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Solar Heat for Industrial Processes

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ECREEE Regional Forum on the ECOWAS Solar Energy Initiative

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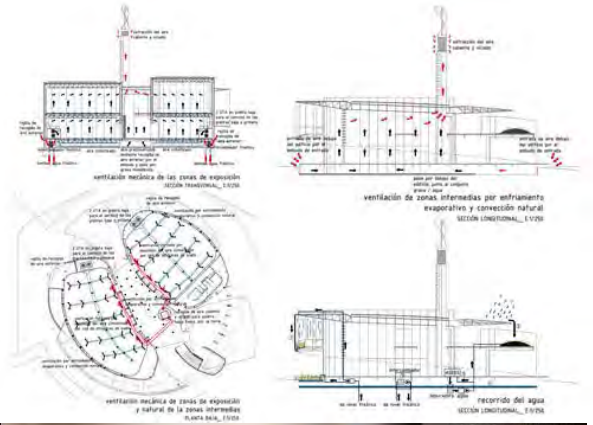


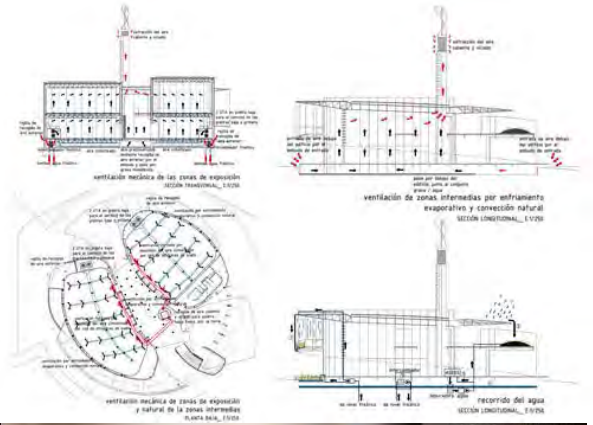
- Cooperative Company funded in 1.999 by two PhD from the Polytechnic University of Catalonia (UPC) . Nowadays 20 people - PhD Engineers, engineers, physicists, etc. – exclusively dedicated to energetic engineering tasks, in four different areas:

- **SOLAR THERMAL SYSTEMS**. Analysis, simulation, optimization, design and planning. *Many large scale systems:175-700kW$_{th}$ and near three thousand dwellings supplied by solar thermal energy.*

- **BUILDING DESIGN CONSULTANCY**. Assessment, simulation, design of constructive solutions, energetic performance certification, etc.

- **ENERGETIC SYSTEMS CONSULATNCY**. Solar Cooling, geothermal, micro-CHP, Industrial Processes, DH&C, high temperature solar plants, etc.

- **SOFTWARE DEVELOPEMENT**. Solar thermal systems, buildings thermal behavior and ventilation dynamic simulation (TRNSYS, TRANSOL, TRNFLOW, etc.)



AIGUASOL collaborates with the Spanish Government as energy consultants in:

- Energy Planning
- Assessment on developing legislation regarding energy efficiency, and renewable energies integration
- Technology feasibility studies
- Evaluation of Renewable Energy resources and its potential to satisfy country's energy demand
- Reference tools development

- Main concepts
- Potential
- Technologies
- Existing Systems
- And more...

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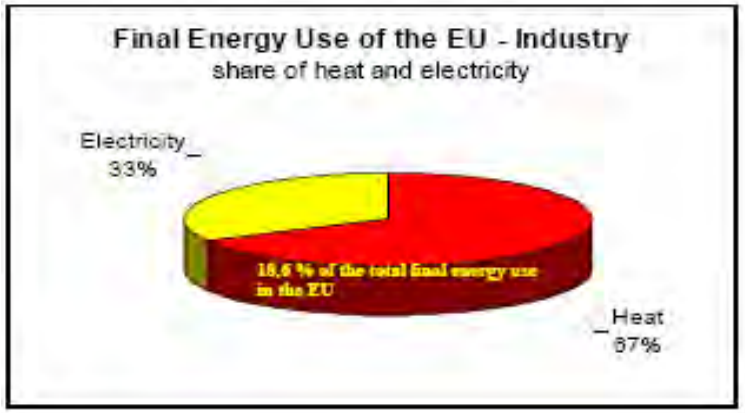
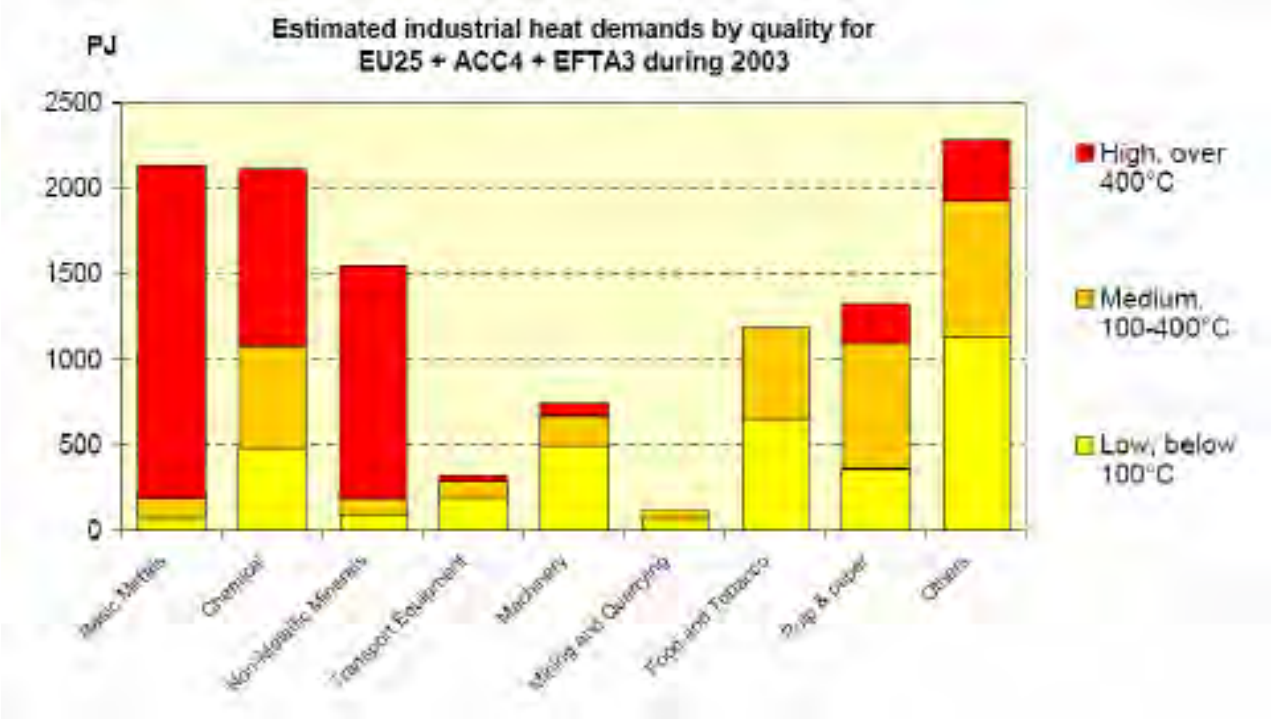
Why and in which industries solar thermal and industrial consumption?





REASONS BEHIND SOLAR ENERGY USE FOR INDUSTRIAL APPLICATIONS

- ELECTRIFICATION IS IMPORTANT, BUT…..
- IT IS ALSO IMPORTANT TO STAND OUT THAT MOST OF THE CONSUMPTION IN ALL COUNTRIES, EVEN INDUSTRIALISED COUNTRIES, IS THERMAL CONSUMPTION, MAINLY IN INDUSTRIAL PROCESSES
  - AND SPECIALLY IN THE AGROFOOD SECTOR, WHICH IS REALLY IMPORTANT IN ECOWAS COUNTRIES!!!!
- AT THE MOMENT, A GREAT QUANTITY OF AGRICULTURAL PRODUCTS ARE EITHER DIRECTLY EXPORTED OR TREATED REALLY FAR AWAY FROM ITS ORIGIN (PLACES WITH ENERGY SUPPLY)
- SOLAR THERMAL ENERGY IS A REALLY ECONOMICALLY FEASIBLE WAY TO PRODUCE ON-SITE ENERGY, EVEN FAR FROM ELECTRIFICATION, AT MUCH LOWER COSTS
- SO, ESTABLISHING A GOOD FRAMEWORK FOR SOLAR THERMAL FOR HEATING (AND COOLING!) FOR AGROFOOD PROCESSES CAN HELP DEVELOP THE CONDITIONS FOR THE ESTABLISHMENT OF AGROFOOD INDUSTRIES IN RURAL AREAS

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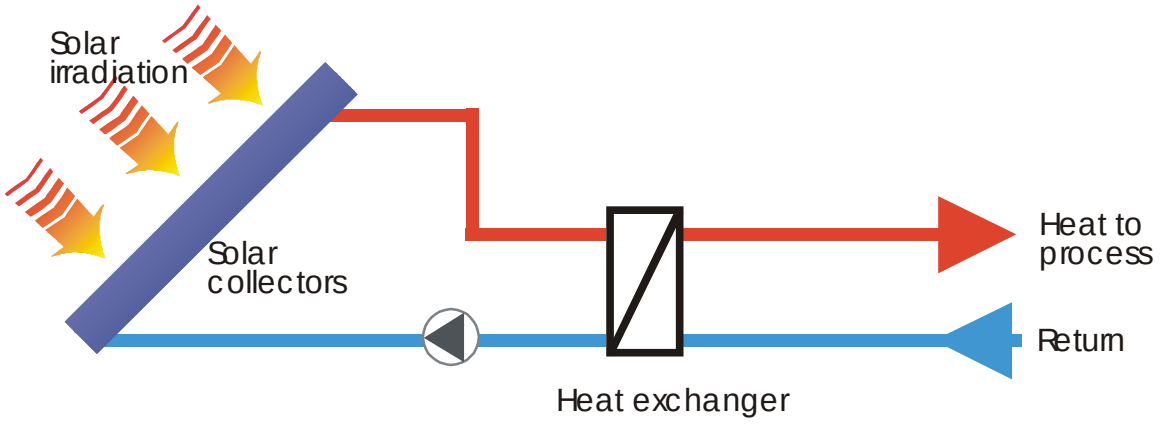
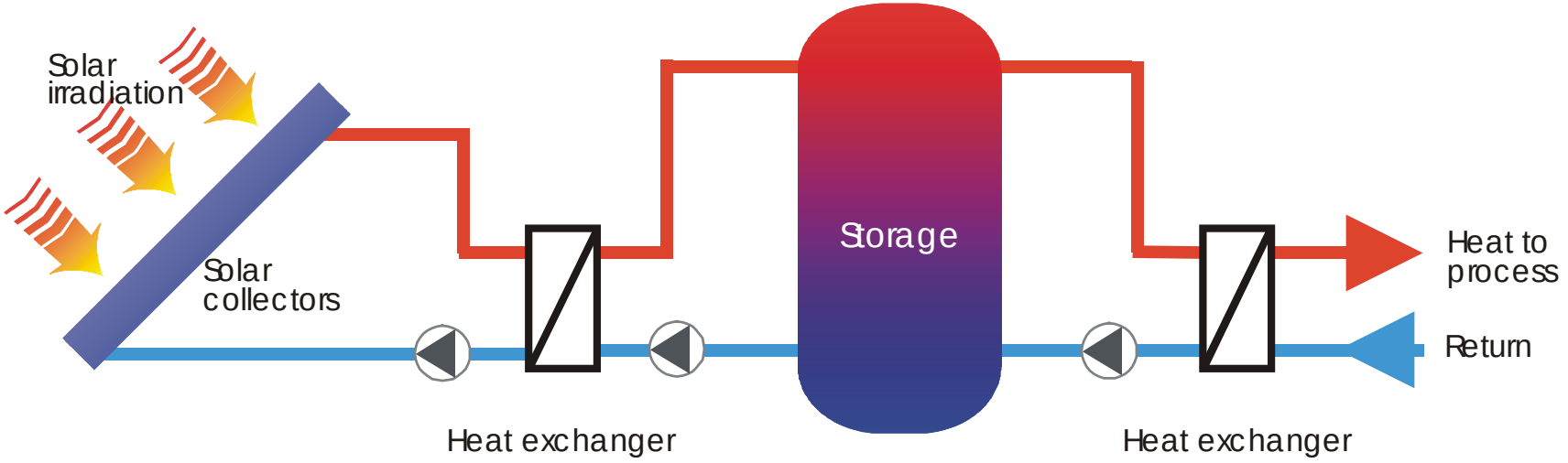
(SOURCE: OPTIPOLYGEN)

