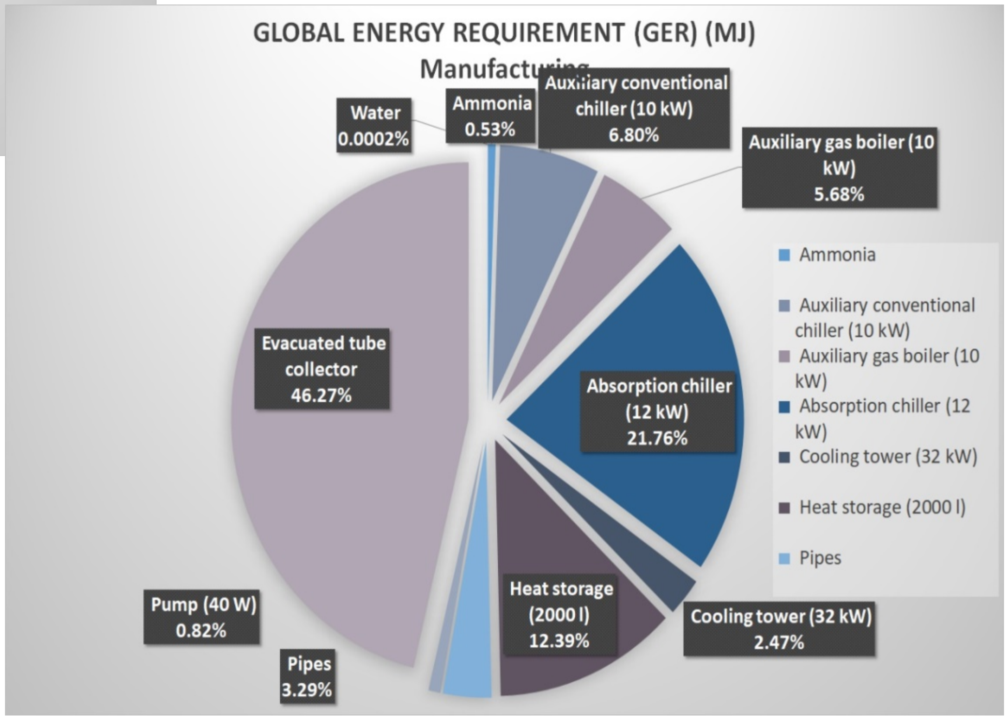
Step 2: Analysis of the results





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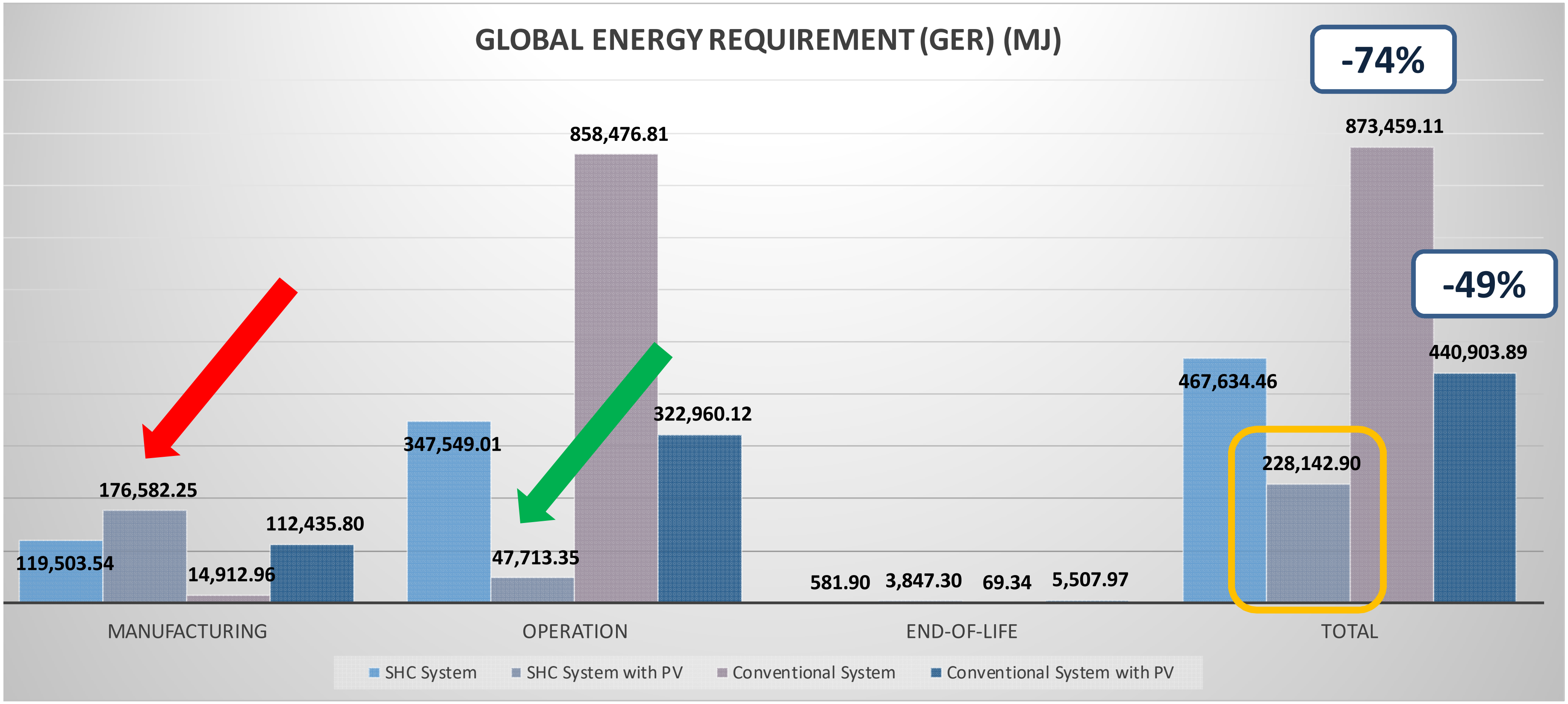
Step 2: Analysis of the results

