

# Examples of application of solar thermal plants in industry

**Process heat integration**

Stand: 06.03.2008

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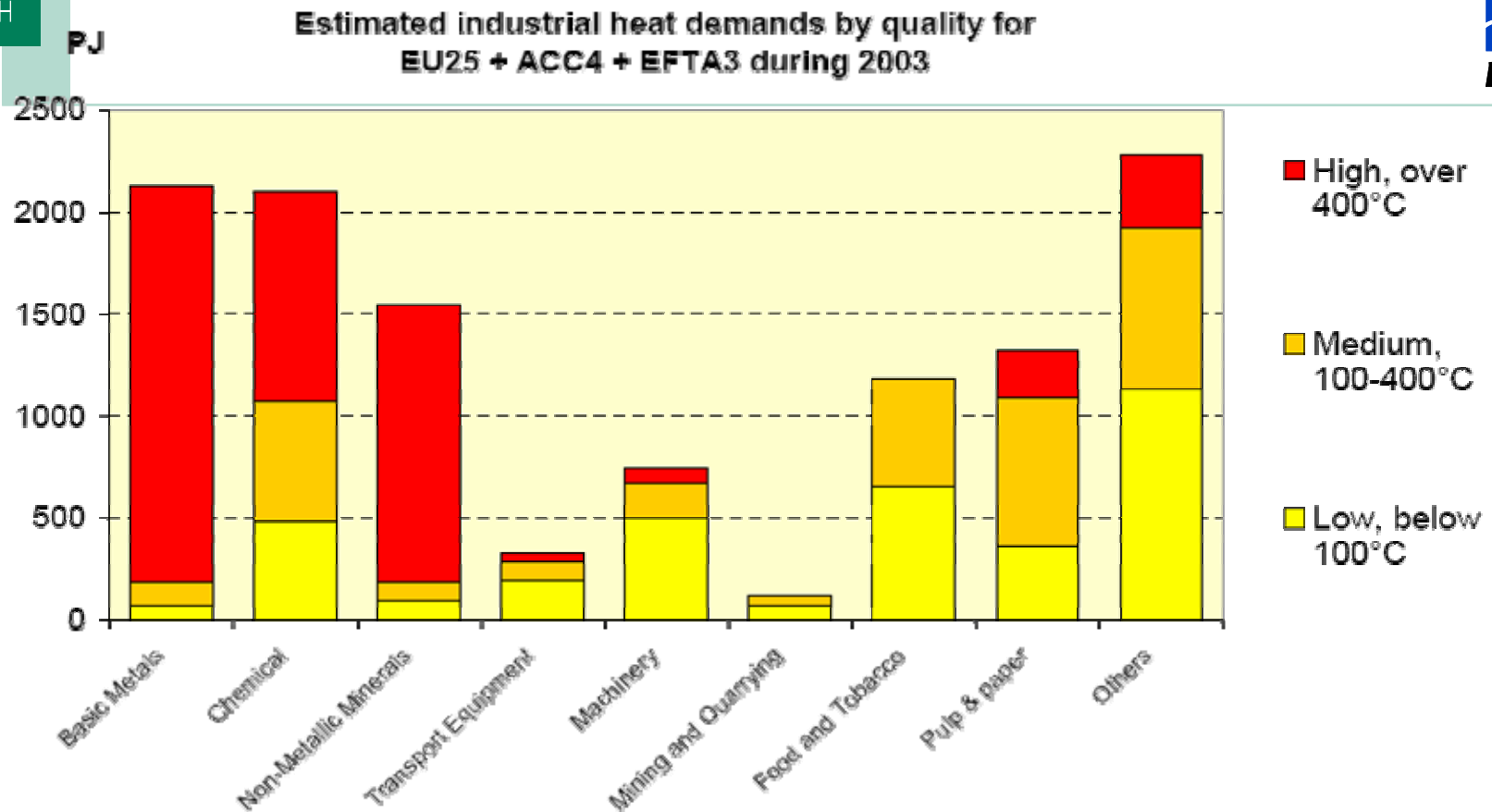
# Zero effect on Climate change

- **Production without energy consumption will never be possible**
- **ZEEs have to concentrate on the “ZERO EFFECT” of gaseous emissions:**
  - ➔ minimize energy consumption
  - ➔ use renewable forms of energy

# There are many ways to a reduction of energy (costs)

- Heat recovery, heat exchangers
- High efficient boilers
- Improved maintenance
- Improved control strategies
- Cogeneration of heat and power
- New technologies
- .....
- Solar heat

Solar thermal energy has to be integrated carefully in order to be economic



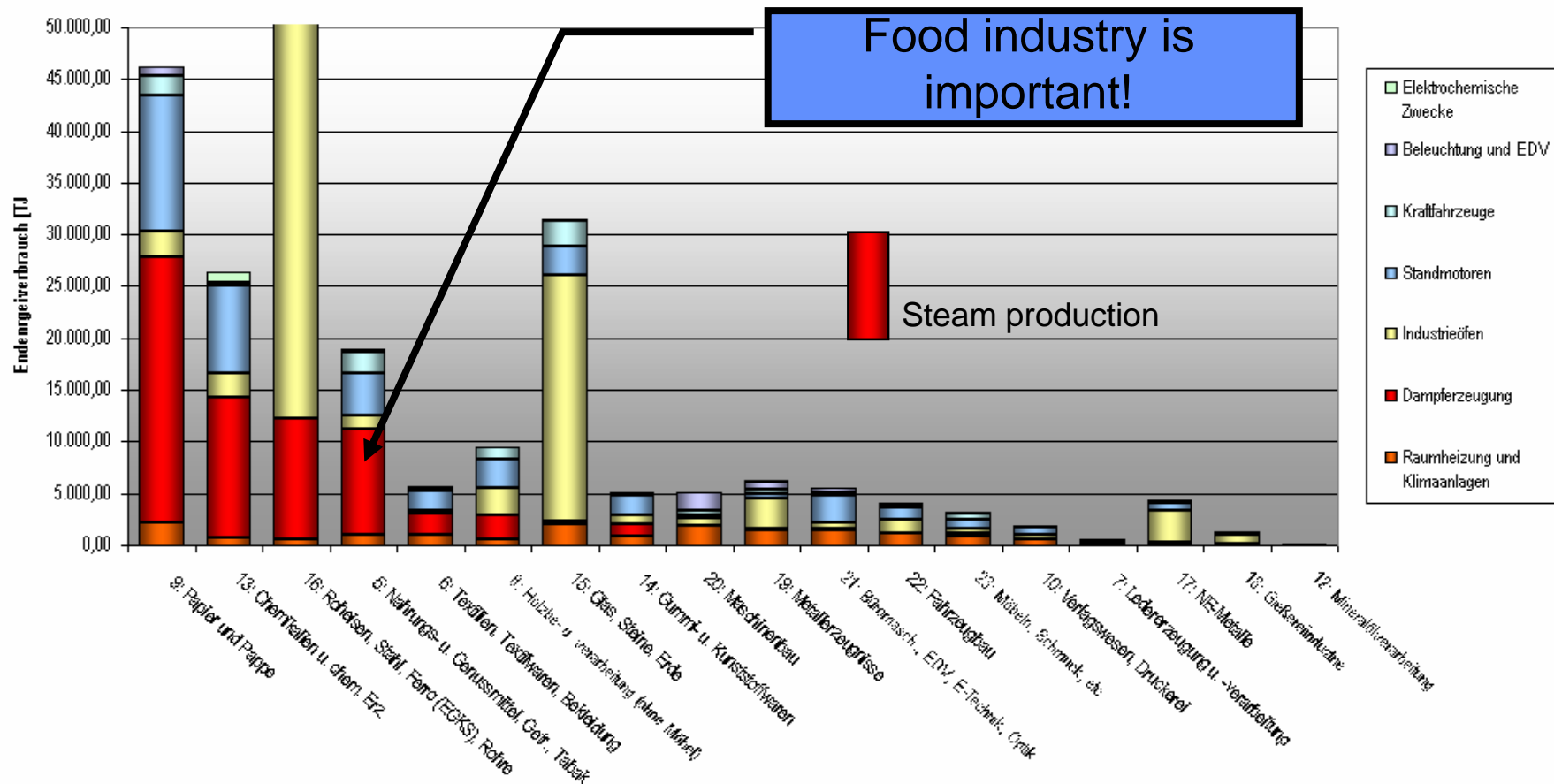
Source: ecoheatcool, final report, 2006

**Figure 7. Industrial heat demands estimated by temperature quality and by manufacturing branch for the whole target area of 32 countries. The figure has been created by using experiences from the German industry reported in (AGFW, 2005) and applied on the IEA database for the target area.**

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# Energy demand for industry in Austria

(Source: Statistik Austria)



# Typically benchmark data do not include temperatures

All consumption figures are expressed in kWh (1 kWh =  $3.6 \times 10^3$  kJ = 860 kcal).

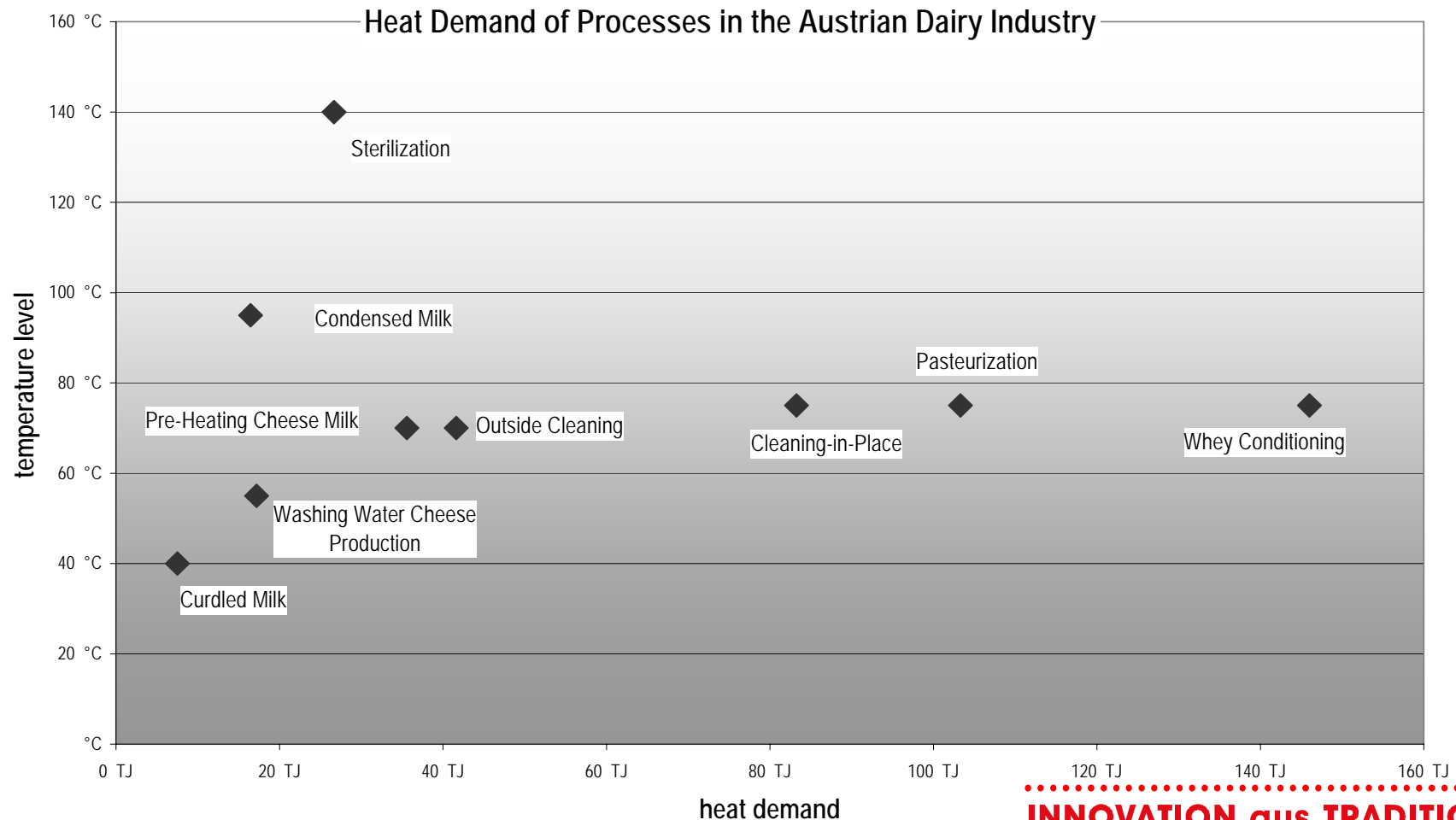
Table 1. Specific energy requirement in modern milk processing plants										
Type of service	Unit	Requirement-including CIP for one ton of milk processed into:								
		Liquid products in bottles		Liquid products in one-way containers		Skim milk powder and butter	Full cream milk powder	Ripened cheeses		Evaporated and condensed milk
		pasteurized	sterilized	pasteurized	UHT			Without whey processing	with whey processing	
Net requirement										
Steam	kg/t	250	300	100	150	880	830	190	700	440
Refrigeration total energy equivalent	kWh/t	50	40	50	40	60	45	70	70	45
Refrigeration electric power requirement	kWh/t	20	16	20	16	24	18	28	28	18
Heating	kWh/t	165	200	70	100	585	530	125	460	295
Electric power (total requirement)	kWh/t	55	70	50	90	90	80	75	100	60
TOTAL NET REQUIREMENT	kWh/t	220	270	120	190	675	610	200	560	355
Gross energy requirement										
For heating (furnace fuel)	kWh/t	205	250	90	125	730	660	155	575	370
For electric power generator fuel)	kWh/t	195	250	180	315	315	280	265	350	210
TOTAL GROSS REQUIREMENT	kWh/t	400	500	270	440	1,045	940	420	925	580
% of energy in steam in total requirement	%	75	74	58	53	87	84	63	82	83
% of energy in furnace fuel in total gross requirement	%	51	50	33	28	70	70	37	62	64