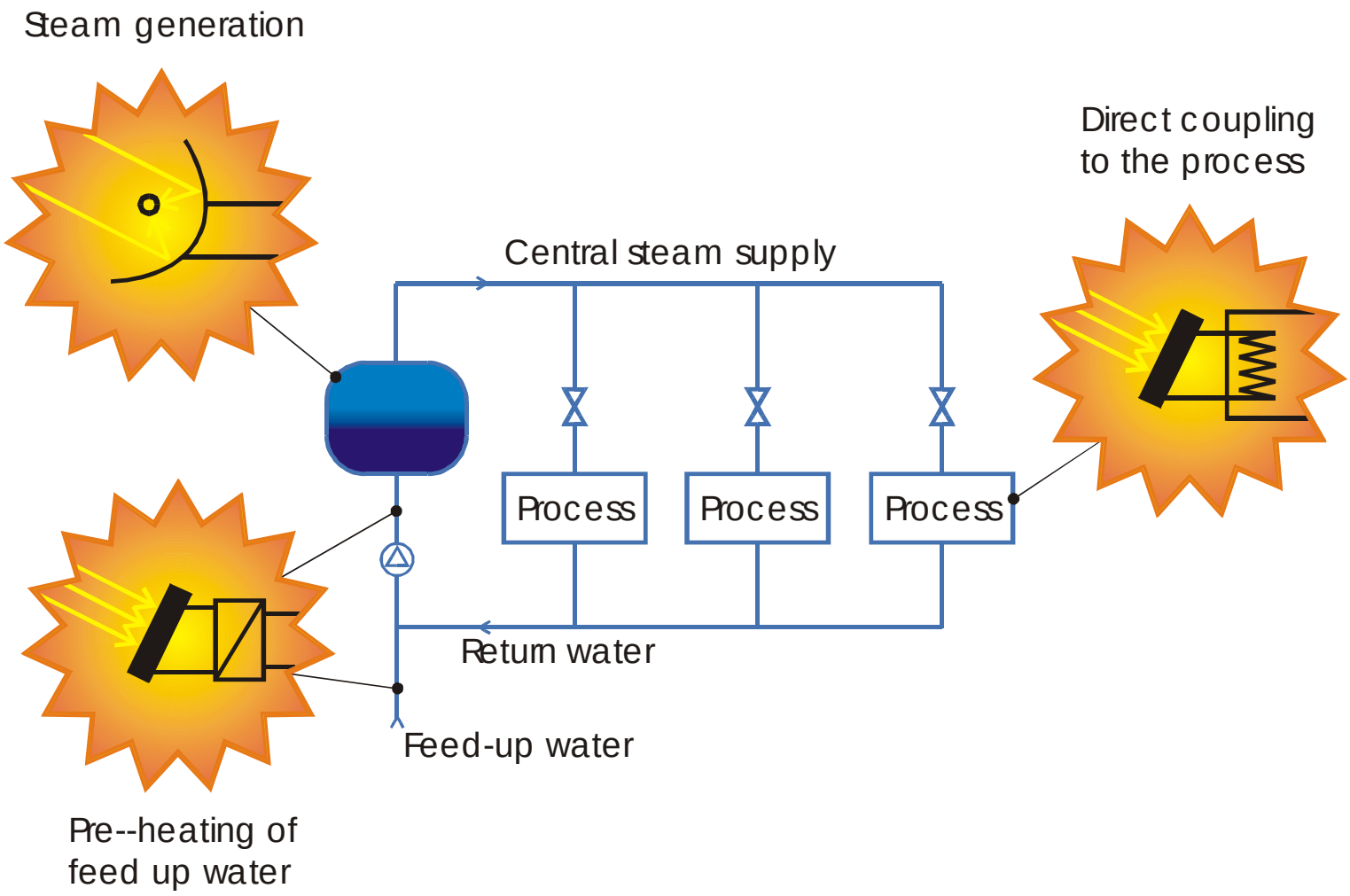
Thermal Process	Temp	Food Sector I	II	III	IV	V	VI	VII
Cooling, chilling	4 to 8°C	X	X		X	X	X	X
Freezing	-15 to -40°C	X	X			X		X
Blanching	80 °C		X					
Cooking, boiling, frying	90 to 150°C or 100 to 300°C	X	X	X				
Degumming	100 °C			X				
Roasting	370 to 540°C (coffee) 130 to 150 °C (cacao)					X	X	
Pasteurisation	72°C				X			X
Bleaching	150 °C			X				
Deodorization	180 – 270 °C			X				
CIP	> 50°C		X		X			X
Baking	300 to 400 °C					X		
Distillation, Evaporation	> 100 °C				X			X
Proofing	40°C					X		
Defrosting	20 to 40 °C	X						
Freeze storage	-18 to -40°C	X	X					X
Cooled storage	4 to 8 °C		X		X		X	X
Air condition	10 to 20 °C	X						

System configurations with and without solar heat storage

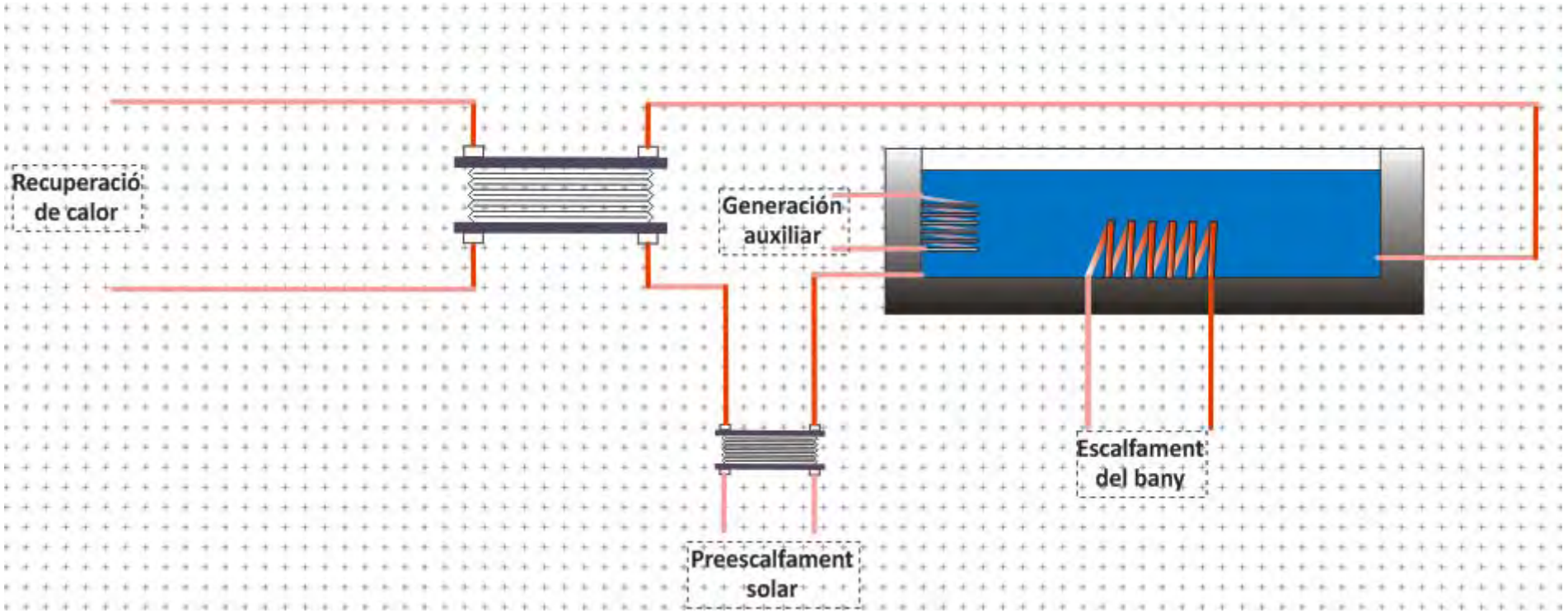




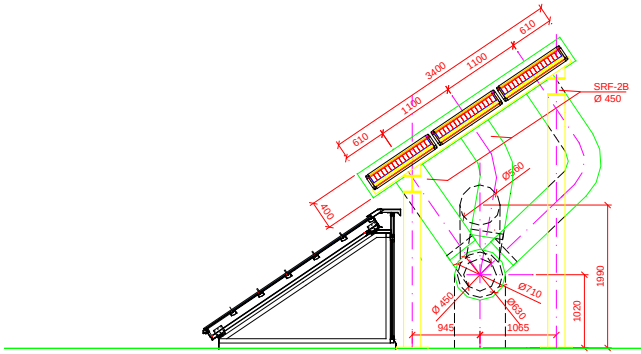
Coupling of the solar system and the conventional heat supply



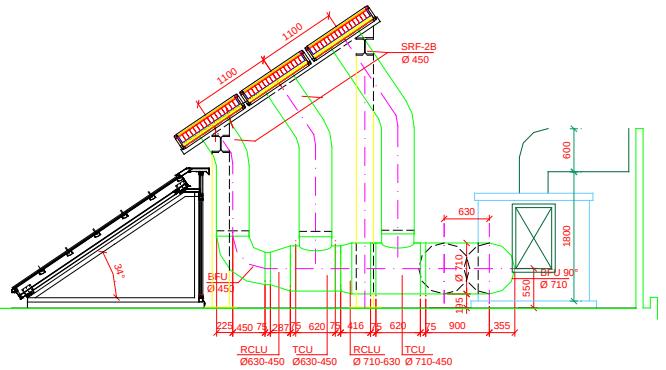
Direct coupling to an industrial process