SYSTEM	GLOBAL ENERGY REQUIREMENT (GER) (MJ)				GLOBAL WARMING POTENTIAL (GWP) (kg CO_{2eq})			
	Manufacturing	Operation	End-of-Life	Total	Manufacturing	Operation	End-of-Life	Total
SHC System	119,503.54	347,549.01	581.90	467,634.46	7,522.10	20,795.83	210.67	28,528.60
SHC System with PV	176,582.25	47,713.35	3,847.30	228,142.90	10,490.07	2,825.69	558.08	13,873.83
Conventional System	14,912.96	858,476.81	69.34	873,459.11	1,916.17	51,335.67	37.86	53,289.70
Conventional System with PV	112,435.80	322,960.12	5,507.97	440,903.89	7,009.47	19,240.40	582.56	26,832.43



Integration of the PV panels: reduction of the total impacts of about 50% despite the increase of the impacts during the manufacturing and end-of-life steps.

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Step 2: Analysis of the results

	$E\text{-}PT=(GER_{j\text{-}th,SHC\text{-}system} - GER_{i\text{-}th,Conventional\text{-}system})/E_{year}$	
	Conventional System	**Conventional System with PV**
SHC System	5.14	~~-2.18~~
SHC System with PV	5.10	5.68

	$GWP\text{-}PT=(GWP_{j\text{-}th,SHC\text{-}system} - GWP_{i\text{-}th,Conventional\text{-}system})/GWP_{year}$	
	Conventional System	**Conventional System with PV**
SHC System	4.73	~~-2.26~~
SHC System with PV	4.69	5.26

	$ERR=E_{Overall,j\text{-}th,SHC\text{-}system}/GER_{i\text{-}th,SHC\text{-}system}$	
	Conventional System	**Conventional System with PV**
SHC System	4.25	~~-0.20~~
SHC System with PV	4.49	1.53

Energy and environmental costs balanced in a time lower than 6 years.

Energy saved overcomes the energy consumption.

Being the impact of the SHC system during operation higher than that of the conventional system with PV, the indices cannot be calculated.