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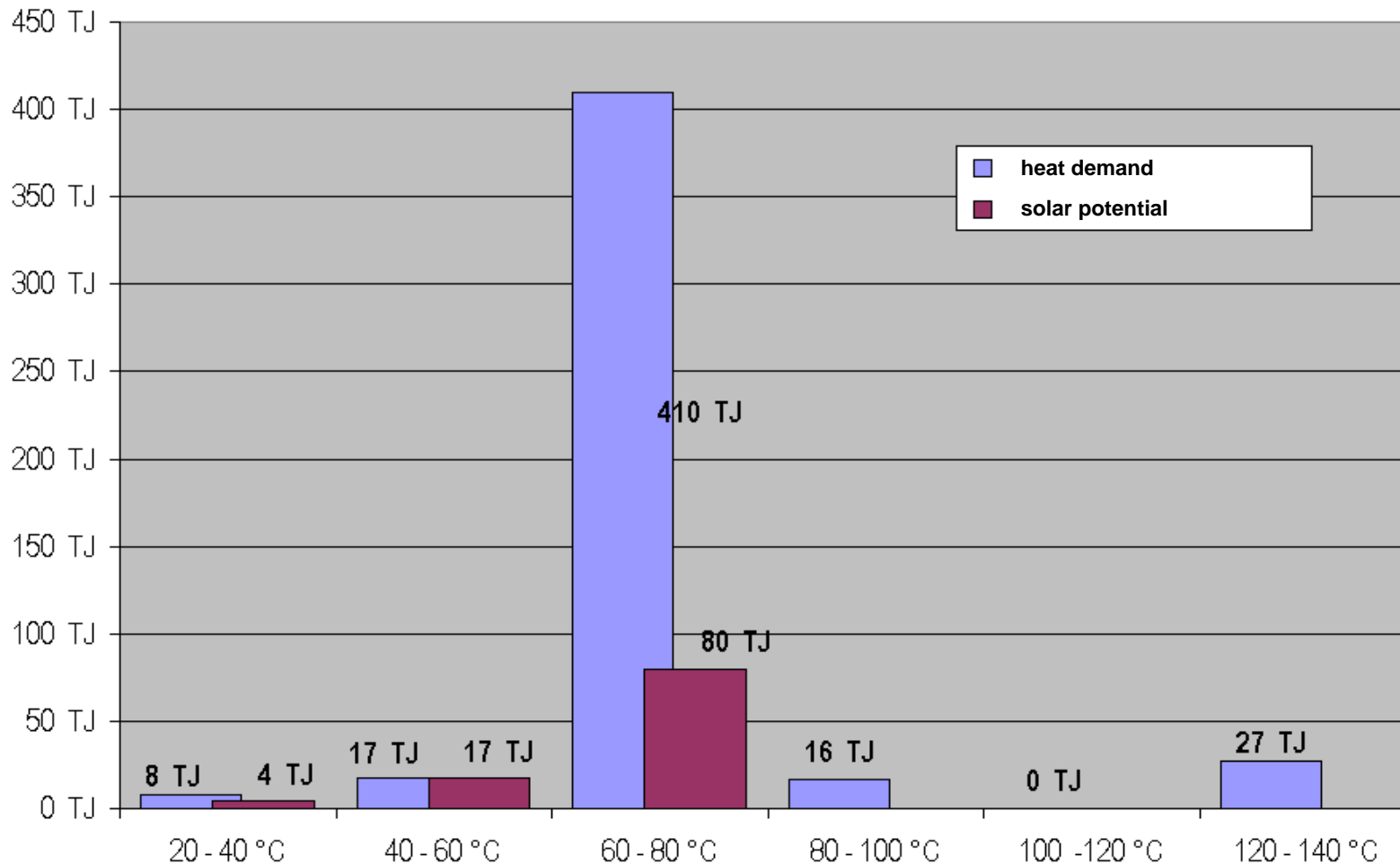
# Typical low temperature processes

- Hot water and steam
- Drying and dehydration processes
- Pre-heating systems
- Evaporation
- Pasteurization, sterilization
- Washing and cleaning
- Chemical reactions

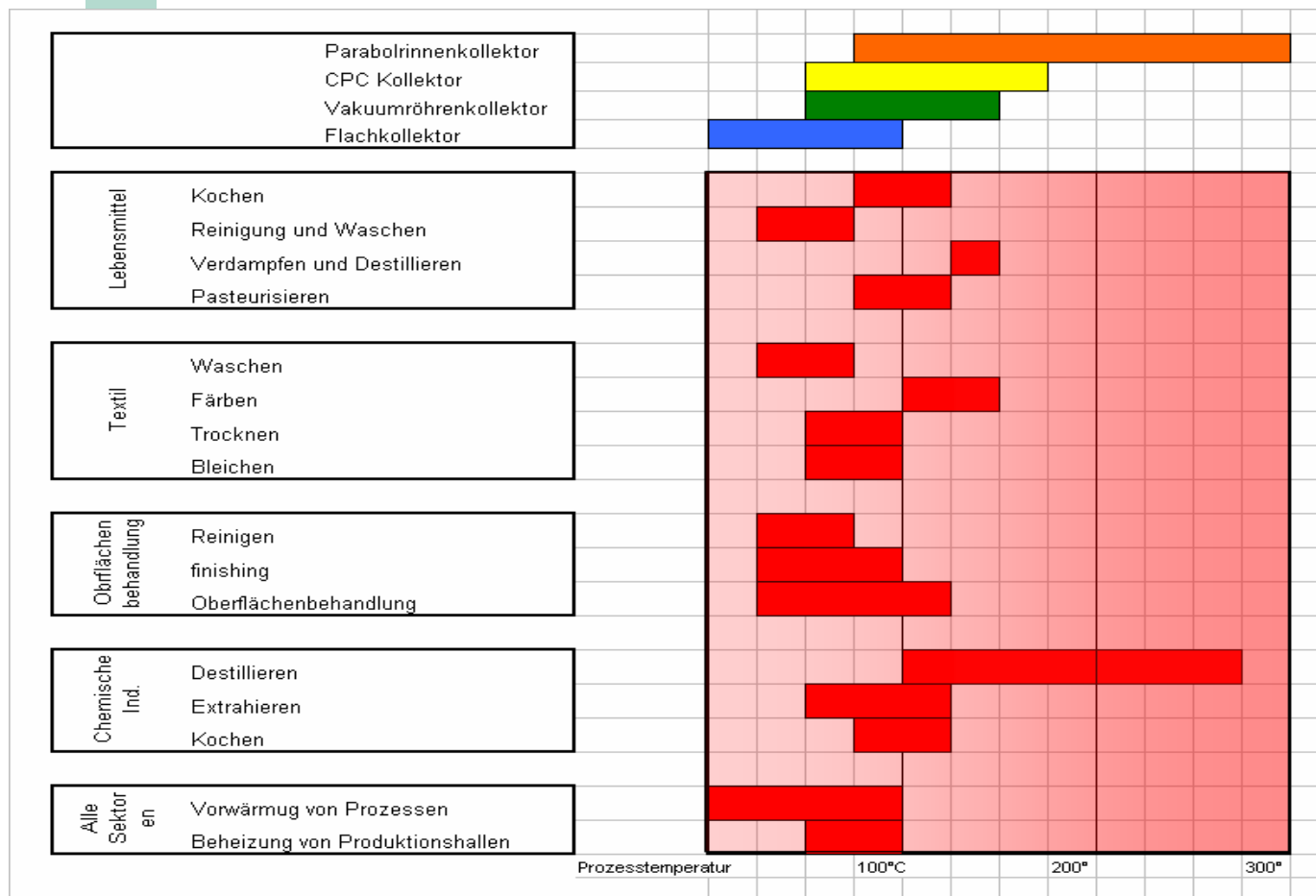
# Case study – Austrian dairy: heat demand on temperature level



# Heat demand in Austria's milk processing industry



# Typical low temperature processes



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Quelle: Müller T. et al.: Produzieren mit Sonnenenergie. Berichte aus Energie- und Umweltforschung, Wien 2004

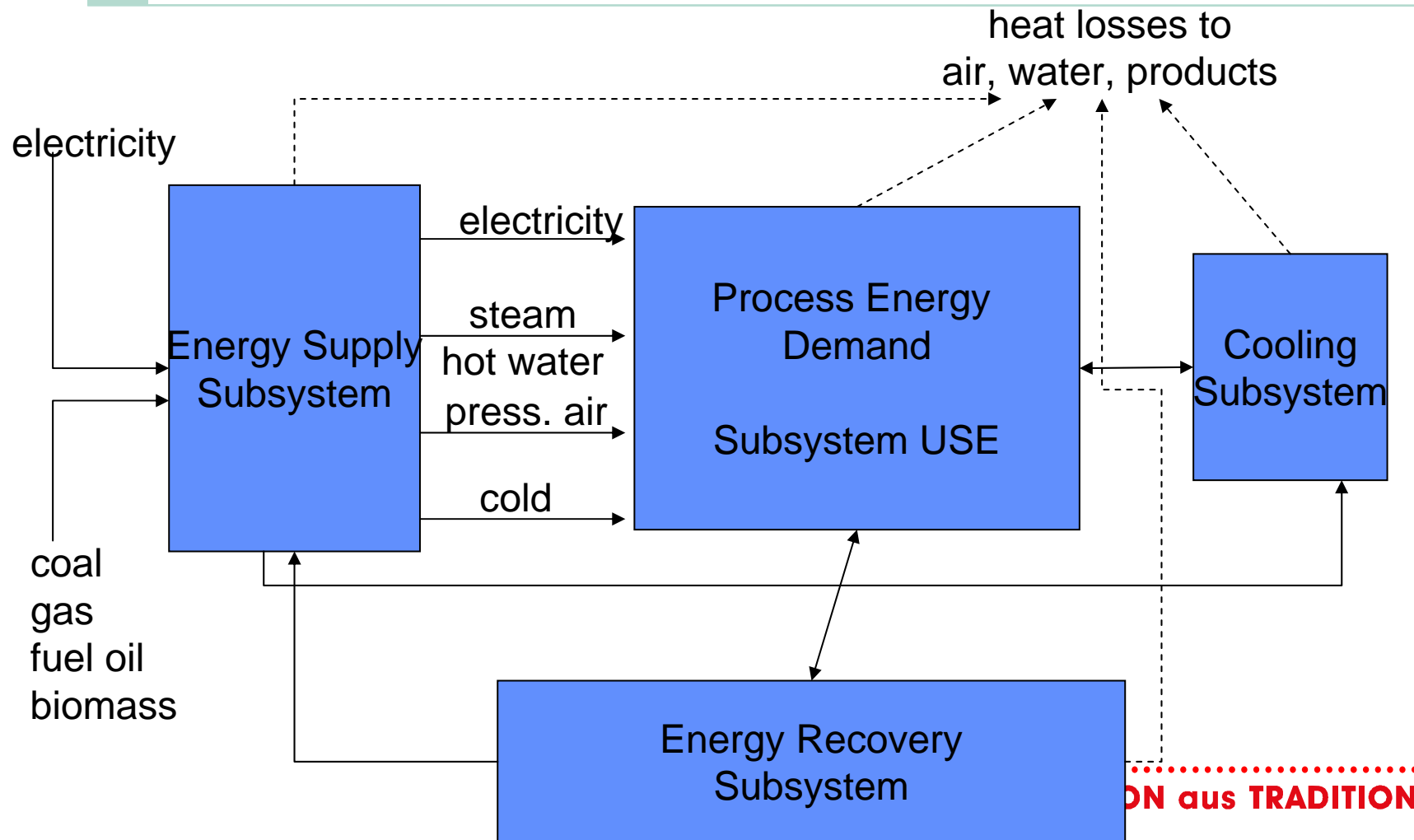
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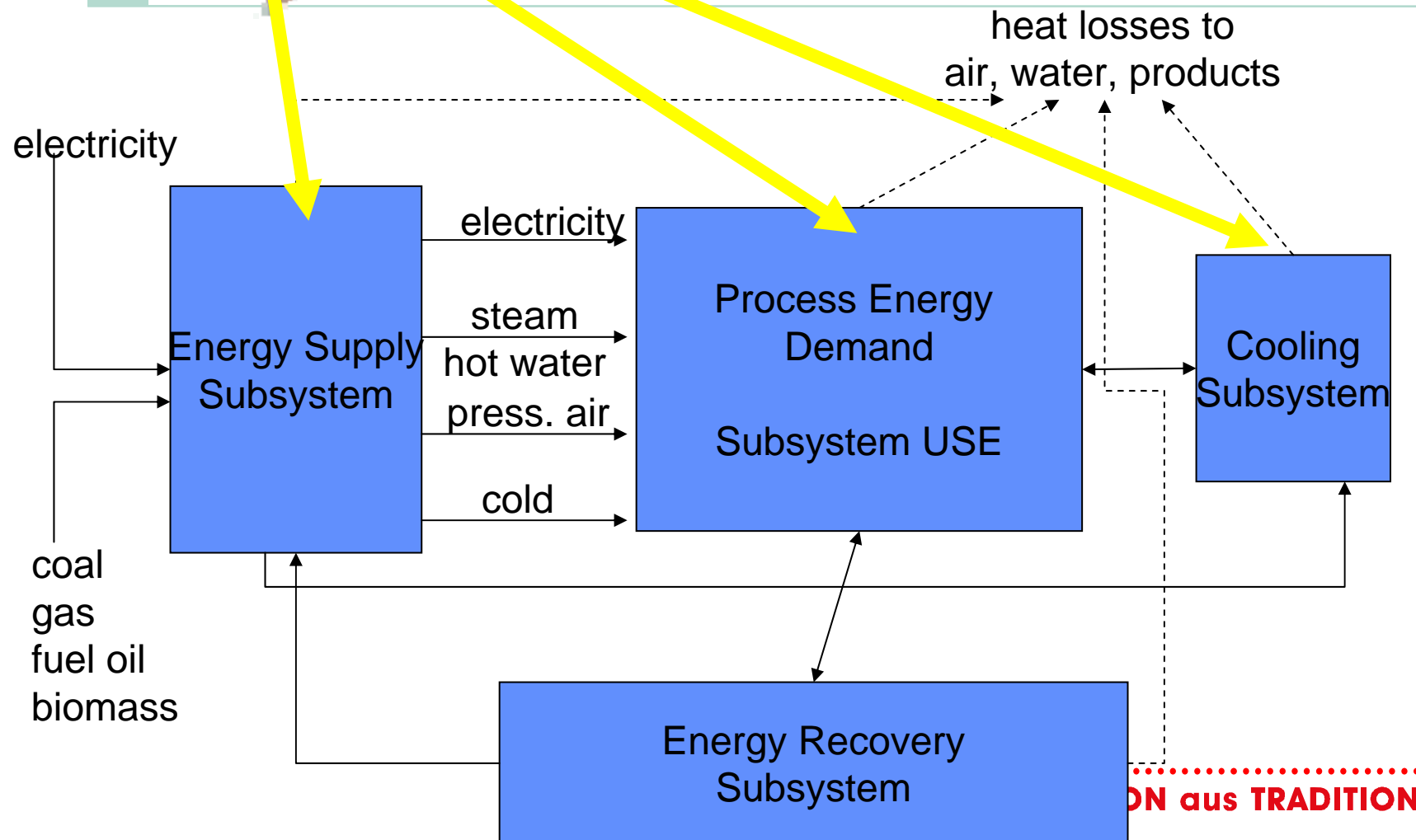
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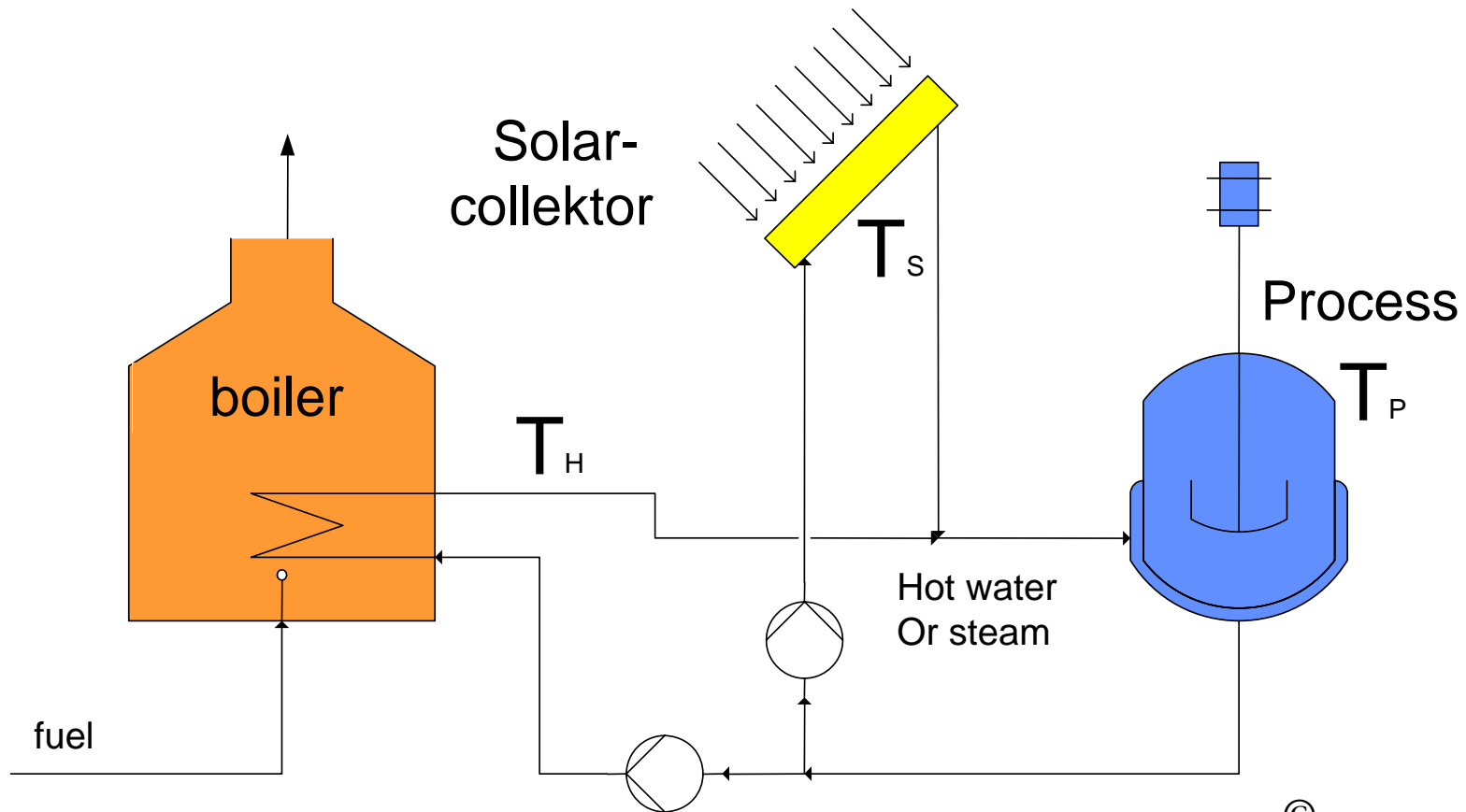
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# Industrial environment