SOLAR AIR HEATERS

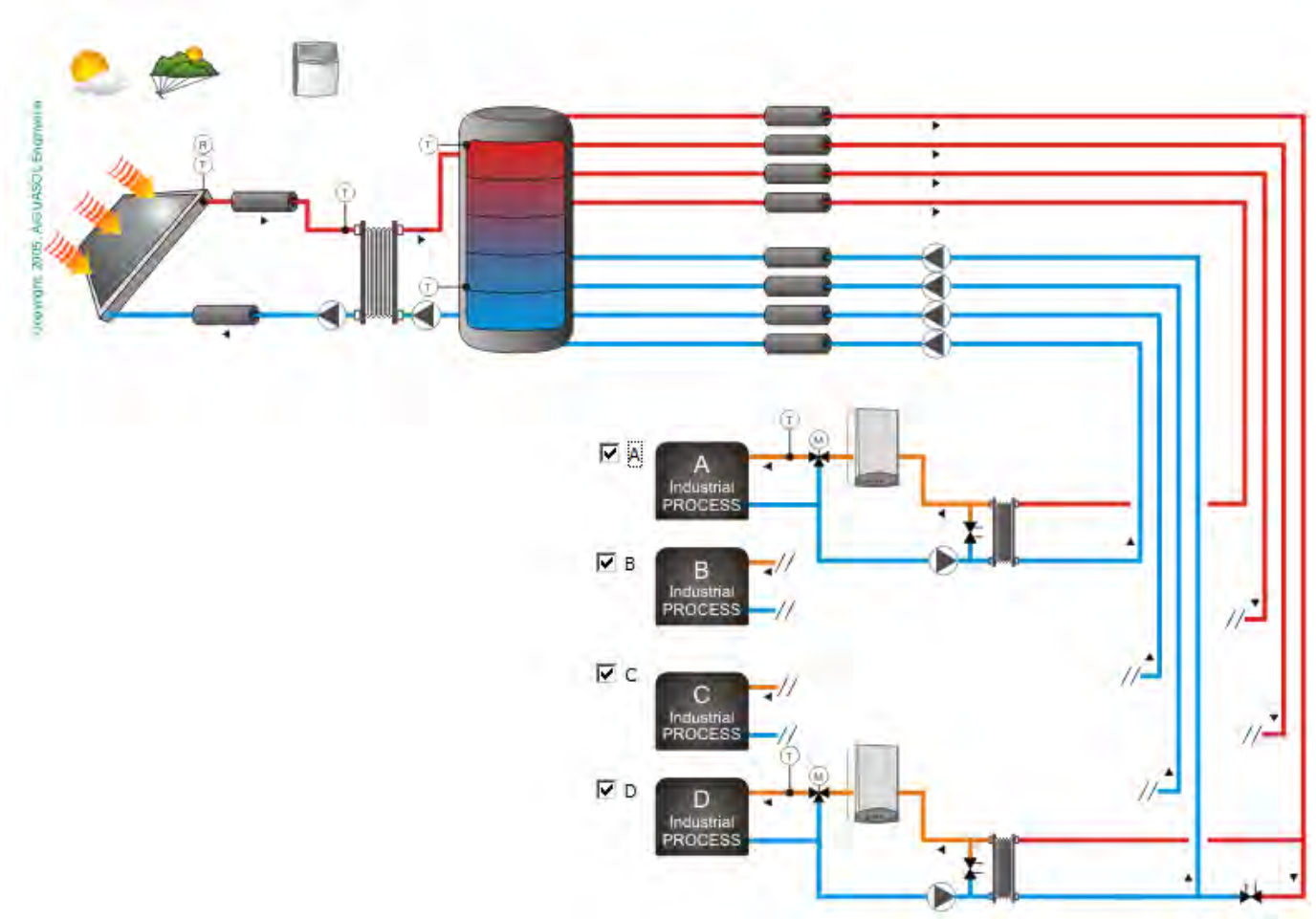


SECTION IN

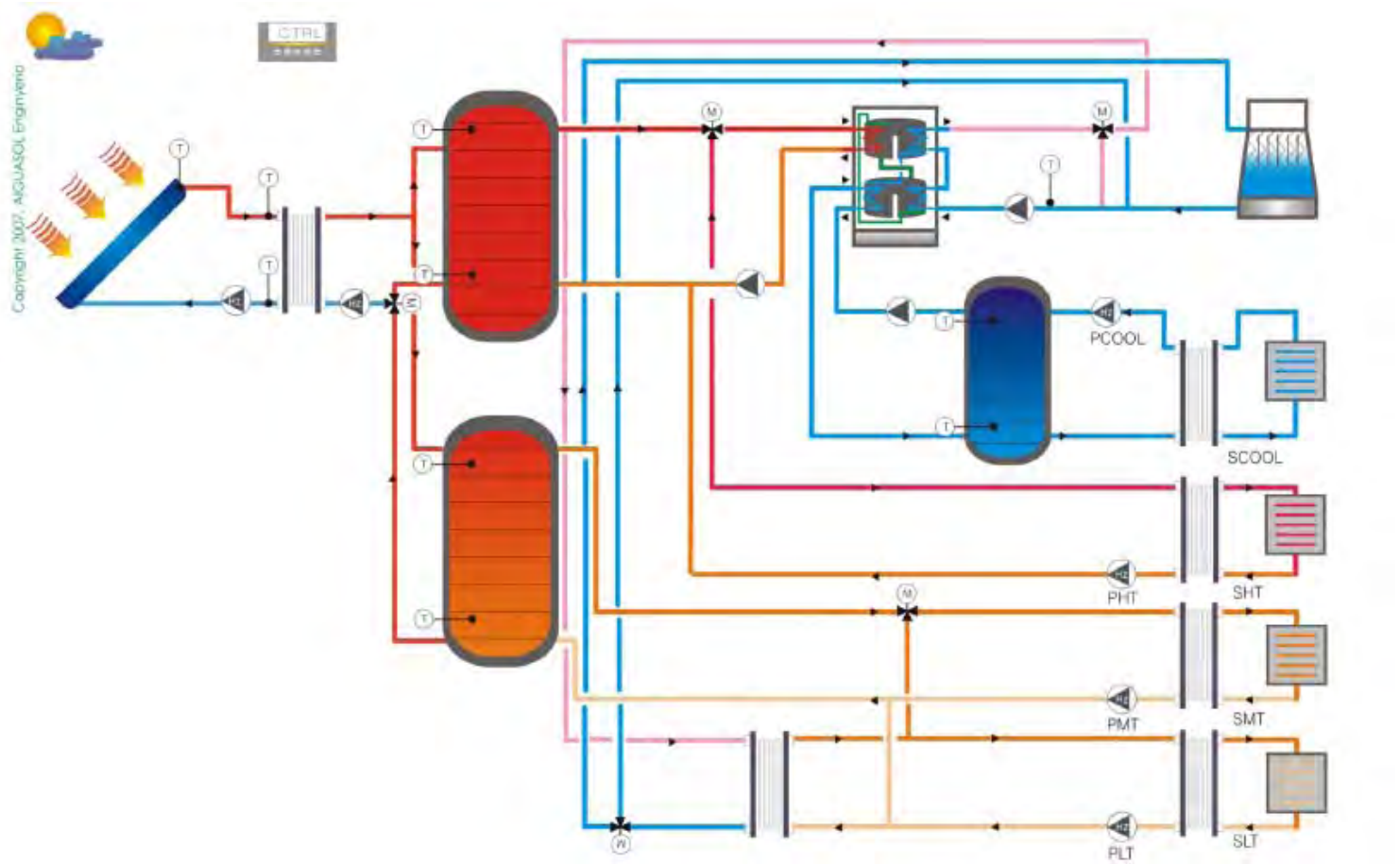


SECTION OUT

SOLAR SYSTEMS CAN COVER DIFFERENT TEMPERATURES!



EVEN COOLING!



- Main concepts
- Potential
- Technologies
- Existing Systems
- And more...

- **INDUSTRIAL SECTORS:**
  - Food industry (breweries, malting, milk)
  - Paper
  - Textile
  - Chemical and pharmaceutical
  - Tanning
  - Cork industry

- **PROCESSES AT LOW AND MEDIUM TEMPERATURE**
  - Hot air for drying
  - Sterilising, pasteurising
  - Distillation and evaporation. Detoxification
  - Desalinisation
  - Washing and cleaning
  - Polimerisation
  - Cold production (absorption cooling)

The industrial sectors showing the higher potential for solar process heat are food, wine and beverage (including breweries), textile, transport equipment (i.e. car washing), paper and part of the chemical sector (up to 250°C).

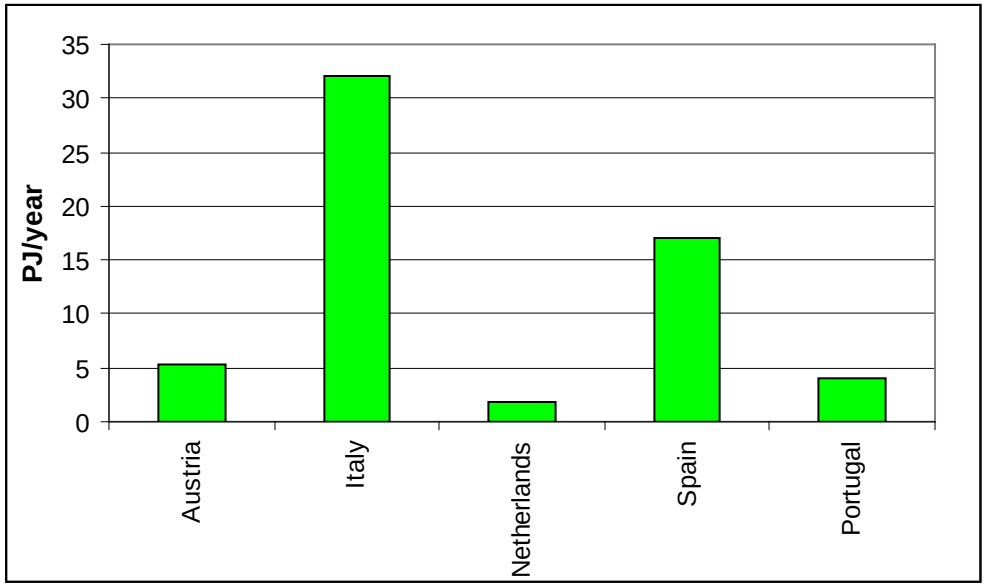
Industry sector	Austria	Iberian Peninsula	Italy	Netherlands	Greece	Germany	Belgium
Food processing	x	x	x	x	x		x
Wine and beverages	x	x	x	x			x
Beer brewing and malt		x	x	x		x	x
Textile	x	x	x	x	x		x
Tanning		x	x		x		
Paper		x	x	x	x	x	x
Tobacco		x	x		x		x
Chemical		x	x		x		x
Transport equipment	x	x	x		x	x	
Other	x				x		x

Overview of the industrial sectors taken into account within different potential studies **(IEA Task33)**

Figure 2. Solar process heat potential [PJ/year].

Country	Industrial final energy consumption in 2002 (Source: Eurostat) [PJ/year]	Industrial heat demand in 2002 (Source: Eurostat[1]) [PJ/year]	Industrial heat demand on total final consumption [%]	Solar process heat potential (including medium temp. application) [PJ/year]	Solar heat on industrial heat demand [%]	Solar process heat potential [Mio m^2]	Solar process heat potential [GW]
Austria	297	220	74.1	5.4	2.4	4.3	3
Spain	1175	841	71.5	17	2.0	10	7
Portugal	243	184	75.6	4	2.2	2.5	1.7
Italy	1652	1136	68.8	32	2.8	15.4	10.8
Netherlands	573	425	74.2	1.5 - 1.95[2]	0.3 - 0.5	0.8 - 1	0.7
Germany	2416	1575	65.2	50	3.2	35	24.5
EU 15	**11372**	**7880**	**69.3**	**199**	**2.5**[3]	**110 - 138**[4]	**77 - 97**
EU 25	**12964**	**9145**	**70.5**	**230**	**2.5**[10]	**128 -160**[11]	**90 - 112**

Industrial energy demand and solar process heat potential for individual Countries and for EU **(IEA Task33)**



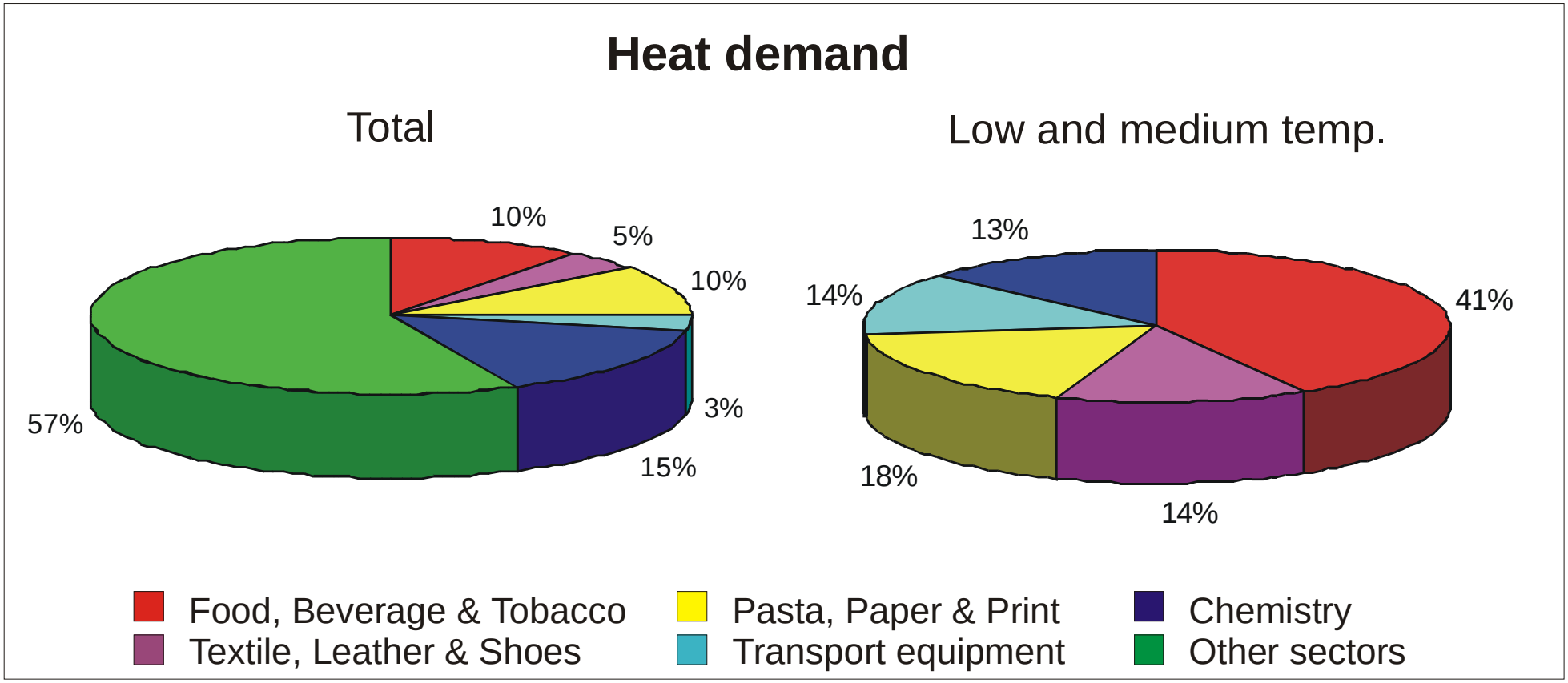
Solar process heat potential [PJ/year].