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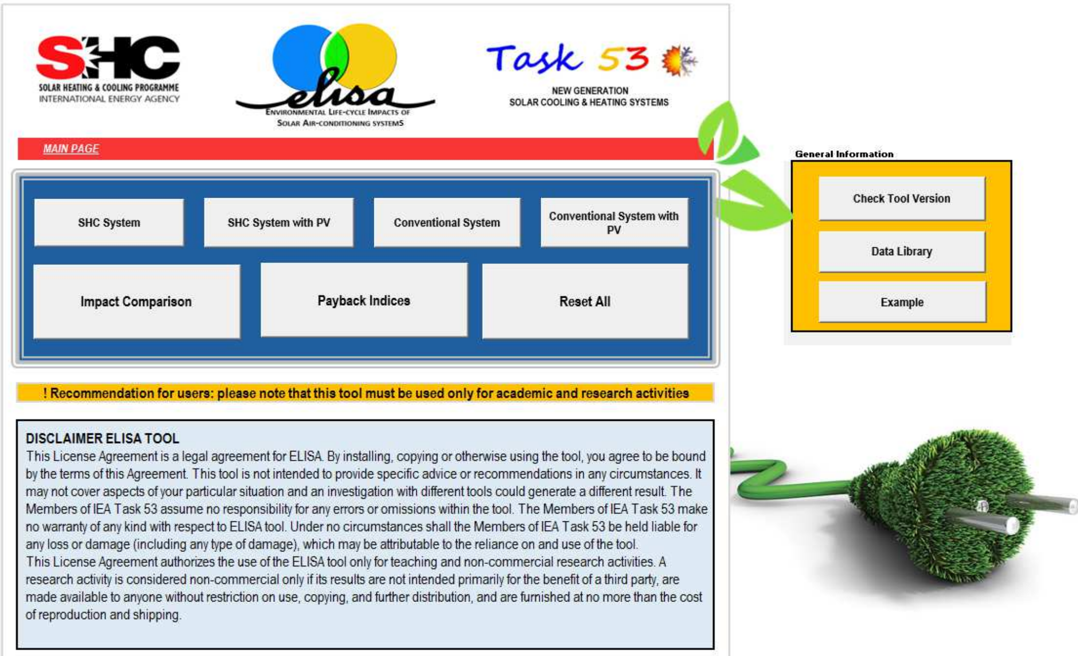

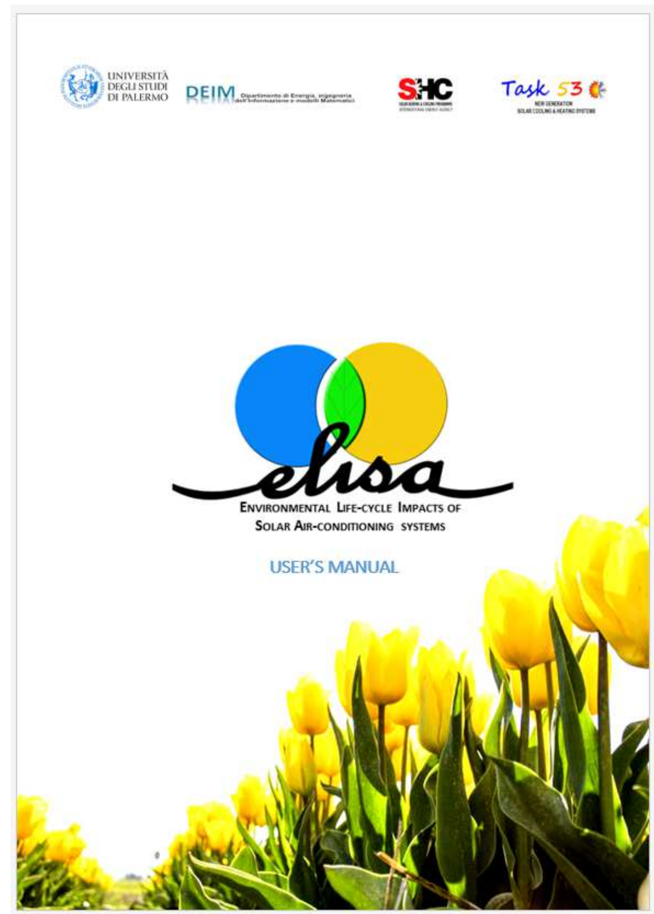

The tool and the user's manual will be freely available on the website of Task 53 of IEA: http://task53.iea-shc.org/

CONCLUSIONS

Simplified tool: it cannot be used for complete and accurate LCAs

Limited data library: new data or updated data

The tool's advantages:

- It gives a general overview and an order of magnitude of the impacts
- It enables users to evaluate if there are real benefits due to the installation of a SHC system in substitution of a conventional one
- It can simplify the introduction of the life-cycle perspective in the selection of the most sustainable heating and cooling system is a specific geographic contexts.
- Appreciated by Members of IEA Task 53

ELISA represents an original and easy-to-use tool that enables researchers, designers, and decision-makers to take environmentally sound decisions in the field of SHC technologies.

THANK YOU FOR YOUR ATTENTION

Prof. Marco Beccali - Dr. Sonia Longo

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