# Integration of solar thermal heat into processes



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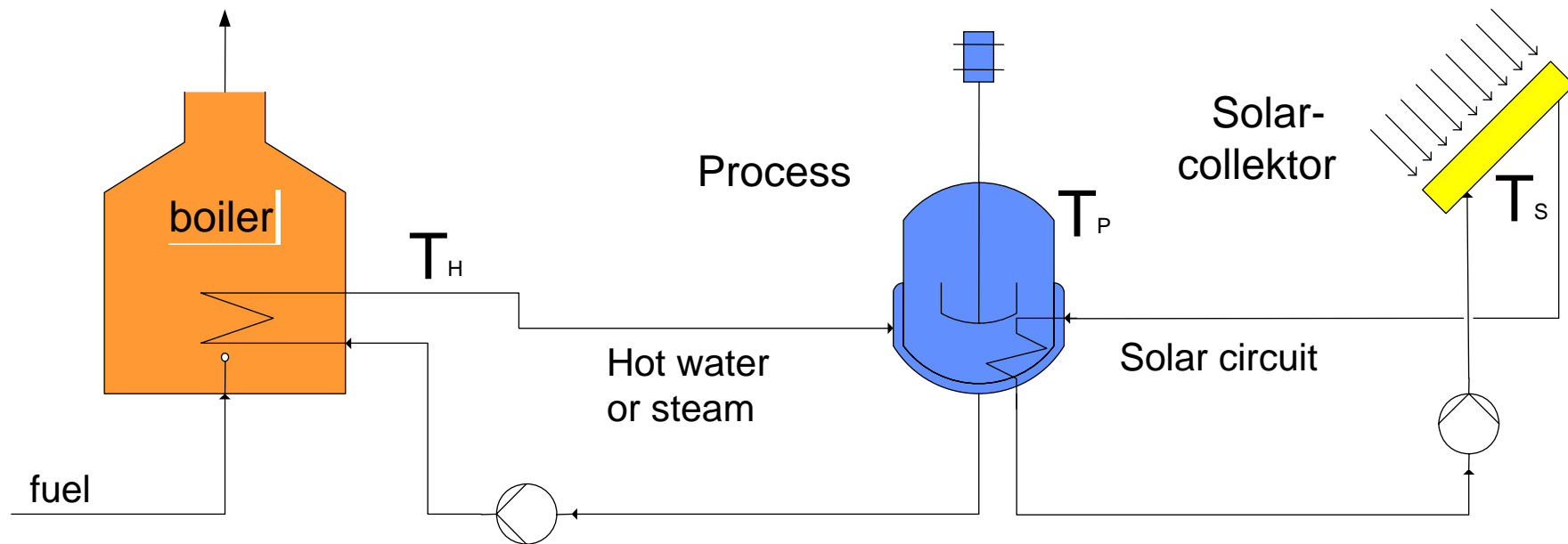
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# Direct process heating



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# Typical processes

- **washing, rinsing**
  - bottles, kegs, ... (food industry)
  - metal parts
  - textiles, ...
- **pasteurisation, sterilisation**
- **chemical reactions, polymerisation**
- **drying**
- **evaporation, distillation**

# Industrial sectors for solar process heat



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process	food	textile	building materials	galvanising anodising	chemicals fine	biochemical	Pharmac. sector	service. sector	pulp & paper	automob. supplier	tanning	painting	wood prod.	timber &
cleaning	X	X	x	X	x	X	X			x	x	X		
drying	X	X	x		x	X	X		x	x	X	X	X	
evaporation and distillation	X				x	X								
pasteurisation	X					X								
sterilization	X					X								
cooking	X													
general process heating	x	x	x	X	x	x	X			x			x	
boiler feed water preheating	X	X	x		x	x			x		x			
heating of production halls	X	X		x	x	x	x			X	X	X	X	
solar cooling	X			x		X	X							

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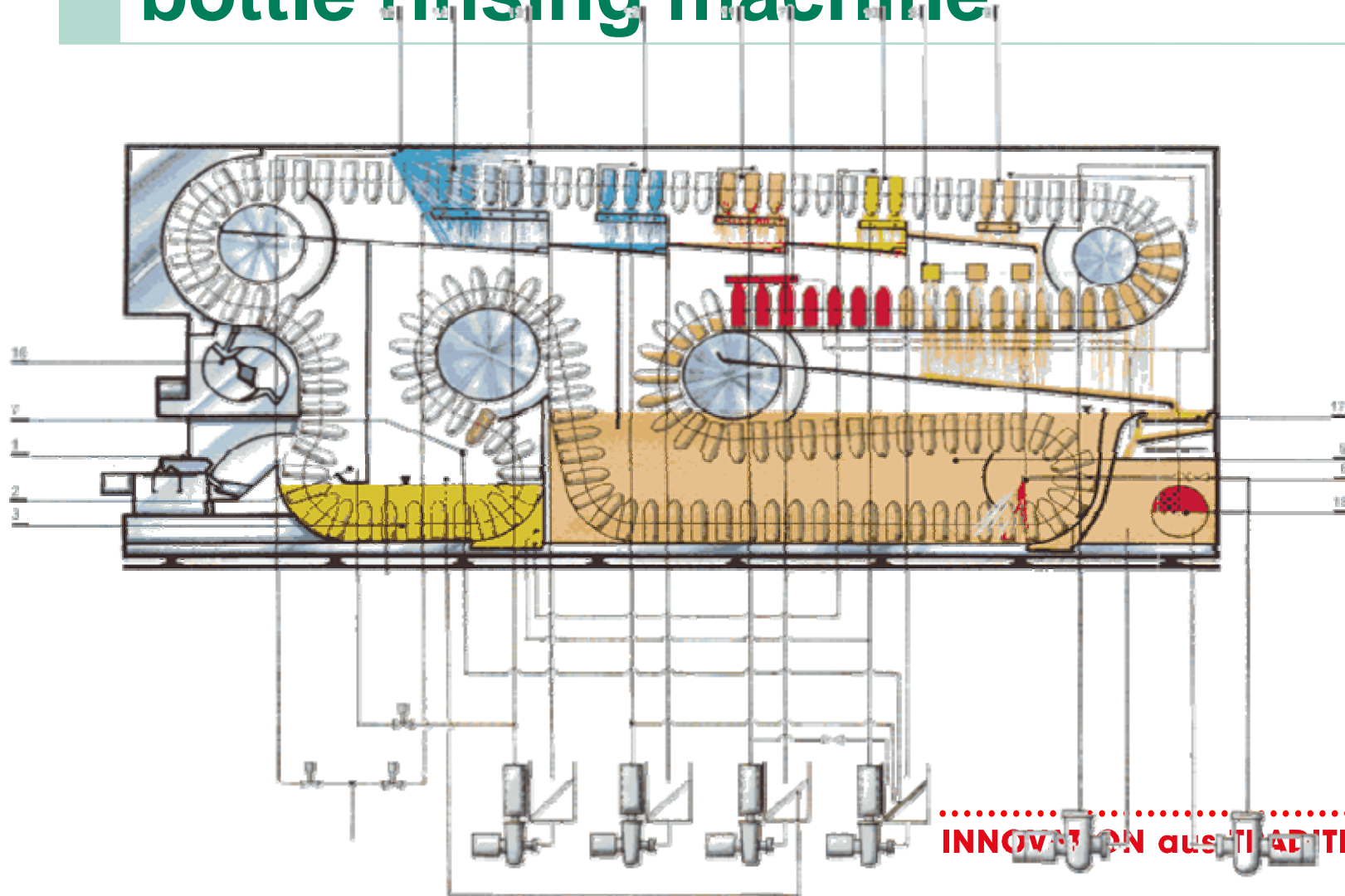
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# Processes and Temperature Levels

Industry sector	Process	Temperate level °C
food and beverages	Drying	30 - 90
	Washing	40 – 80
	Pasteurising	80 – 110
	Cooking	95 – 105
	Sterilising	140 – 150
	Heat treatment	40 – 60
Textile industry	Washing	40 –80
	Bleaching	60 – 100
	Dying	100 – 160
Chemical industry	Evaporation	95 – 105
	Distillation	110 – 300
	various chem. processes	120 - 180
all	preheating of boiler feed water, heating of production halls	30 – 100 ..... <del>30 – 60</del> ..... <b>INNOVATION aus TRADITION</b>