Industrial Sectors	TWh
Food, beverage and tobacco	1.4
Textile,Leather and shoes	0.4
Paper	1.6
Transport equipment	0.6
Chemistry*	0.8

** Estimated: no case studies available*

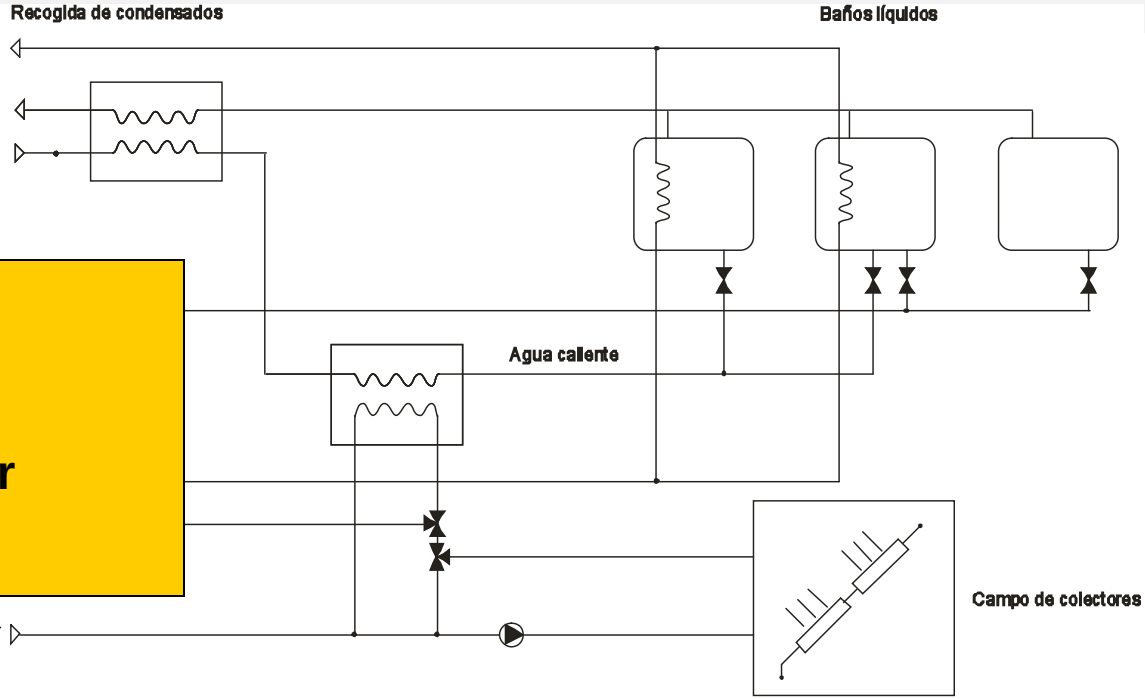
Potential for solar process heat in Spain by industrial sector. Data in TWh/year

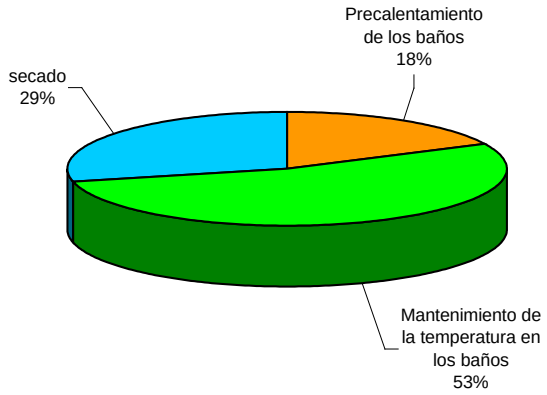
- Low (<60ºC) and medium (<160ºC) temperature heat demand in Spain



Example: Fibracolor (Girona). Textile industry

Preheating of hot water for baths (washing, bleaching, dying)
Temperature: < 90 ºC
Continuous demand: 8000 hrs / yr

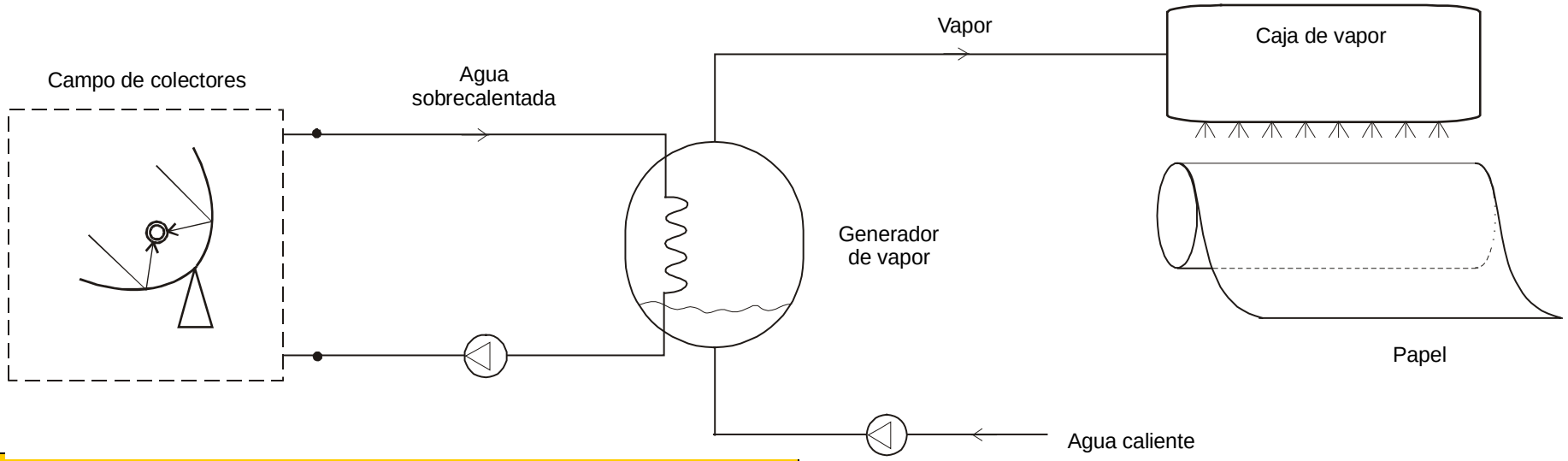




Other processes:

- **Bath heating (substitution of vapour)**
- **Drying processes (hot air from 140 to 220 ºC)**

Example: Kimberley & Clark (Salamanca). Paper industry

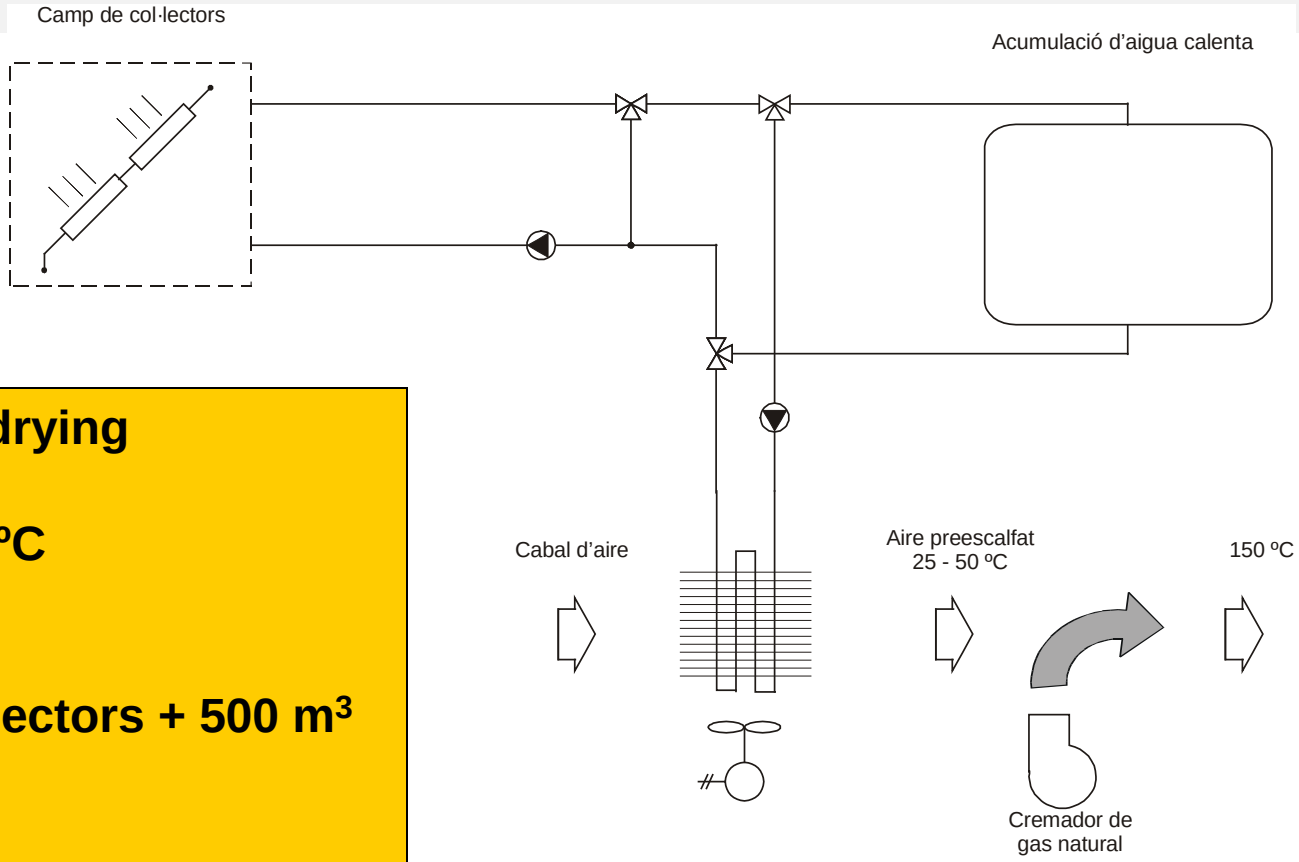


Vapour for heating of paper

Temperature: 135 ºC
Continuous demand: 7 days/week.

1000 m^2 parabolic trough collectors
Energy saving: 500 kWh/m^2

Example: Promic (Vic, Barcelona). Animal food



Preheating of air for drying

Air temperature: 150 ºC
6 days/week

2000 m² flat plate collectors + 500 m³ storage (sundays)