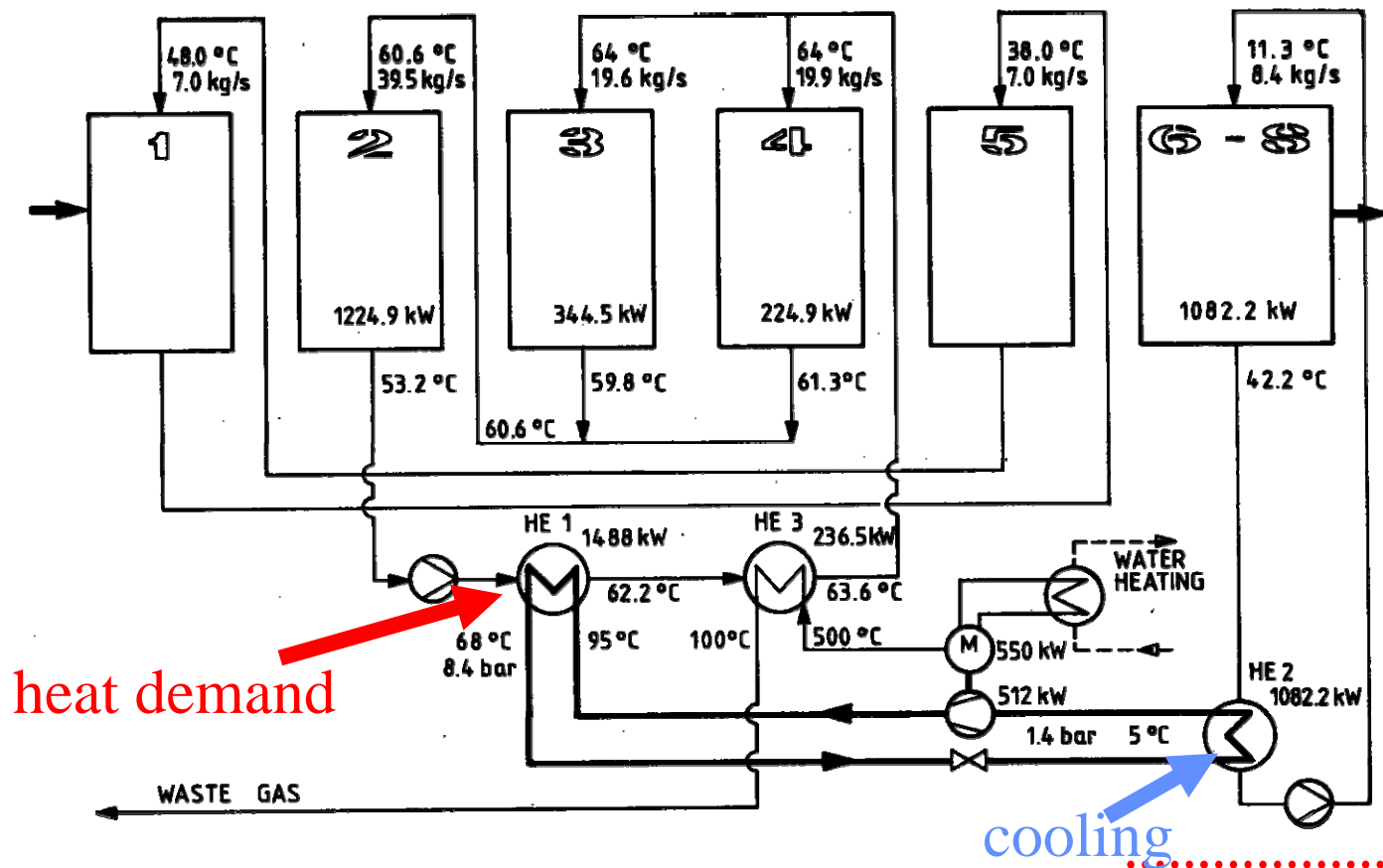
# bottle rinsing machine



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# pasteuriser

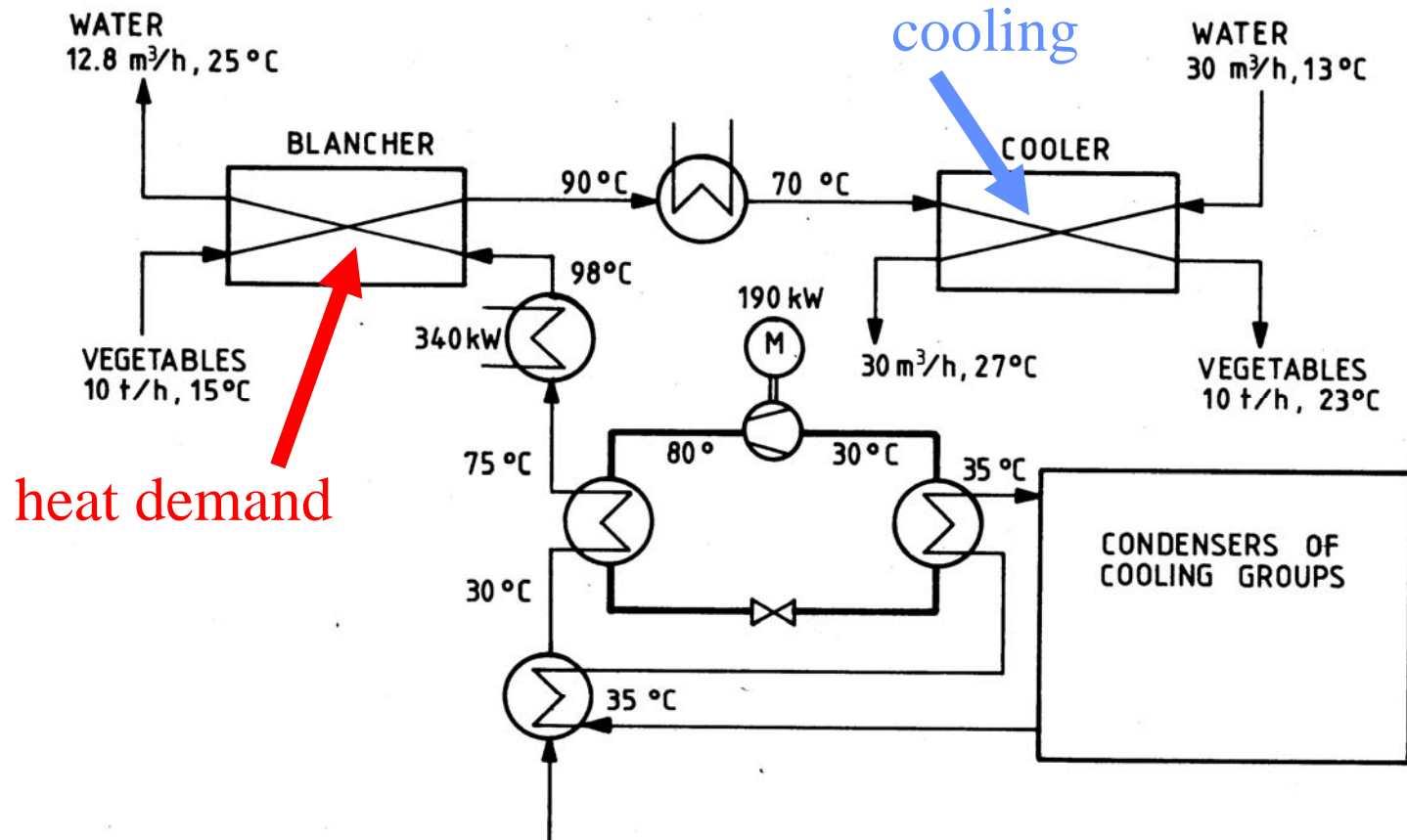


heat demand

cooling

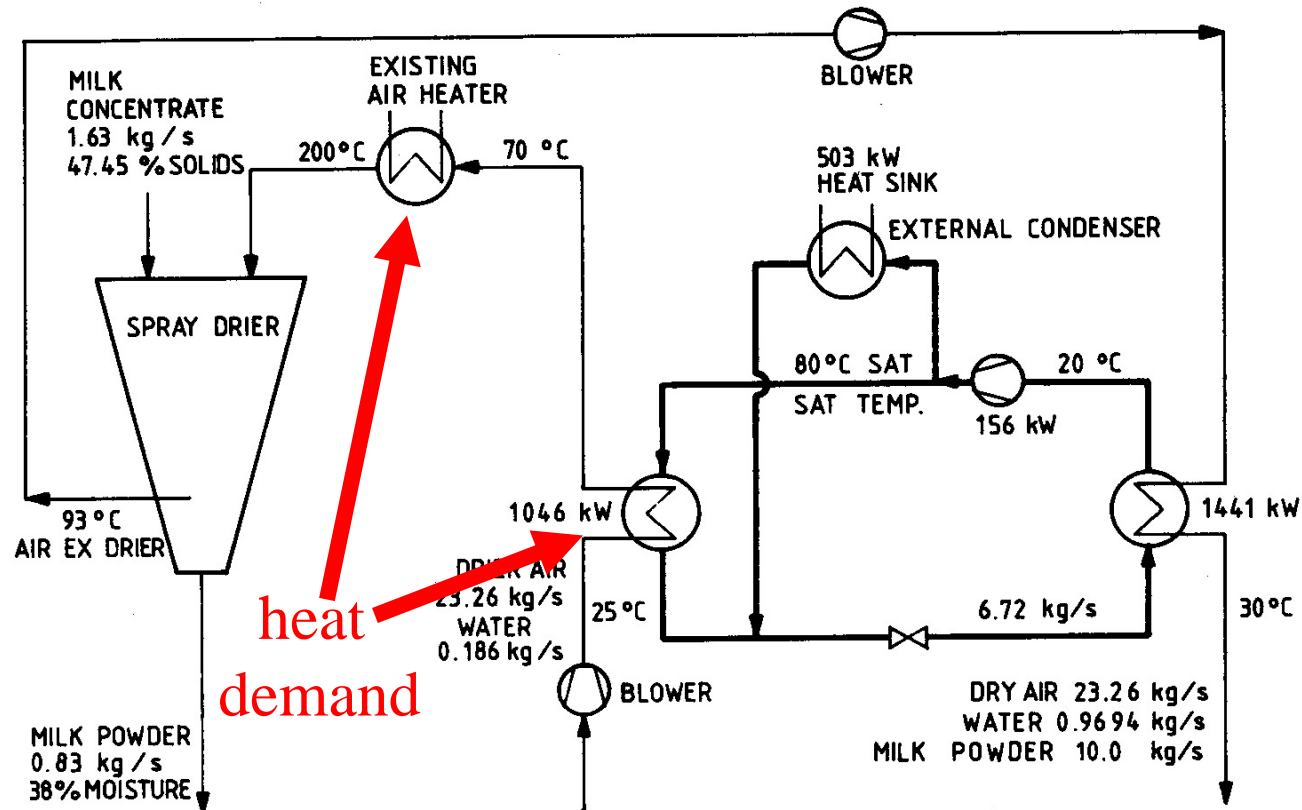
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# blanching line for vegetables

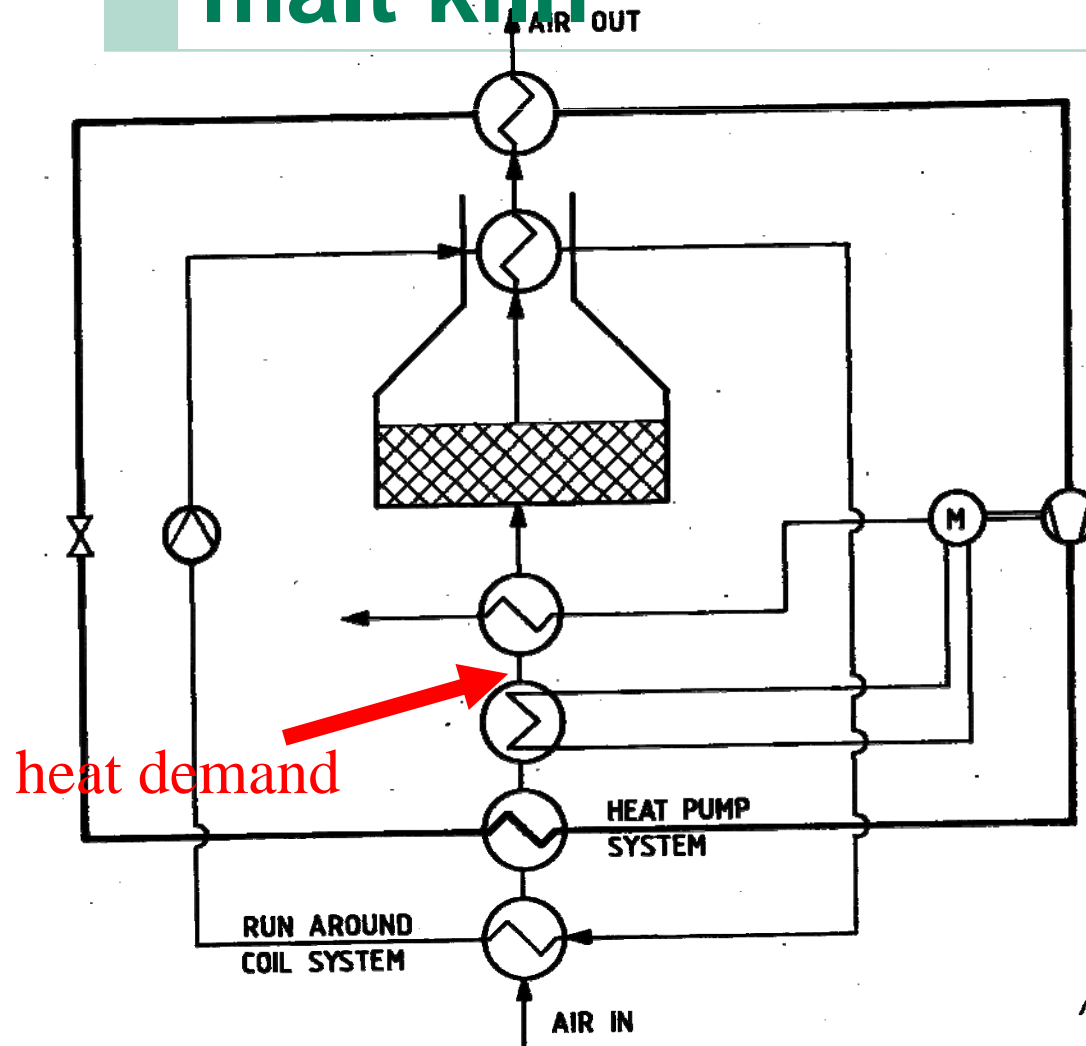


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# spray drier for milk



# malt kiln



## conclusions

- **there are low temperature processes in practical all sectors of industry**
- **heating and cooling is required very often at the same time (heat integration, heat pumps)**
- **solar heating of processes is more efficient, backing of conventional heating system might be easier**



# Berglandmilch

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JOANNEUM



RESEARCH

JOANNEUM RESEARCH

Institute for Sustainable Techniques and Systems

# Site of Berglandmilch – Cheese-Dairy



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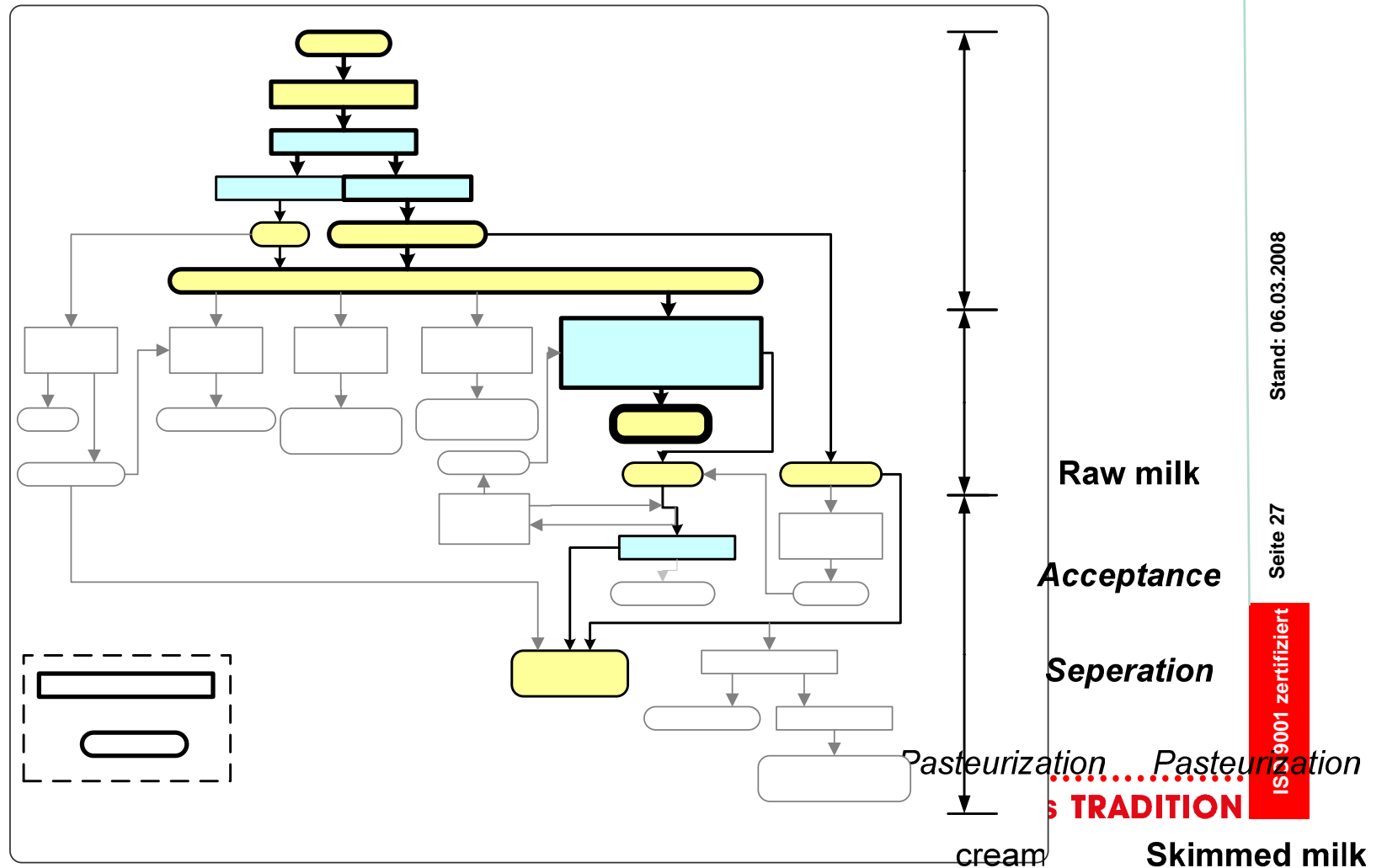
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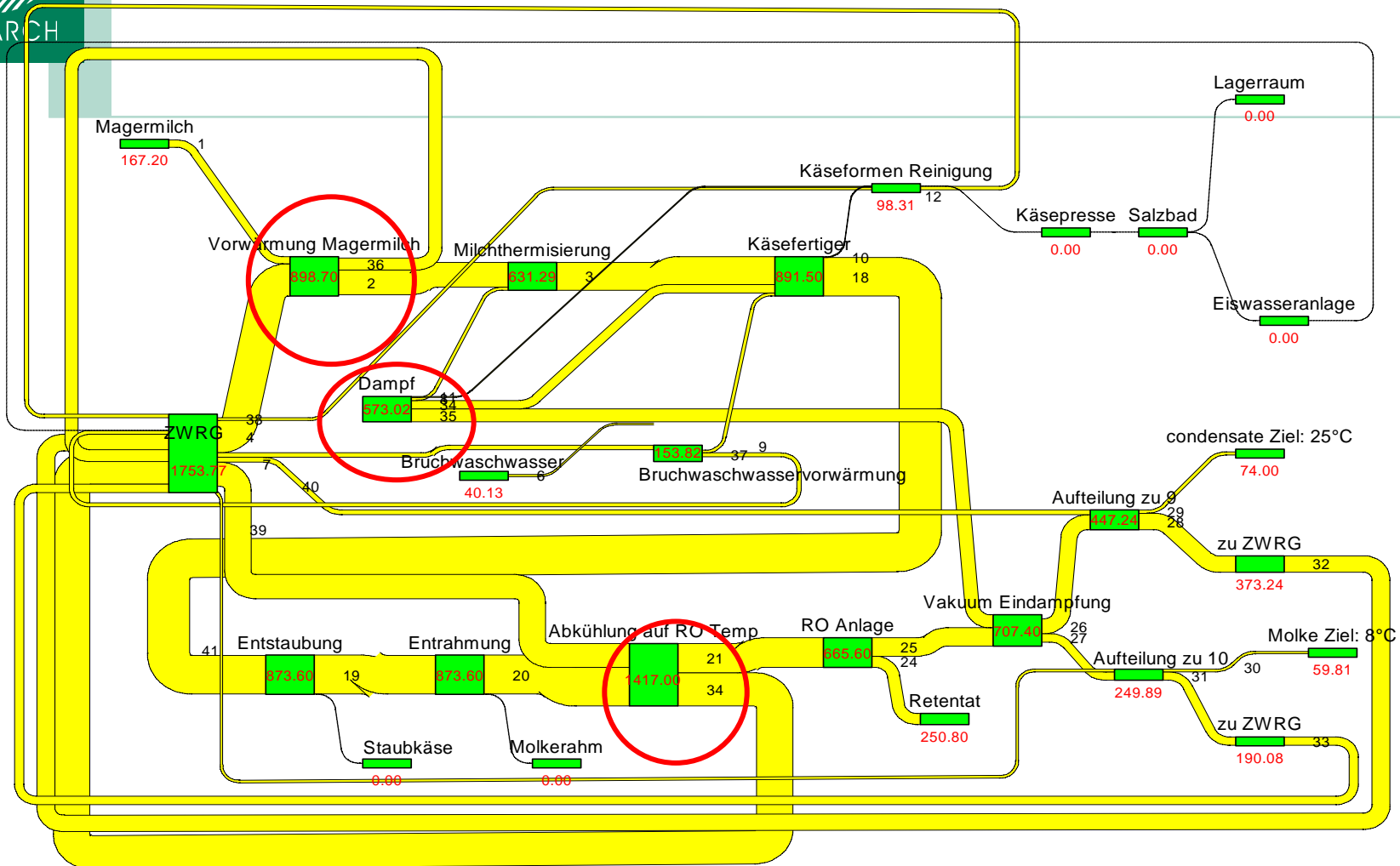
# Temperature levels and energy demand of liquid streams

Nr.	Stream	Medium	Process	Temp.	Mass Flow	HE is possible with stream nr.
				°C	kg/h	
1	Preheating	milk	Preheating of milk	8 → 32	14108	7, 9, 10
4	Adwater	water	Adding water to cheese making process	12 → 57	1552	7, 9, 10,
7	Whey 1	whey	To RO cleaning of whey	42 → 12	14249	1, 8, 11
8	Whey 2	whey	Whey filtrate after RO to vacuum evaporation	12 → 50	6031	7, 9, 10
11	Whey 3	whey	Rest whey after RO to waste water treatment	12 → 25	8218	7, 9, 7
9	Whey 4	Whey	Cleaned whey	60 → 25	3837	1, 4, 8, 11
10	Whey 5	whey	Remaining whey	60 → 8	2193	1, 4, 8, 11
14	Cleaning 1	water	External cleaning	12 → 65	2822	7, 9, 10
5	Cleaning 2	water	Internal cleaning	45 → 60	1411	7, 9, 10