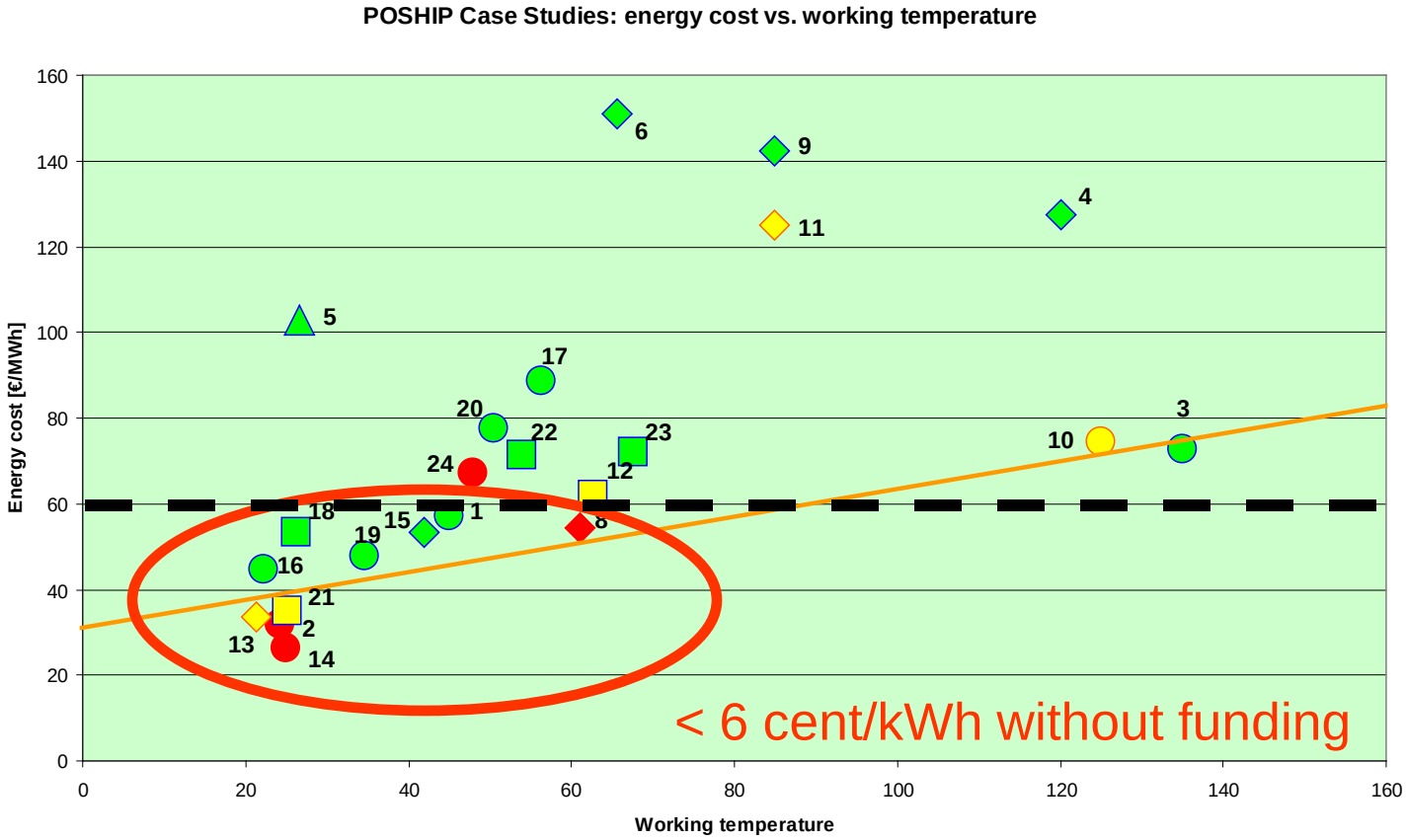
750 kWh/m², pay-back 7 years

Solar fraction: 11 %

Solar process heat: evaluation criteria

Evaluation criteria

- Continuity of the heat demand
- Working temperature
- (heating-preheating)
- Climatic conditions
- System size

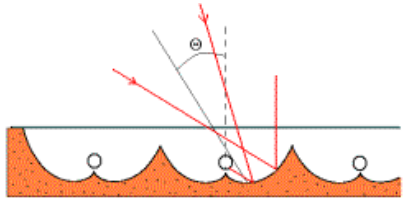


Solar heat costs for the systems studied
Colors: solar radiation in kWh/m2: > 1750 (red), 1600 – 1750 (yellow), 1400-1600 (green)
Symbols: continuous demand (circles), continuous 5 days / week (rombs), seasonal(triangles).

- Mains concepts
- Potential
- Technologies
- Existing Systems

- Air collectors
- Flat Plate Collectors (FPC)
  - High selective surfaces (TiNOX, Sunselect etc.)
- Evacuated Tube Collectors (ETC)
  - Including CPC reflector
- Evacuated Flat Plat Collector (EFPC)

- Concentrating Parabolic Collectors (CPC)

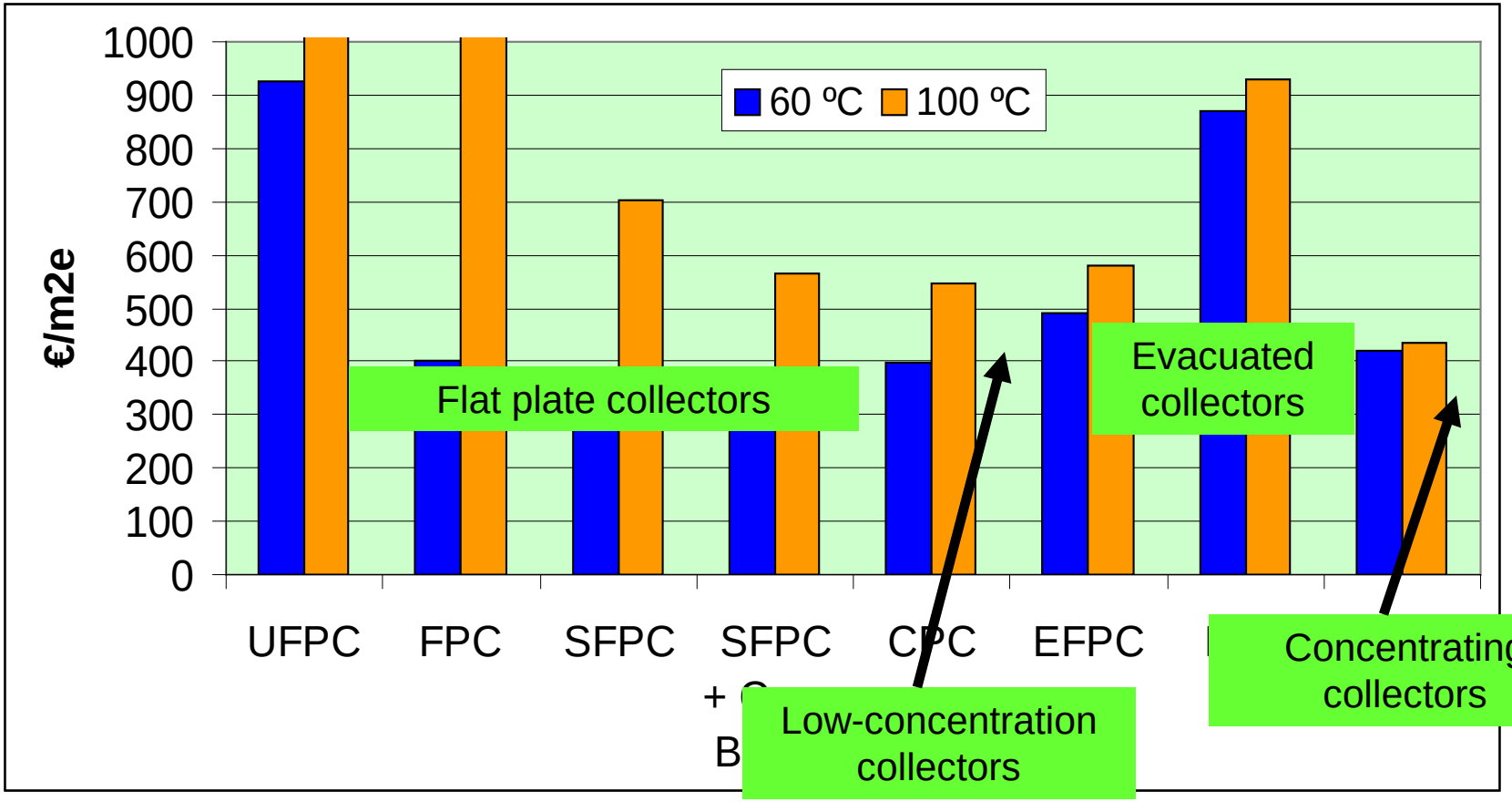


- FPC with anticonvective barriers
  - Teflon Film
  - Transparent Insulation (TIM)

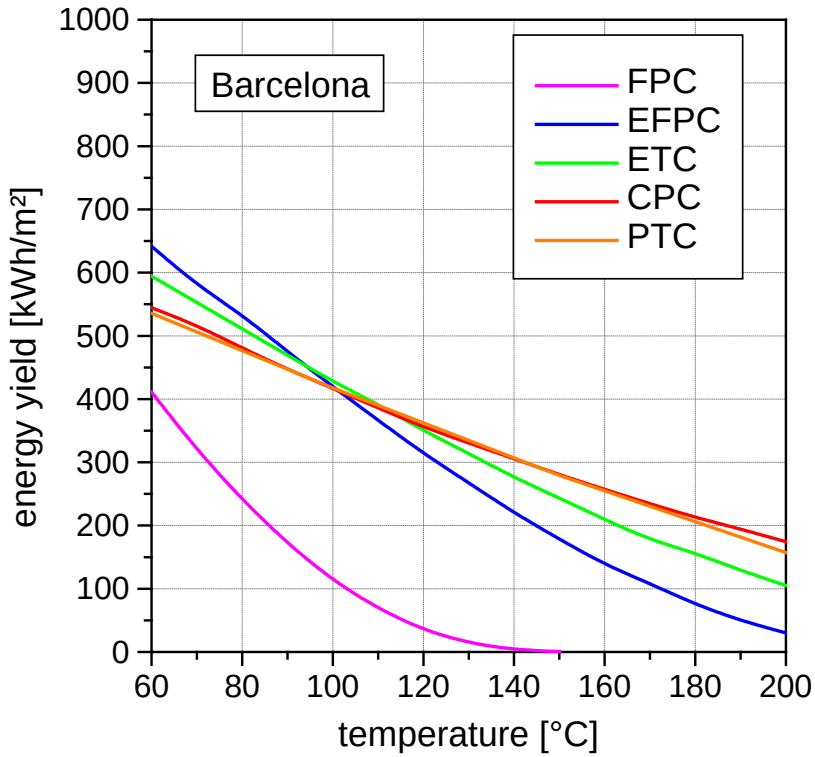
- Parabolic Trough Collectors (PTC):
  - IST (EE.UU.)
  - LS-3 (SOLEL, Israel)
  - Sopogy (EE.UU.)
  - PEurotrough (Synthesis Solar, Alemania)
  - Direct Steam Generation (DISS)
  - …

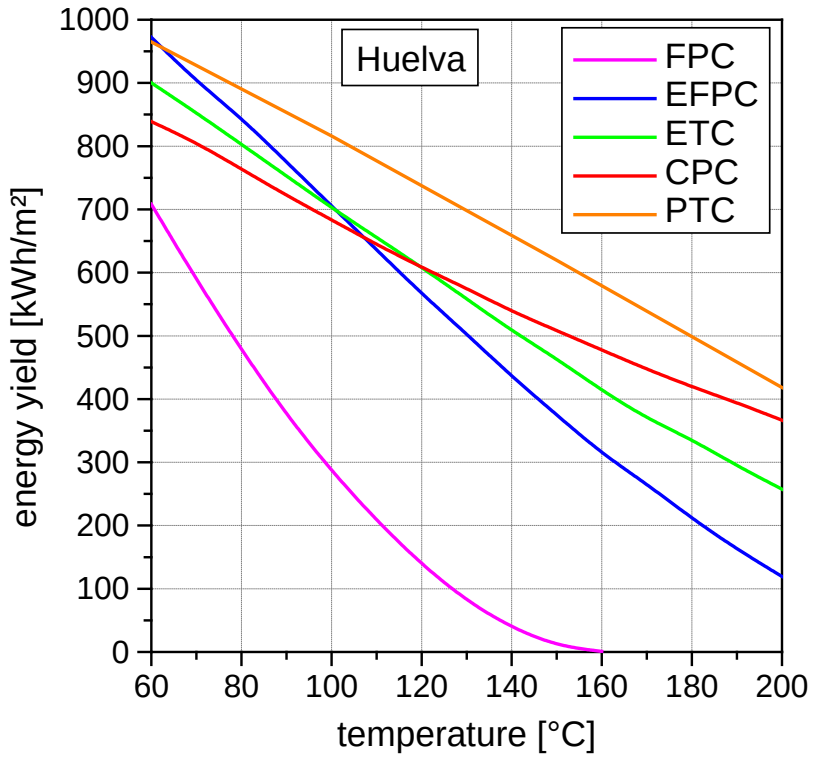
- Fresnel Collectors
  - PSE-Miroxx
  - CCSTAR
  - AIRA
  - …

Collectors Technology (3): Cost Comparison

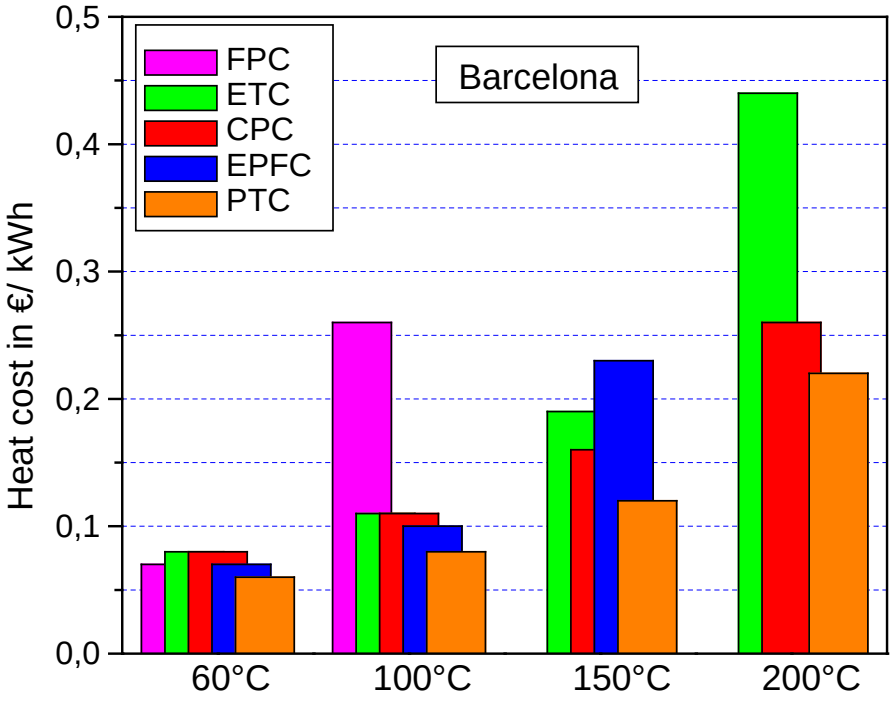


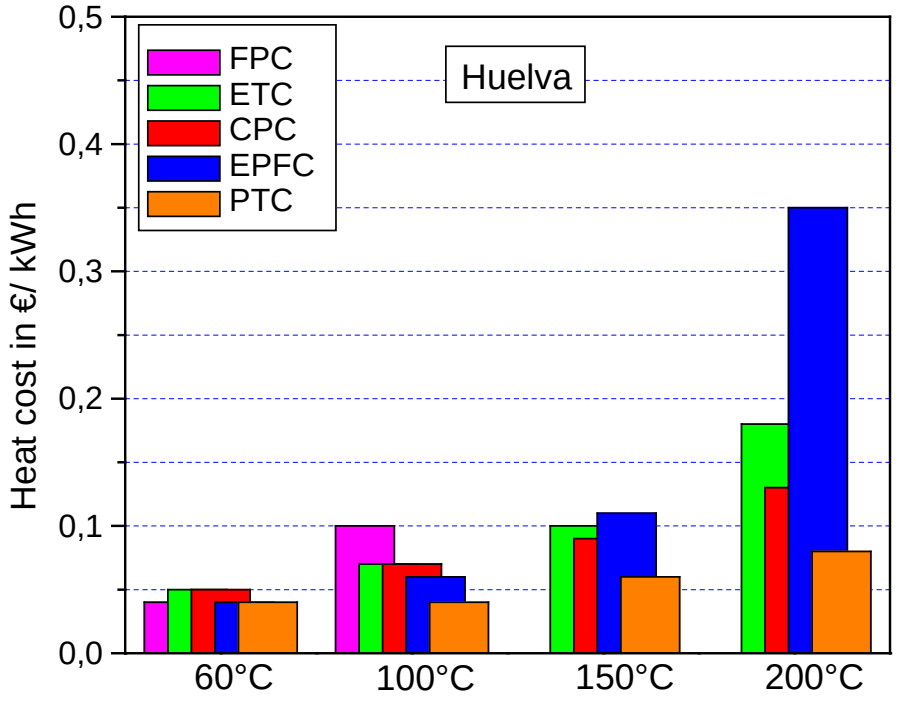
Solar gains (useful heat)
Comparison of collectors





Resulting energy cost (useful heat)
Comparison of collectors





- Mains concepts
- Potential
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- Existing Systems
- And more...

- 92 solar systems have been identified in 20 different countries with a total equivalent power of 41,6 MWth

- 50% of plants are previous to year 2.000

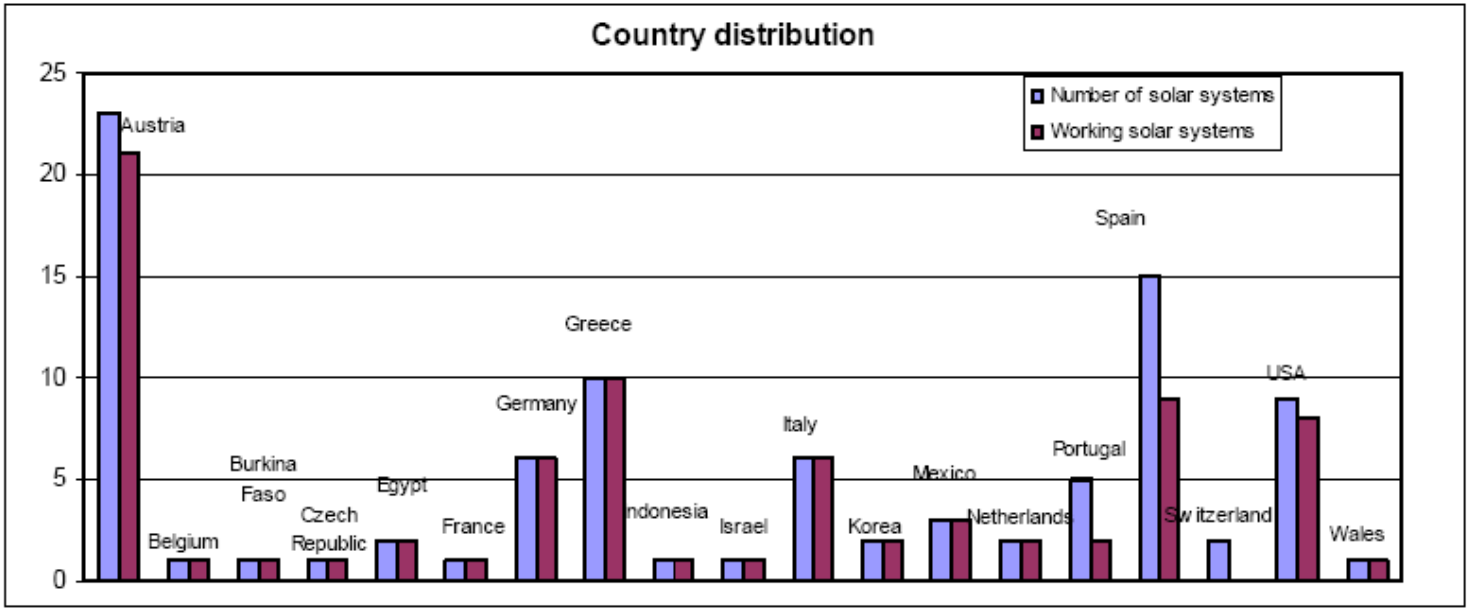

Figure 2. Solar industrial process heat plants reported within Task 33/IV - SHIP: distribution by Country. Number of projects: (a) total and (b) plants in operation. State: March 2006.

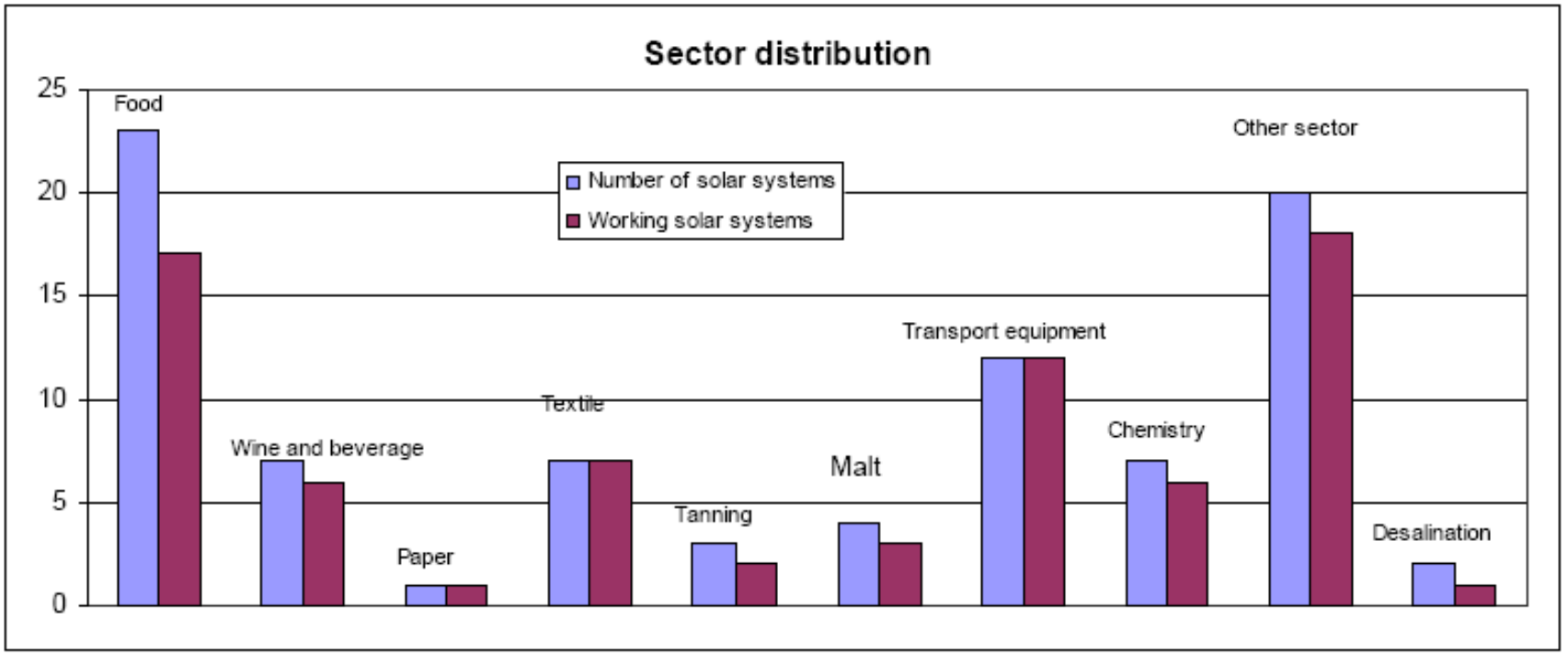

Figure 4. Solar industrial process heat plants reported within Task 33/IV - SHIP: distribution by industrial sector. Number of projects: (a) total and (b) plants in operation. State: March 2006.

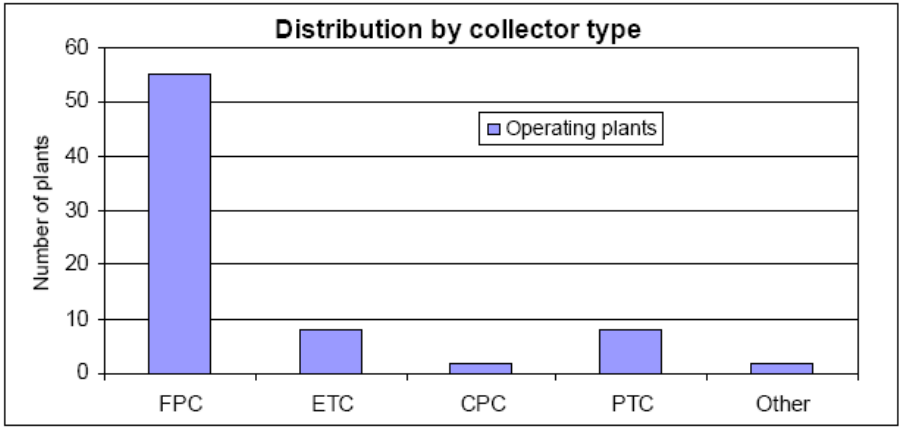

Figure 6. Solar industrial process heat plants reported within Task 33/IV - SHIP: distribution by solar collector type. Plants in operation. State: March 2006

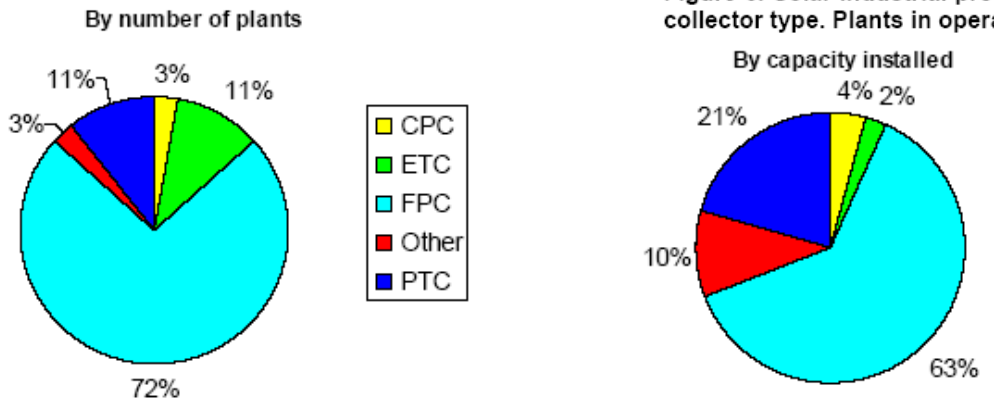

Figure 7. Solar industrial process heat capacity installed as reported within Task 33/IV – SHIP. Share by solar collector type: number of projects in percentage (left side) compared to the capacity installed (right side). Plants in operation. State: March 2006

- **Technologies and temperature level distribution**

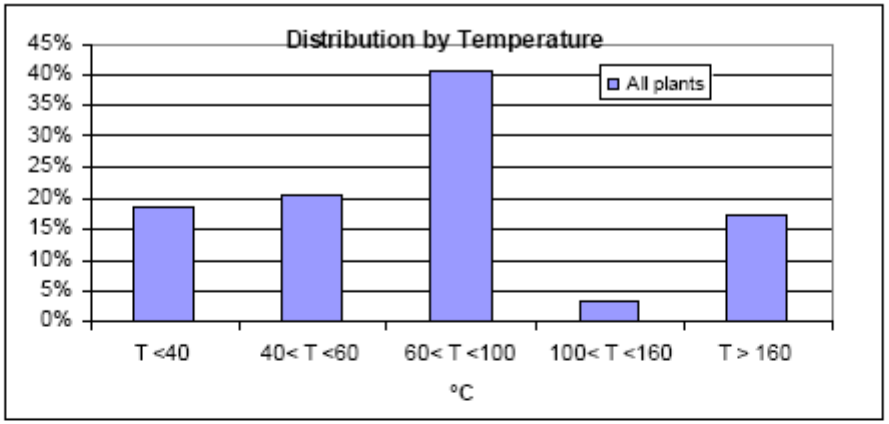

Figure 11. Solar plants reported to Task SHIP: distribution by working temperature (outlet temperature from solar system to load). Plants in operation and shutdown. State: March 2006.