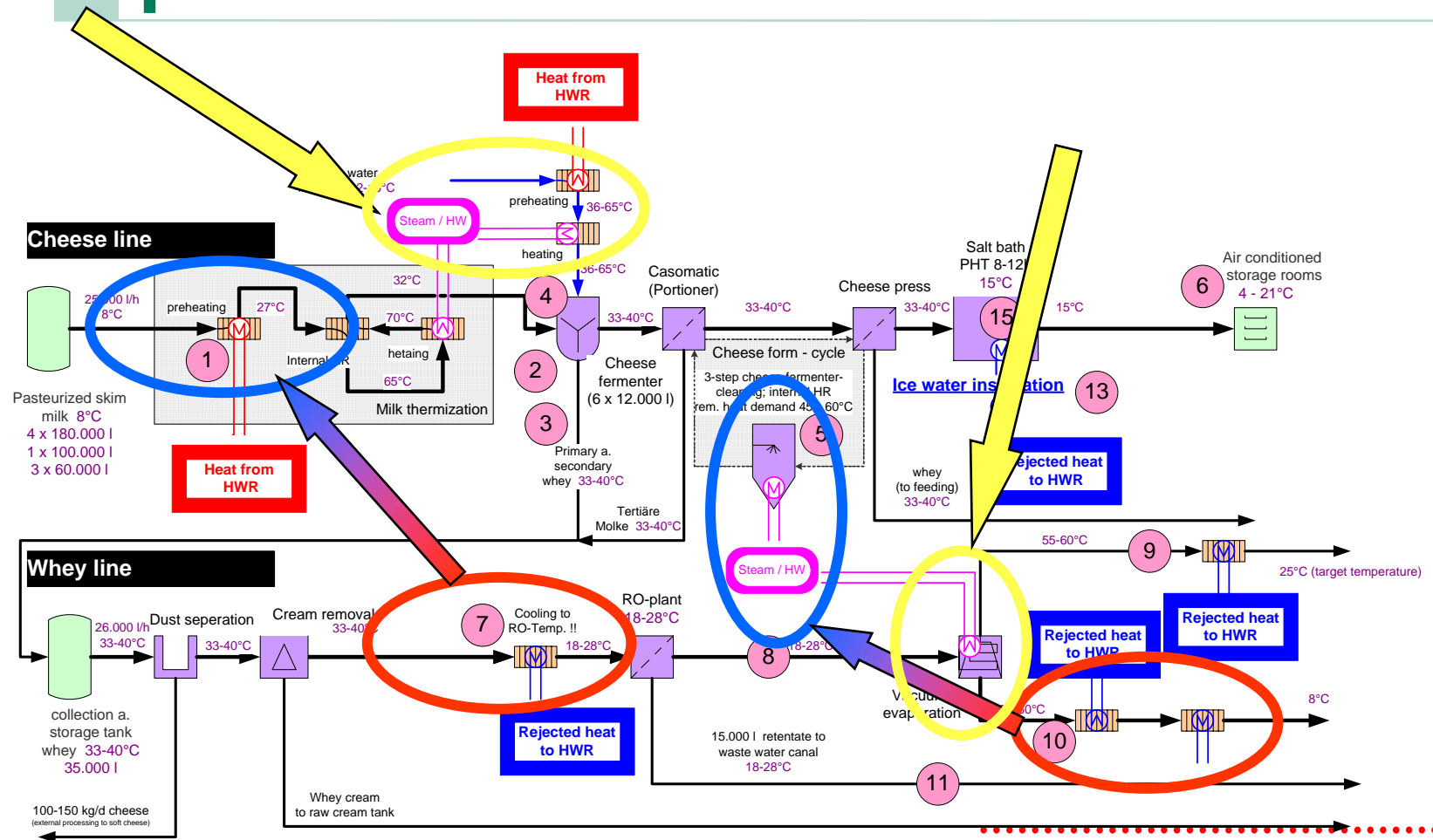
# Flow Sheet for Cheese Production



# Flows Sankey (actual state)



# Production processes - process flow sheet



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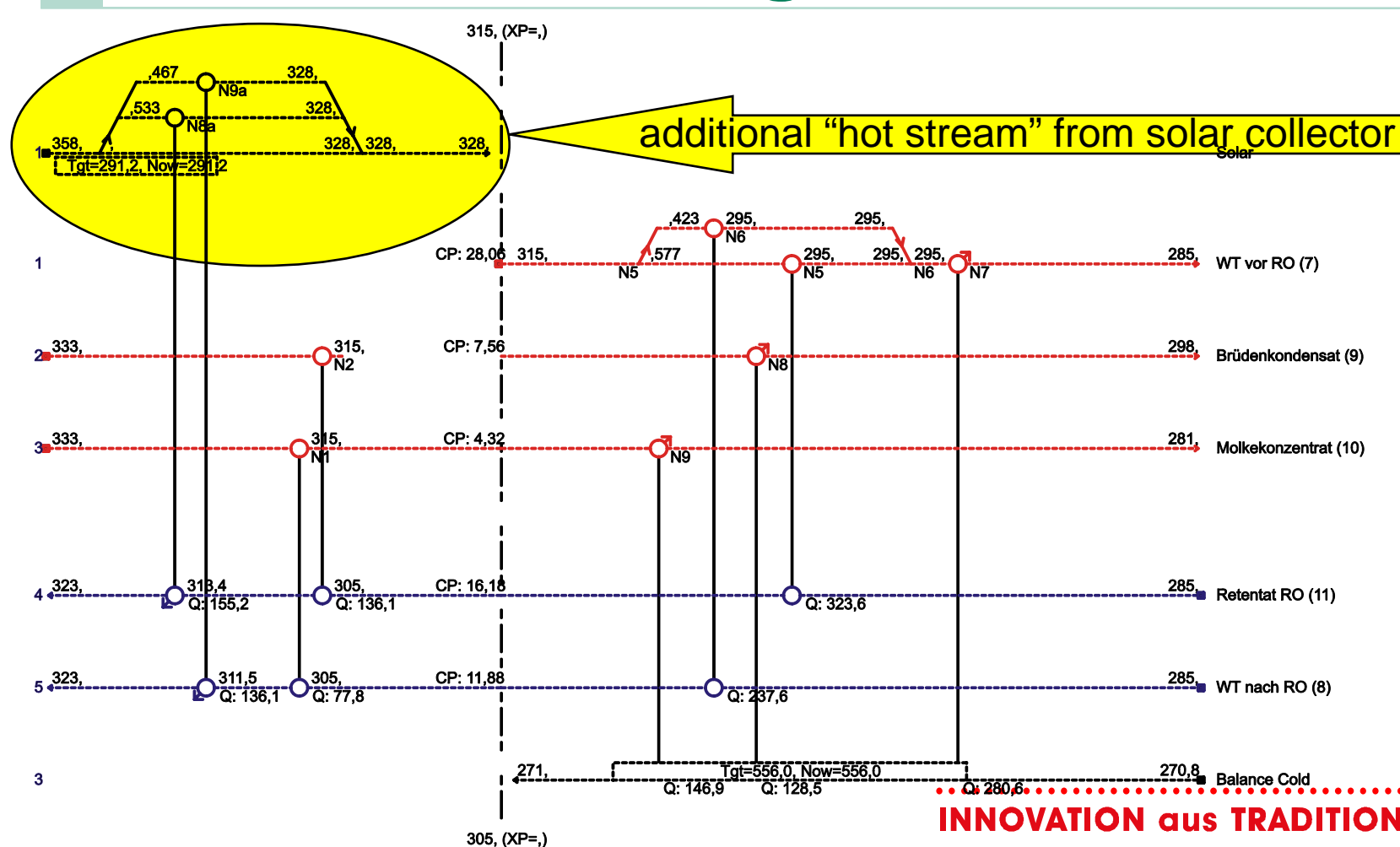
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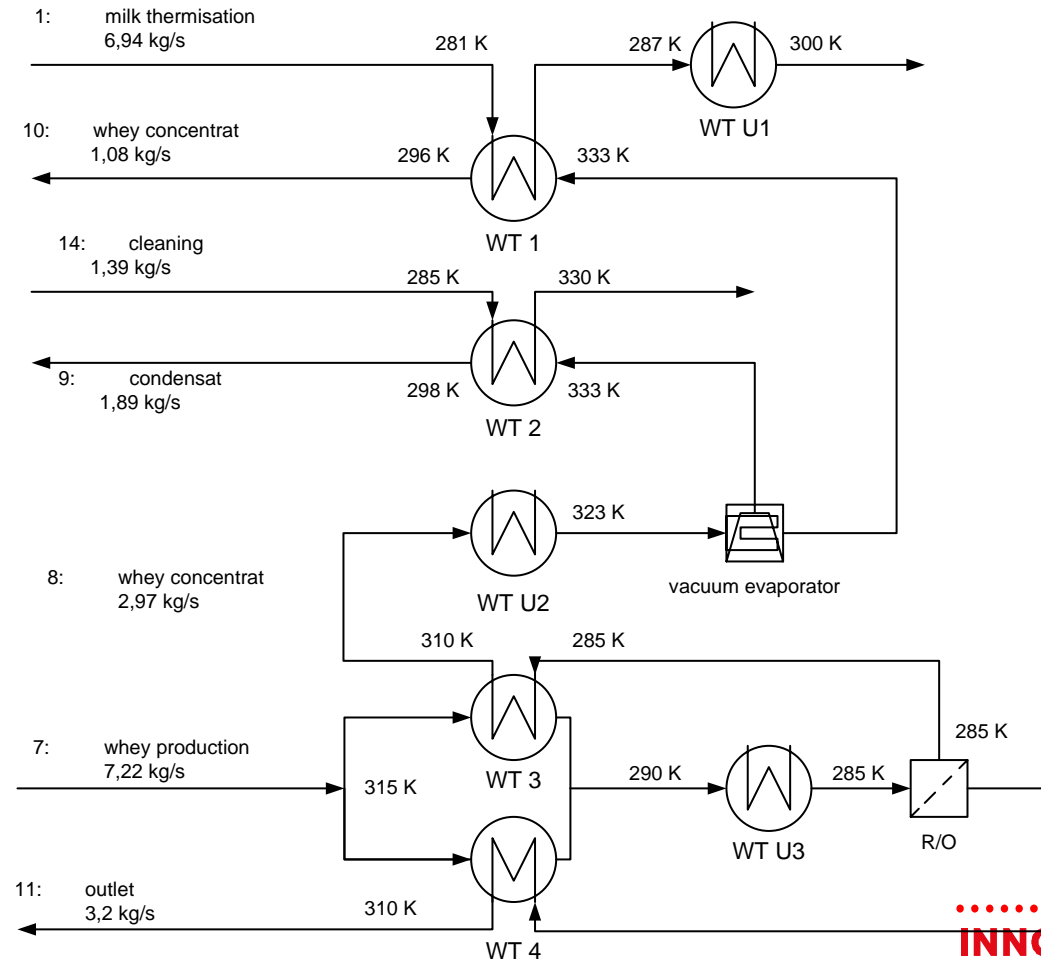
### Heat integration scheme obtained by PINCH analysis

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# The heat exchanger network



# Proposed heat exchanger network



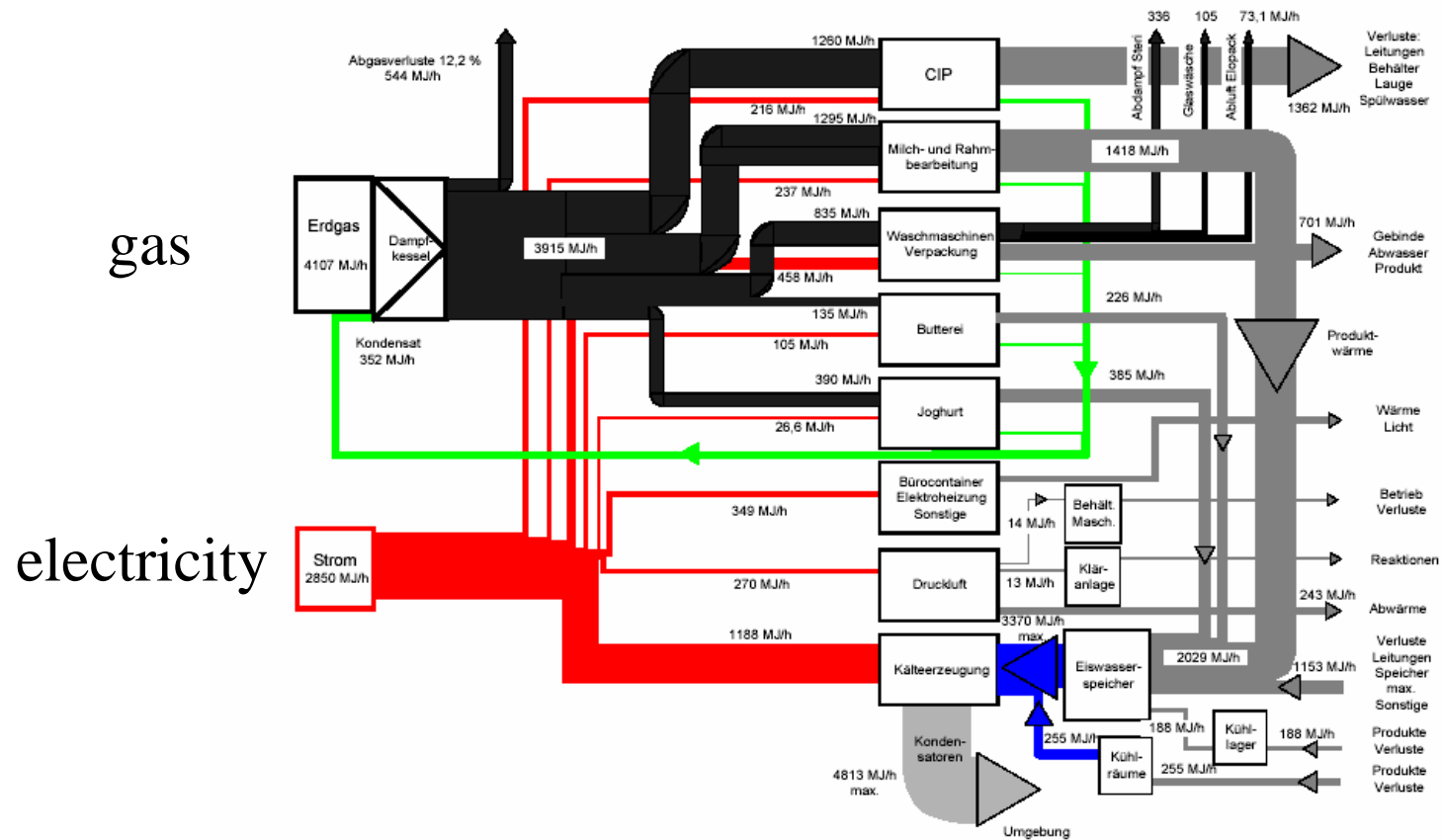
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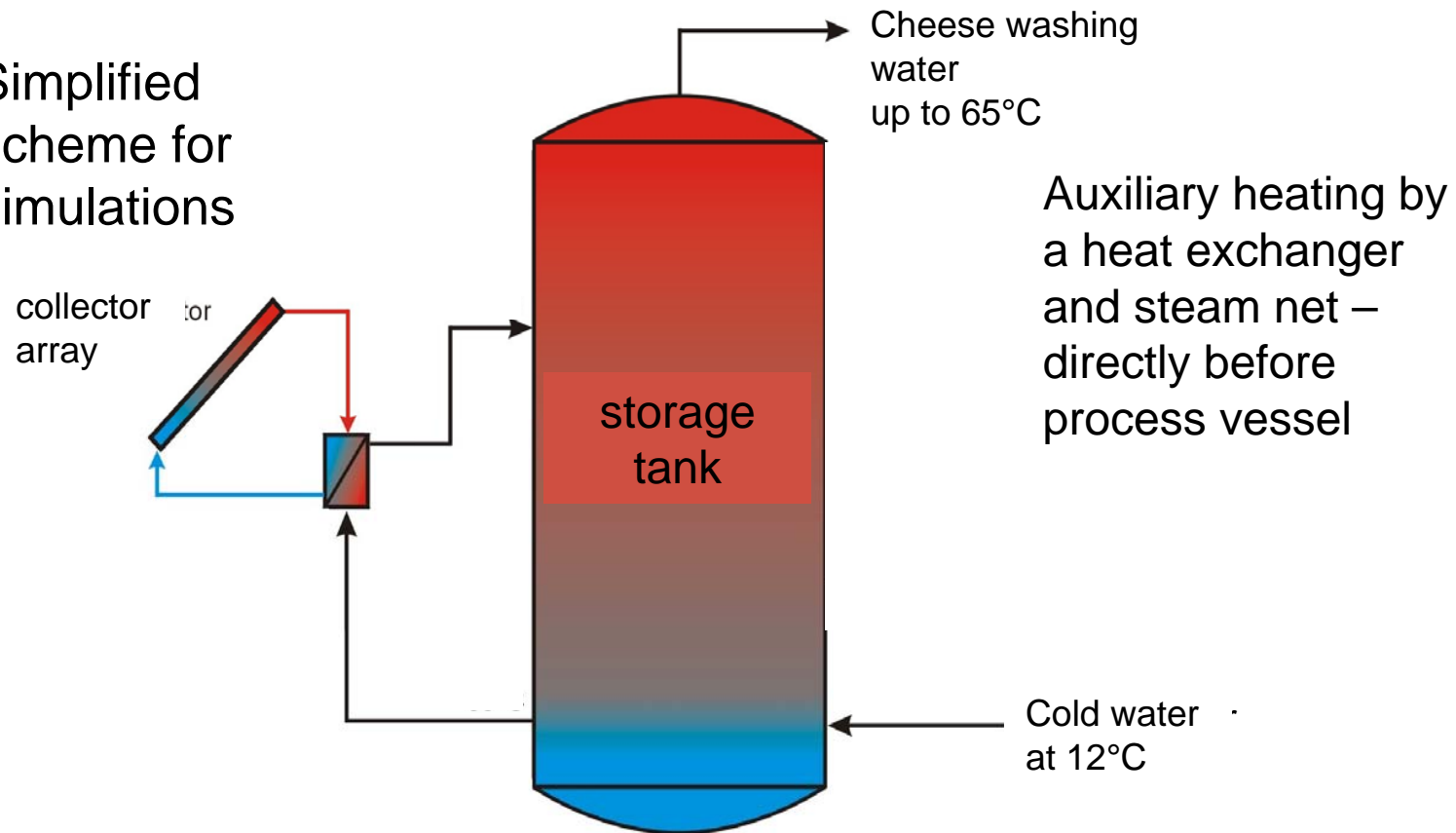
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# Production processes - Sankey diagram