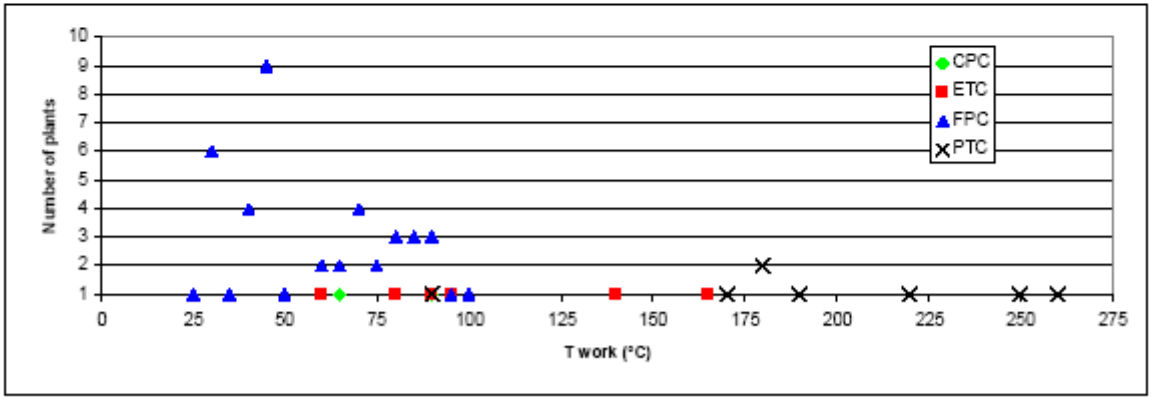

Figure 12. Solar plants reported to Task SHIP: correlation between the type of collectors and the working temperature (outlet temperature from solar system to load). Plants in operation and shutdown. State: March 2006

- **Lessons learnt from plants in operation**
  - Up to now, the information available on the operational behaviour of the reported plants are very scarce.
  - For very few projects the following failures and operating problems have been reported:
    - Automatic control failures
    - Low flow rate and inadequate level of antifreeze in the primary circuit
    - De-aeration problems in the solar circuit,
    - Hydraulic circuit (e.g. long distance between the solar plant and the storage, scarce insulation of the pipes)
    - Heat losses in storage tanks and in heat exchangers
    - Inadequate level of maintenance (dirty glasses, deposition of material from exhaust gasses on collectors' glasses)
    - Control of the tracking systems.

CONTANK, Transport equipment

Company name: Parking Service S.A.
Location: Castellbisbal

Information on the process

Industrial sub – sector: Car and lorry washing
Industrial process: Car washing, degreasing
Working temperature [°C]: 20÷80

General information on the solar system

Year of construction: 2004
Designer and/or installer: AIGUASOL
Installed thermal capacity [kW]: 357 (510 m²)
Collector type: Flat plate collector (Sonnenkraft)
Storage tank [m^3]: 40
Storage tank volume/Solar collector area (V/A) [lt/m^2]: 78.4
System concept: SPOHX water ???

Performance of the solar system

Annual useful solar heat [MWh/a]: 429
Annual specific useful solar heat [kWh/kW*a]: 1201.68 (840 $kWh/m^{2*}a$)
Solar fraction [%]: 22
Technical problems or failures: n.a.

Economics

Total investment cost [€]:268,546
Total cost per kW installed [€/kW]: 752 (527 €/ m^2)
Co – financing [€ or %]: 48% (IDEA/ICAE)

Data source: *AIGUASOL*

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MAFRICA
SLAUGHTERHOUSE(Spain)

Heating of water to 70ºC

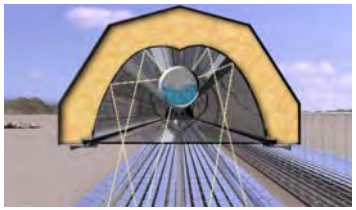
Collectors: 600 m2 Fresnel (increasing to 3000 m2)

Colectors: 70-90°C

Investment: 90k€

Year: 2010

Source: aiguasol



Fratelli Rizzi (Verona)

Industrial sector: wine (hot water and space heating)

Temperature: 35-60 °C

Potència instal·lada : 42kW (60m²)

Collectors : Evacuated tube CPC

Solar production: 517kWh/m².any

Solar fraction: 20% (heating)

Solar fraction : 70% (hot water)

Source: Kloben

Plant:	**AQUINOVA**
Location:	**Huelva (Spain)**
Solar field:	**1316 m2 (flat plate)**
Process:	**Fish farm (water heating)**
Working temp.:	**30 – 40 ºC**
Source:	**SODEAN**

INTEGRACIÓ DE RENOVABLES:
b Integrables, Solar Tèrmica

Plant:

TE-PE S.A.

Location:

Sevilla (Spain)

Solar field:

260 m2 (flat plate)

Process:

Water heating (olive production)

Working temp.:

50 – 60 ºC

Source:

SODEAN

Plant:

Tyras

Location:

Trikala (Greece)

Solar field:

1040 m2 (flat plate)

Process:

dairy

Working temp.:

80 ºC

Source:

CRES /

Solenergy Hellas SA

INTEGRACIÓ DE RENOVABLES:
b Integrables, Solar Tèrmica

Plant:

El NASR

Location:

Egypt

Solar field:

1900 m2 (parabolic trough)

Process:

Saturated steam (173 ºC/8bar) for processes in the pharmaceutical industry

Working temp.:

173 ºC

Source:

Fichtner Solar GmbH

Plant:

SODESA

Location:

Pozo Izquierdo, Gran Canaria (Spain)

Solar field:

48 m2 (flat plate)

Process:

Sea water desalination

Working temp.:

20 – 95 ºC

Source:

Fraunhofer ISE

Plant:

SARANTIS

Location:

Oinofita Viotias (Greece)

Solar field:

2700 m2 (flat plate)

Process:

Solar cooling in cosmetics industry

Working temp.:

90 ºC

Source:

CRES / SOLESA

Plant:

BRISA

Location:

Carcavelos (Portugal)

Solar field:

663 m2 (CPC)

Process:

Space heating and cooling

Working temp.:

80 ºC – 90 ºC

Source:

AO SOL Ltda.

NEFERIS WINERY (Tunisie)

Cooling of 23 tanks

Cooling power: 13 kWf

Collectors: 88 m2 Fresnel

Temperature: -5, 5°C

Colectors: 120-180°C

Investment: 120k€

Year: 2008

Source: POLIMI

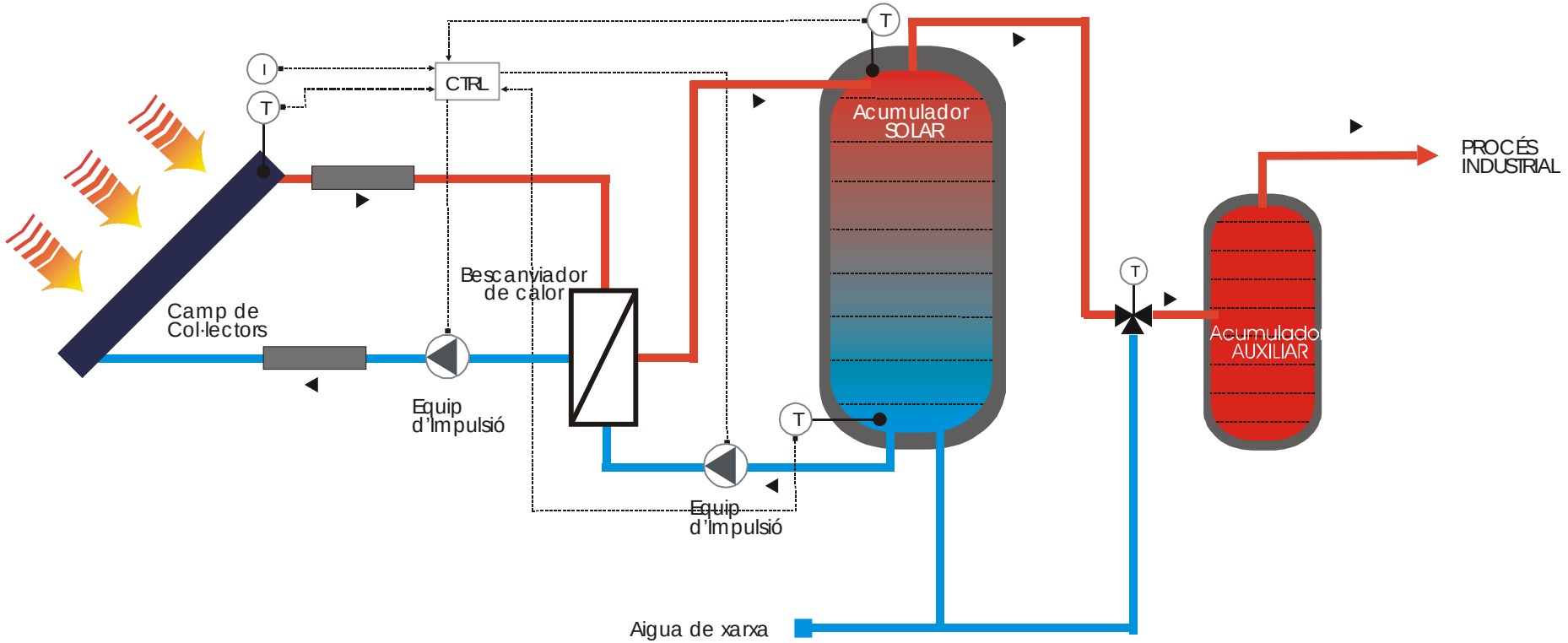
PARKING SERVICE solar process heat plant

APPLICATION

- Hot water (60ºC) for container washing
- Industrial sector: transport equipment
- Heat demand: 1990 MWh/year
- 70 – 80 m^3 / day, 5,5 days/week

PARKING SERVICE solar process heat plant
Plant scheme

Solar storage in serial connection with storage for auxiliary heating



PARKING SERVICE solar process heat plant
Technical data

- **Selective flat plate collectors**
- **Solar collector field: 357 kW (510 m^2)**
- **Inclination: 25 º (/horiz.)**
- **Orientation: -24 º (/south)**
- **Solar storage: 40 m^3 (78,4 l/m^2)**
- **Collector flow rate: 17 l/m^2h**
- **Auxiliary heating: steam boiler**

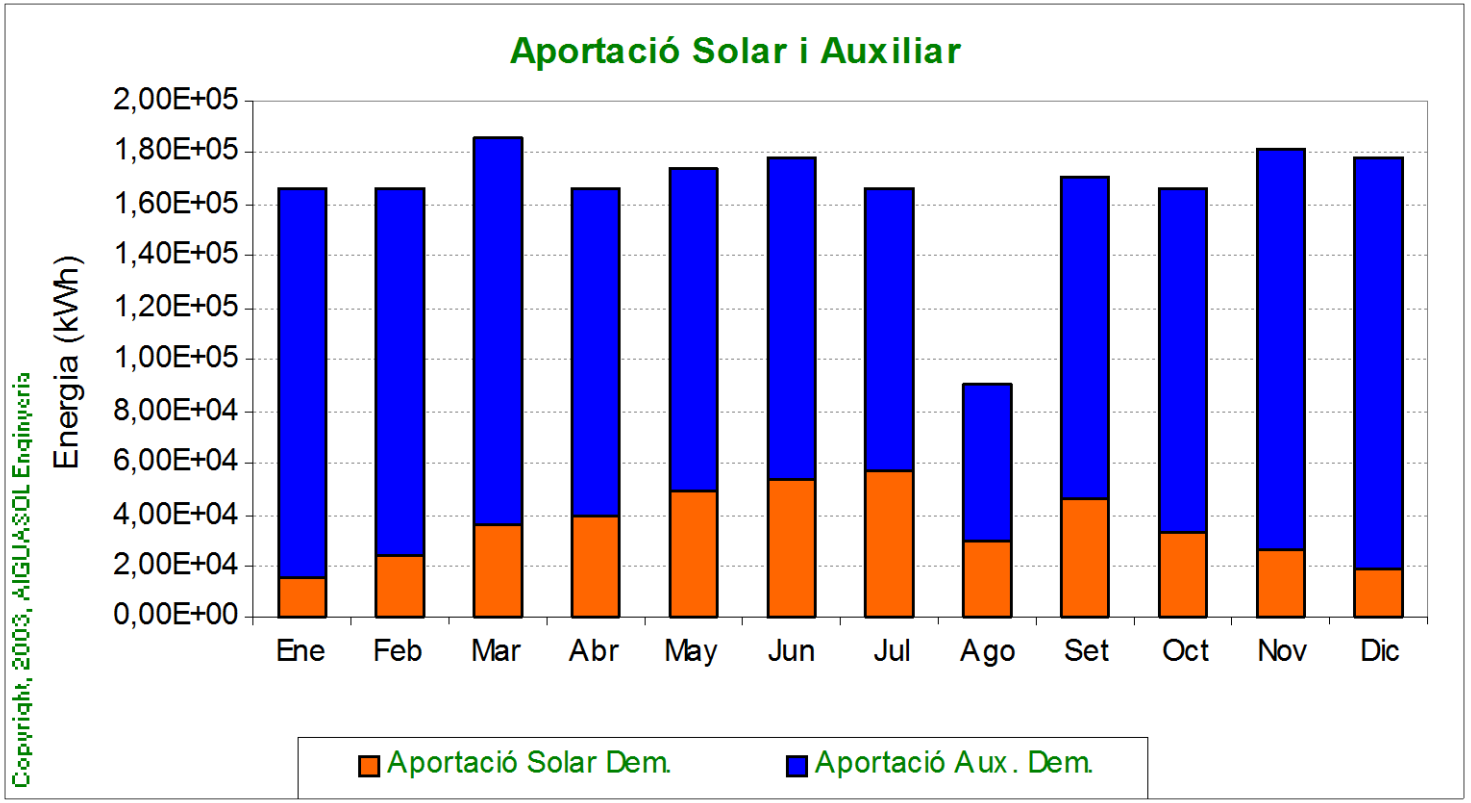
Investment cost : 268.545,92 €

Project co-financed by IDAE, ICAEN

PARKING SERVICE solar process heat plant
Design details

- Non pressurized storage (without expansion vessel -> cost reduction)
- Low flow system: less installation cost <-> very small loss of efficiency
- Low inclination of collectors: 25º (compromise between optimum output per unit area and optimum use of available roof space)
- Anti-legionella protection: serial connection with auxiliary storage above 70 ºC, chemical treatment
- Dynamic simulation with the Aiguasol software TRANSOL (based on TRNSYS)
- $\Delta T = 16 – 17$ K

PARKING SERVICE solar process heat plant
Energy balance (simulation)



- **Useful solar heat: 429 MWh/yr**
- **Solar fraction: 21,6 %**
- **Useful heat per collector area: 840 kWh/ m^2 . yr**

- Main concepts
- Potential
- Technologies
- Existing Systems
- And more...

FOUR BIG PILLARS OF SOLAR THERMAL SYSTEMS FOR PROCESSES

METEOROLOGY

WE HAVE VERY GOOD CONDITIONS FOR THE INSTALLATION OF THESE SYSTEMS!

TECHNOLOGY (LOCAL TECHNOLOGY)

One of the biggest advantages of solar thermal technology is the use of local technology (neither very machine-intense nor very energy-intense manufacture processes)

-> development of low cost solar collectors for medium temperature

CUSTOMER'S PROFILES AND NEEDS

Only certain demand profiles can cope with solar thermal technology, but they are significantly important in our coutries (yesterday in the presentations some of you showed how significant is your primary sector)

POLICIES

WE NEED TO ESTABLISH POLICIES IN VARIOUS LINES TO ALLOW THE DEVELOPMENT OF A GOOD MARKET

... and where should we go ?

- ***Demonstration plants***

  Limited possibility to develop projects by national funding only

  -> A concerted programme for large-scale solar systems ?

  Virtuous circle: large systems -> stimulation of demand -> reduction of system cost and improvement of quality (industrial-scale production, qualifiaction of installers, ...).

- ***RTD***

The REAL potential for solar process heat is at medium and high temperature:
heating after waste heat recovery, solar cooling, solar thermal electricity

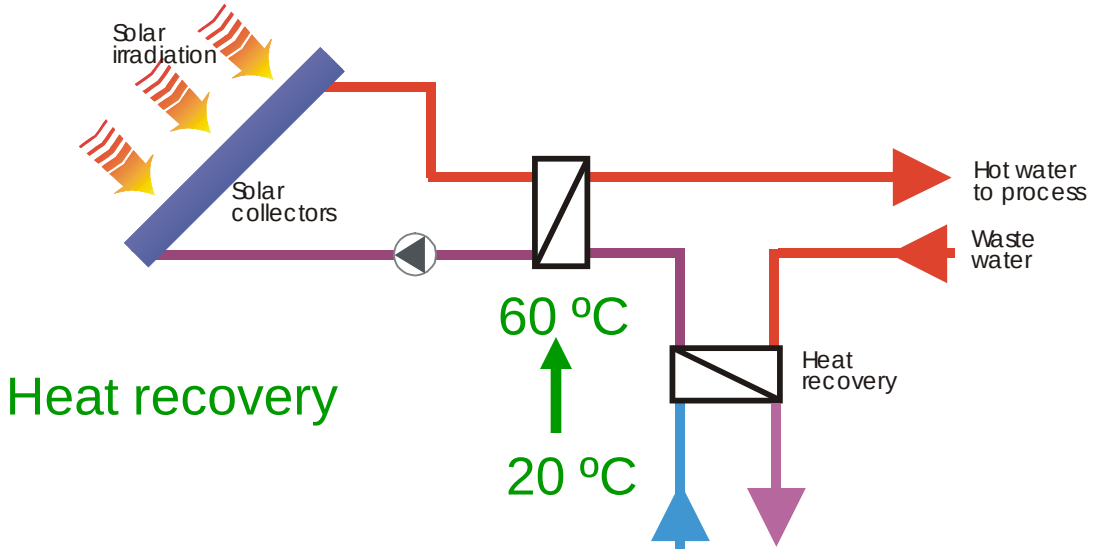
-> demonstration plants for medium temperature systems
-> development of low cost solar collectors for medium temperature

Where to go – low or medium temperature ... ?

Energy costs for medium temperature systems (> 60 ºC) are higher

But ... The best way to cover the low-temperature heat demand is (nearly) always: heat recovery (waste water, exhaust air,...) by heat exchangers or heat pumps

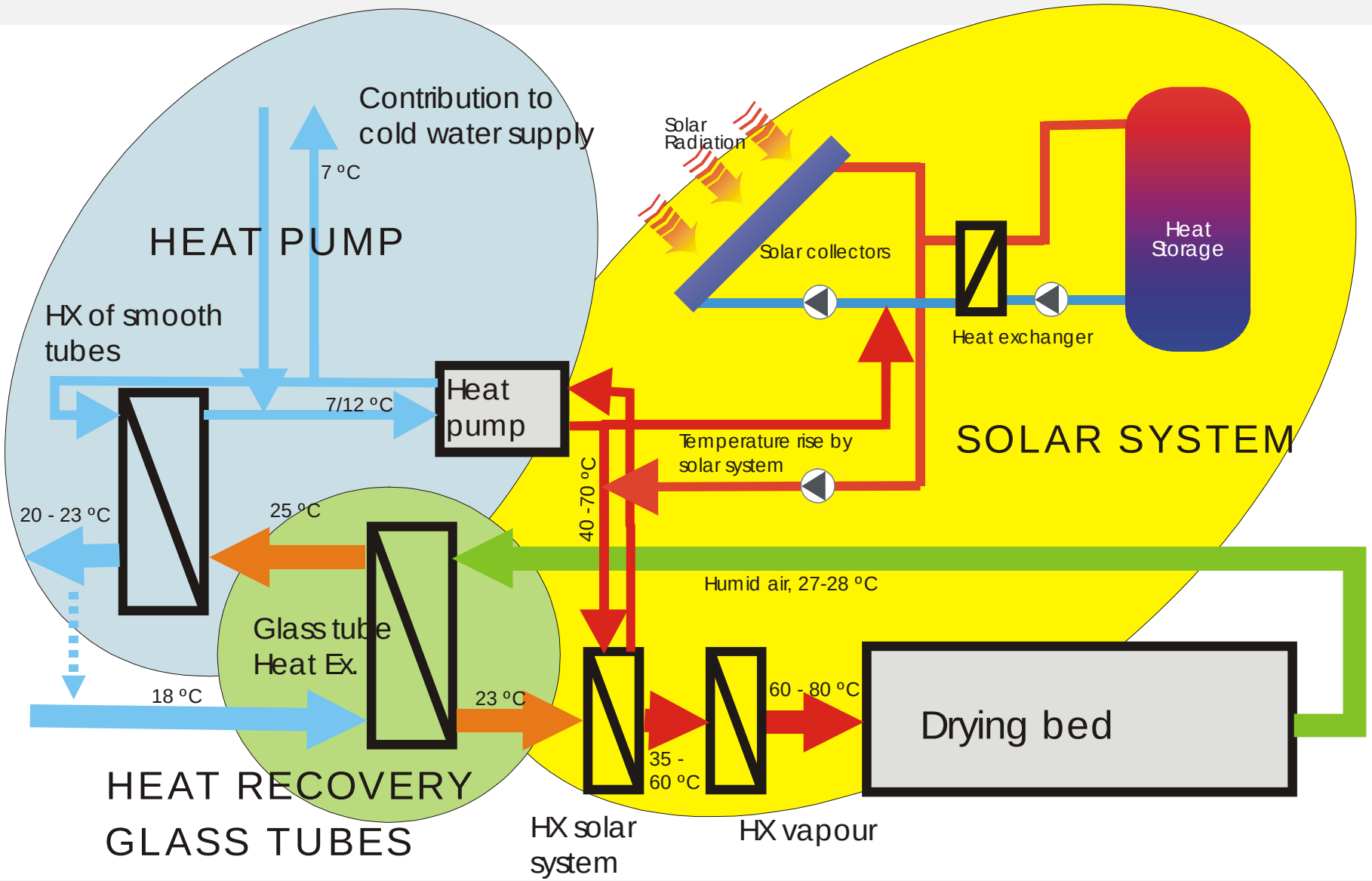
-> The REAL potential for solar thermal applictions is for T > 60 ºC ?



... and where should we go ?

¿ Are solar systems always the best way to save energy ?

-> INTEGRAL SOLUTIONS required considering solar thermal, waste heat recovery, cogeneration and possible improvements in the processes


Contribution to cold water supply
7 ºC
HEAT PUMP
HX of smooth tubes
7/12 ºC
Heat pump
Solar Radiation
Solar collectors
Heat exchanger
Heat Storage
SOLAR SYSTEM
Temperature rise by solar system
40 - 70 ºC
20 - 23 ºC
25 ºC
Humid air, 27-28 ºC
Glass tube Heat Ex.
18 ºC
23 ºC
35 - 60 ºC
60 - 80 ºC
Drying bed
HEAT RECOVERY GLASS TUBES
HX solar system
HX vapour

aiguasol

THANKS FOR YOUR ATTENTION

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