# Hydraulic Concept

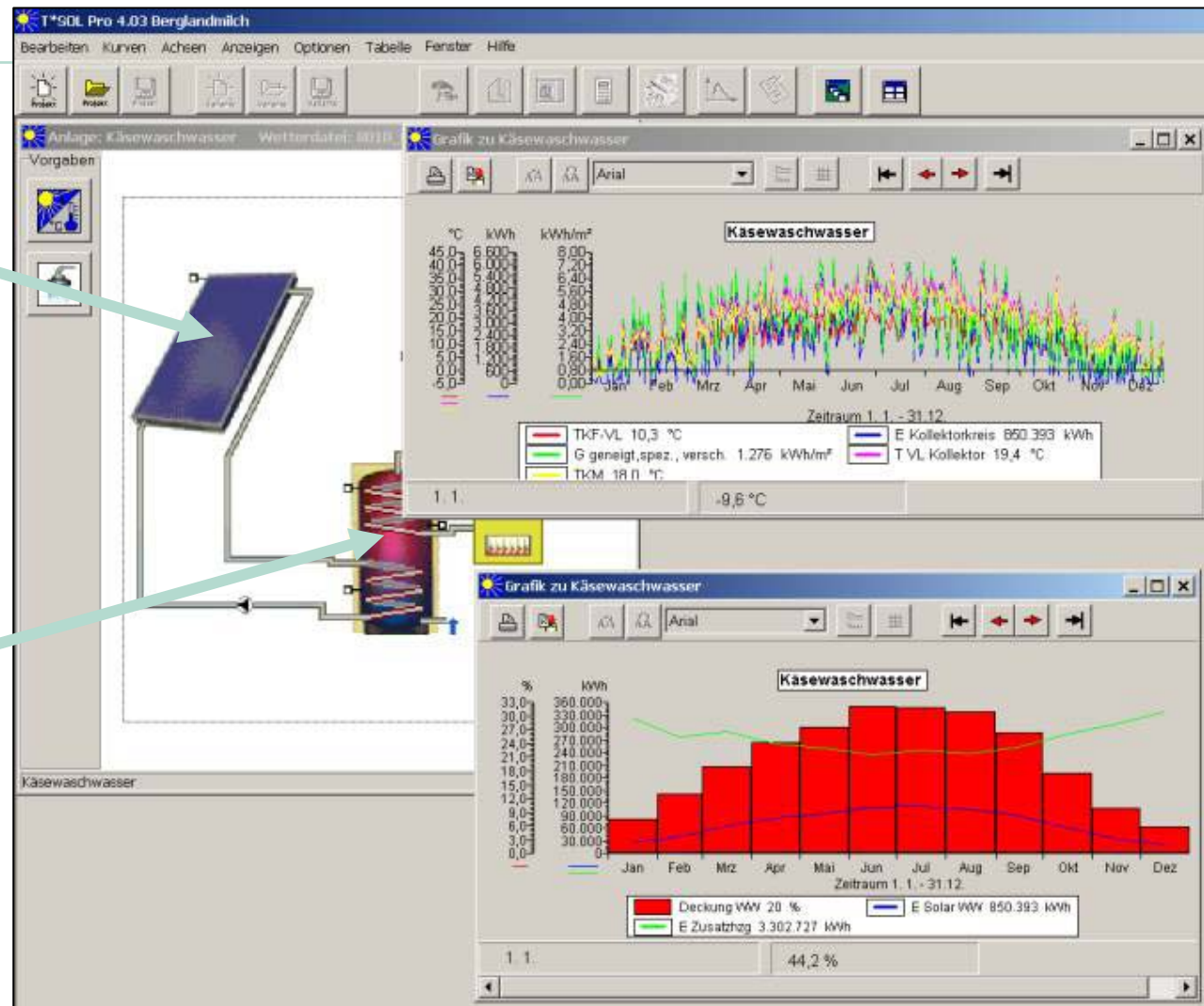
Simplified  
scheme for  
simulations



# Simulation of two Alternatives

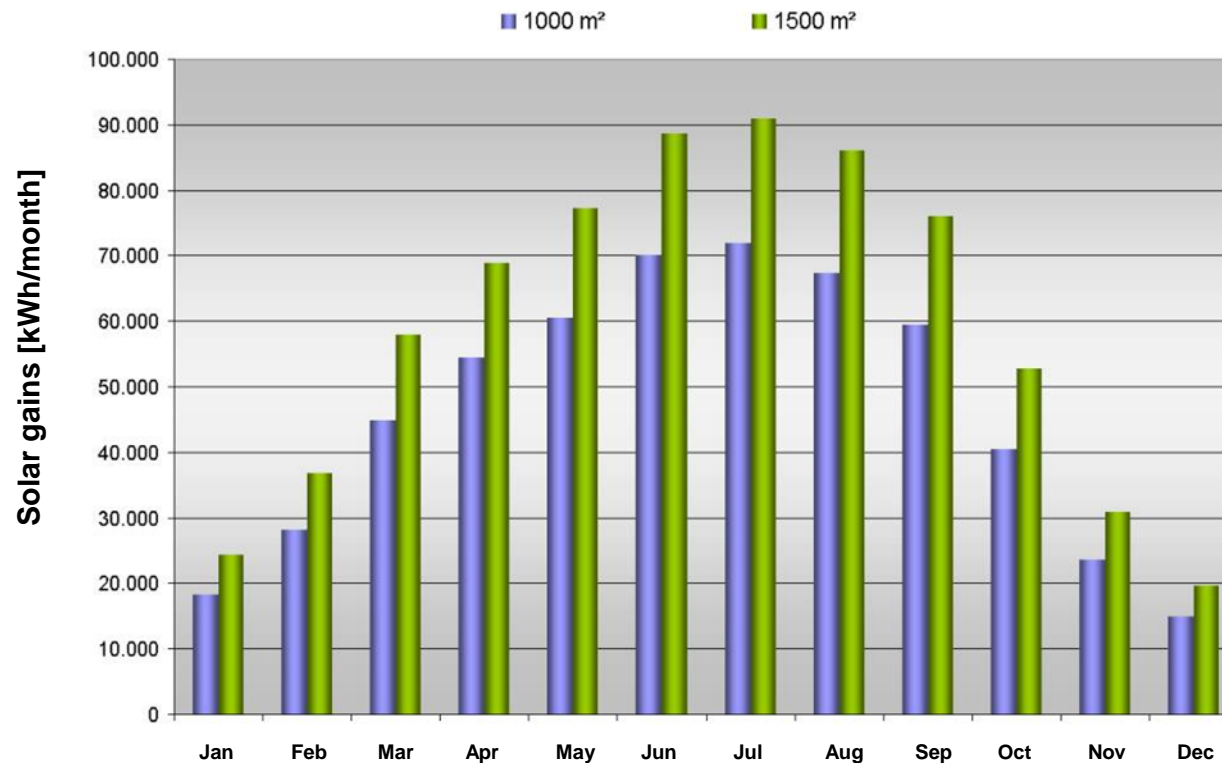
1.000 m<sup>2</sup>  
or  
1.500 m<sup>2</sup>

100 m<sup>3</sup>



## Results – Solar Gains

Collector area	1.000 m <sup>2</sup>	1.500 m <sup>2</sup>
Solar gains [MWh/a]	553	710
Gas savings ( $\eta=65\%$ ) [m <sup>3</sup> /a]	85.000	109.000
Reduced CO <sub>2</sub> – emissions [t/a]	170	218



# TCA without subsidies

Investment solar installation	€ 300.000.-
Investment heat exchanger	€ 20.000.-
one-time charge (material,..)	€ 581.000.-
	<hr/>
	€ 901.000.-

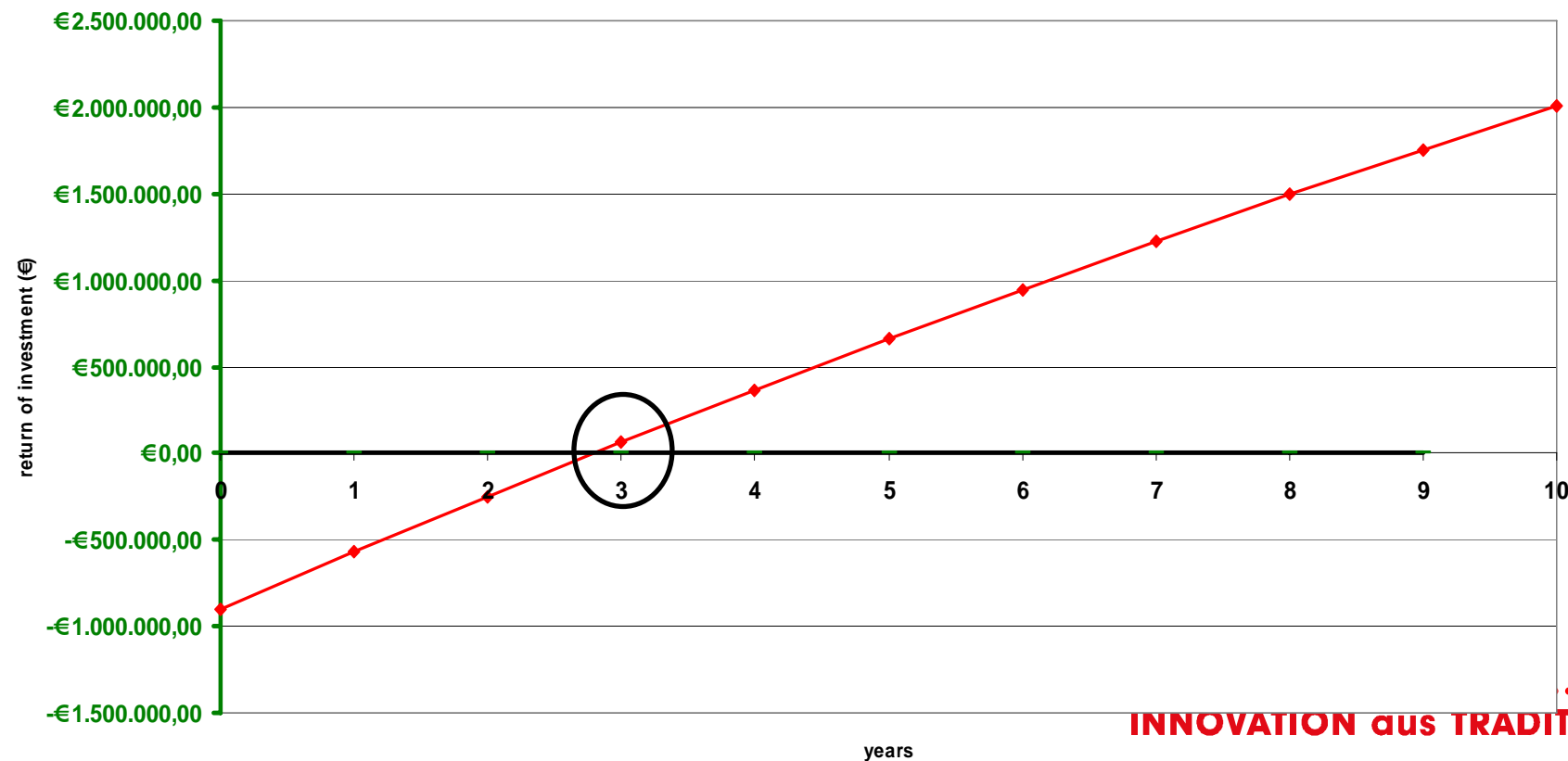
**saving of operating costs per year**  
(minimization of gas consumption)

**€ 345.621.-**

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# Return of Investment

Return of investment for solar heating equipment at Berglandmilch



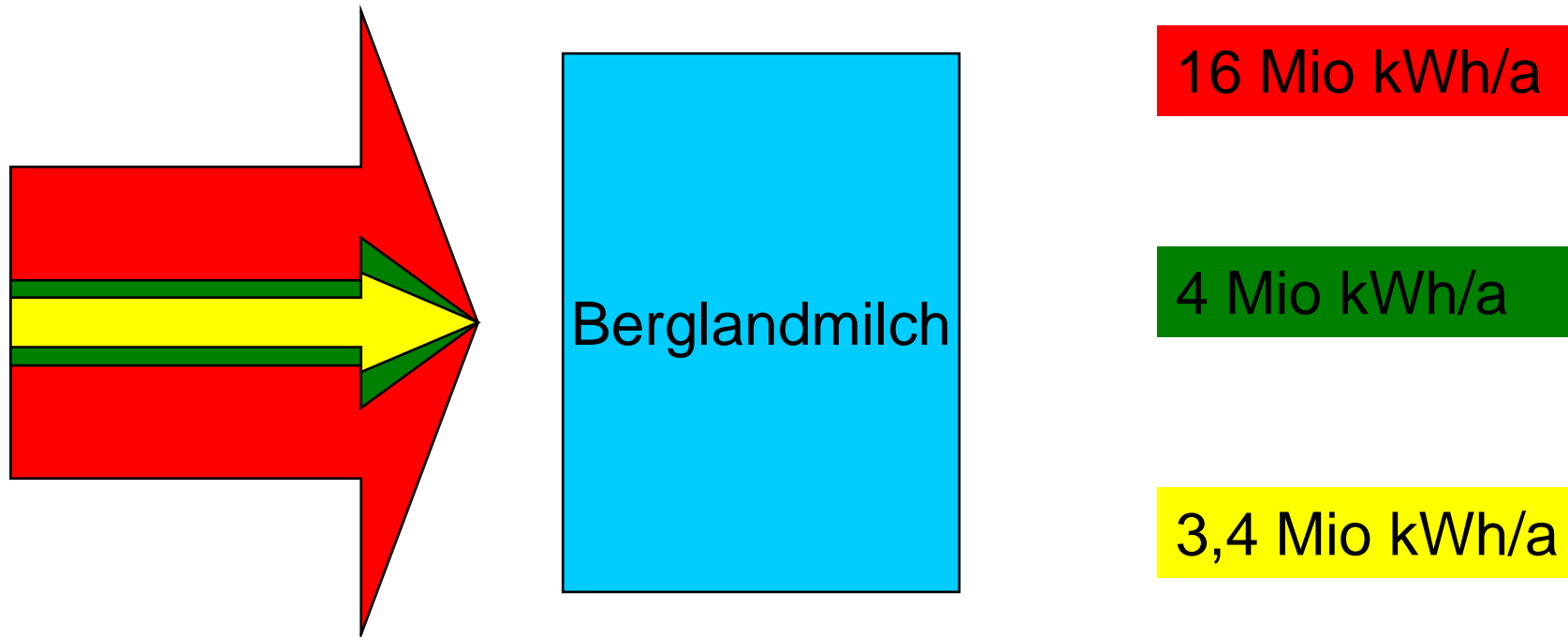
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# Total Energy Consumption



**saving in fossil energy app. 80%**

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## TCA without funding

Investment solar installation	€300.000.-
Investment heat exchanger	€20.000.-
one-time charge (material,..)	€581.000.-
	<hr/>
	€901.000.-

**saving of operating costs per year**  
**(minimisation of gas consumption)**

**€345.621.-**

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# Calculation

solar process					replaced/alternative process					financial valuation factors	
years	investment costs	non recurring costs (other than investments)	annual operating costs	total	investment costs eg heat exchanger	market value of replaced equipment/salvage value	saved costs (non recurring costs like repairs)	saved annual operating costs	total	net present value	internal rate of return
	[€]	[€]	[€]	[€]	[€]	[€]	[€]	[€]	[€]	[€]	%
0	-€ 300.000,00			-€ 300.000,00	-€ 601.000,00				-€ 901.000,00	-€ 901.000,00	
1				€ 0,00				€ 345.691,70	€ 345.691,70	-€ 568.604,13	-61,63%
2				€ 0,00				€ 347.420,16	€ 347.420,16	-€ 247.394,67	-11,42%
3				€ 0,00				€ 350.894,36	€ 350.894,36	€ 64.549,14	6,43%
4				€ 0,00				€ 354.403,30	€ 354.403,30	€ 367.494,57	13,29%
5				€ 0,00				€ 357.947,34	€ 357.947,34	€ 661.701,19	16,11%
6				€ 0,00				€ 361.526,81	€ 361.526,81	€ 947.421,08	17,23%
7				€ 0,00				€ 365.142,08	€ 365.142,08	€ 1.224.899,05	17,57%
8				€ 0,00				€ 368.793,50	€ 368.793,50	€ 1.494.372,85	17,52%
9				€ 0,00				€ 372.481,43	€ 372.481,43	€ 1.756.073,36	17,28%
10				€ 0,00				€ 376.206,25	€ 376.206,25	€ 2.010.224,82	16,94%

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# Return of Investment

Return of investment for solar heating equipment at Berglandmilch



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# Concept Solar Plant Berglandmilch

- Technical feasibility given
- Pay back in approx. 6 years possible
- Energy costs will be reduced
- Environmentally sound production → marketing?

**[Wolford]**  
*WIEN PARIS LONDON*



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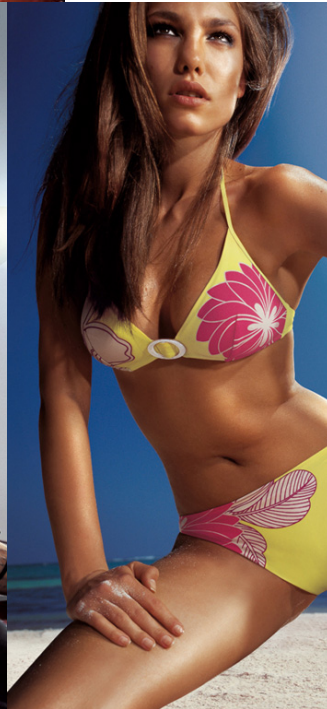
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# Introduction of Woflord



Today, Woflord, a company operating for over 50 years, is specialising in the manufacture and sales of high quality leg- and bodywear, in particular stockings, tights, bodies, swimwear and lingerie in the luxury segment. The Woflord AG runs 10 international branches and sells its goods through mono-brand boutiques and partners in 60 different countries worldwide. Through co-branding Woflord entered seasonal collaborations with famous international designers, such as Jean Paul Gaultier, Philipp Starck and currently Vivienne Westwood, Karl Lagerfeld and Emilio Pucci. For Fall 2004 Woflord has also been producing tights and bodies for the Italian world brand Giorgio Armani through a license agreement



**Woflord**  
WIEN PARIS LONDON

Source: [www.wolford.com](http://www.wolford.com)



# Production of Tights

1  
Choice of yarn

4  
Forming



2  
Knitting / steaming

5  
Quality control

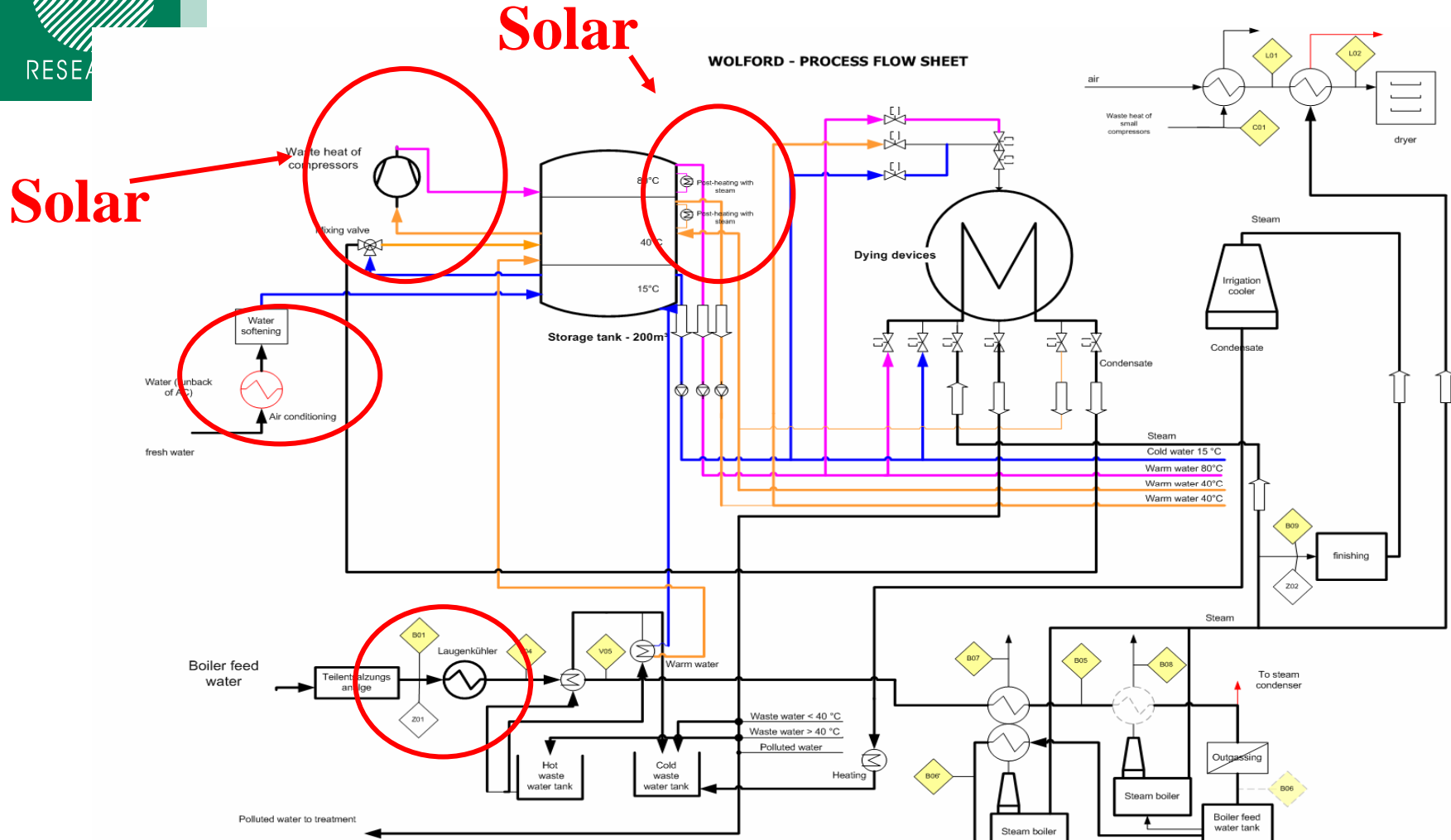


3  
Sewing/Dyeing

6  
Dispatch



# Wolford: process flow sheet



Measurements	Preheating boiler feed water										Finishing		air preheating		
	B01 / Z01	V04	V05	B02	B05	B06	B06'	B07	B08	B09 / Z02	L01	L02	C01		
Temperature [°C]	12,7	11,8	14,2	66,6	93,2	97,2	120-125	224,8	176,3	100 - 110	40-45	80-90	50-55		
flow rate [m³/h]										63					
note						heat exchanger not in operation, temperature as B05?									

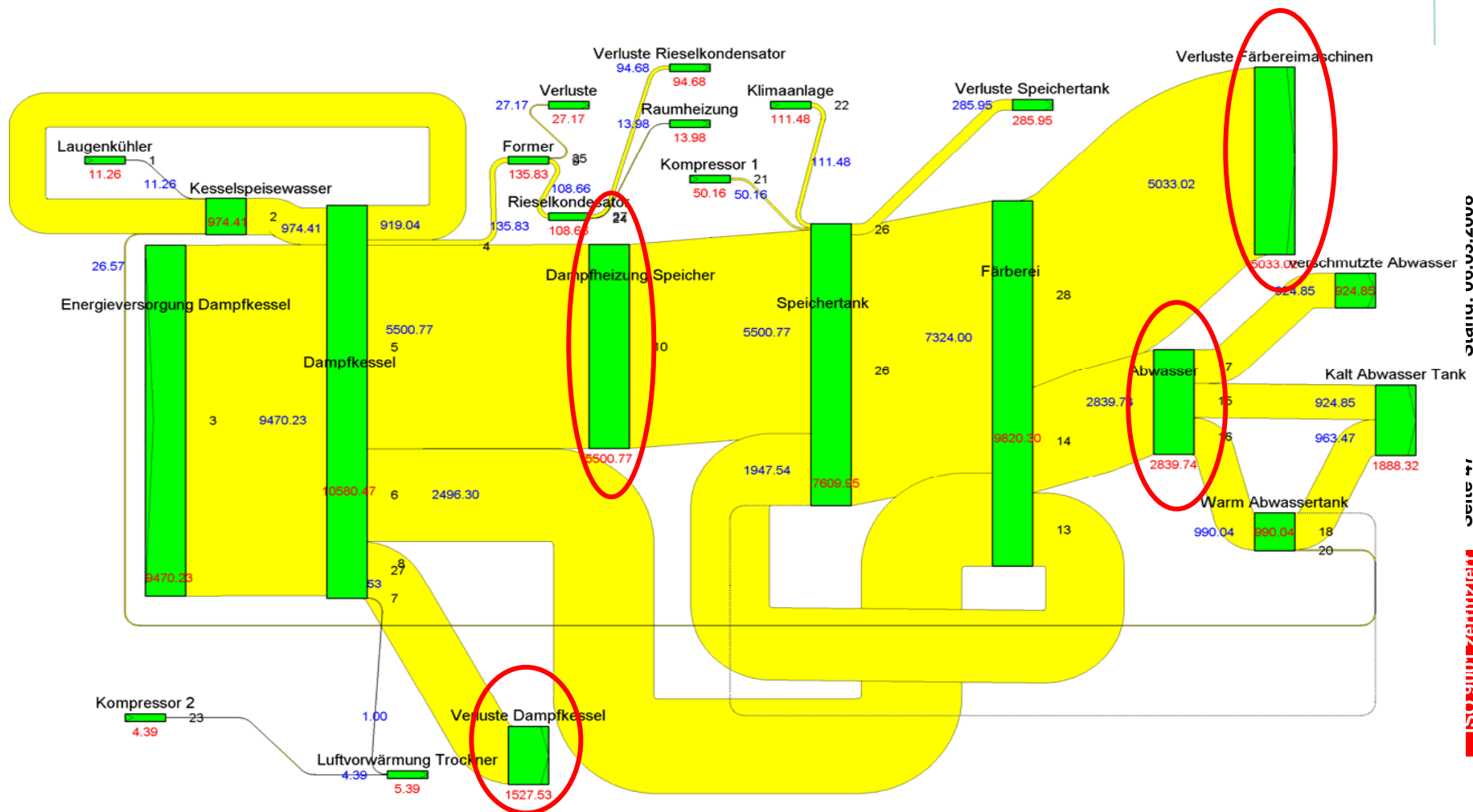
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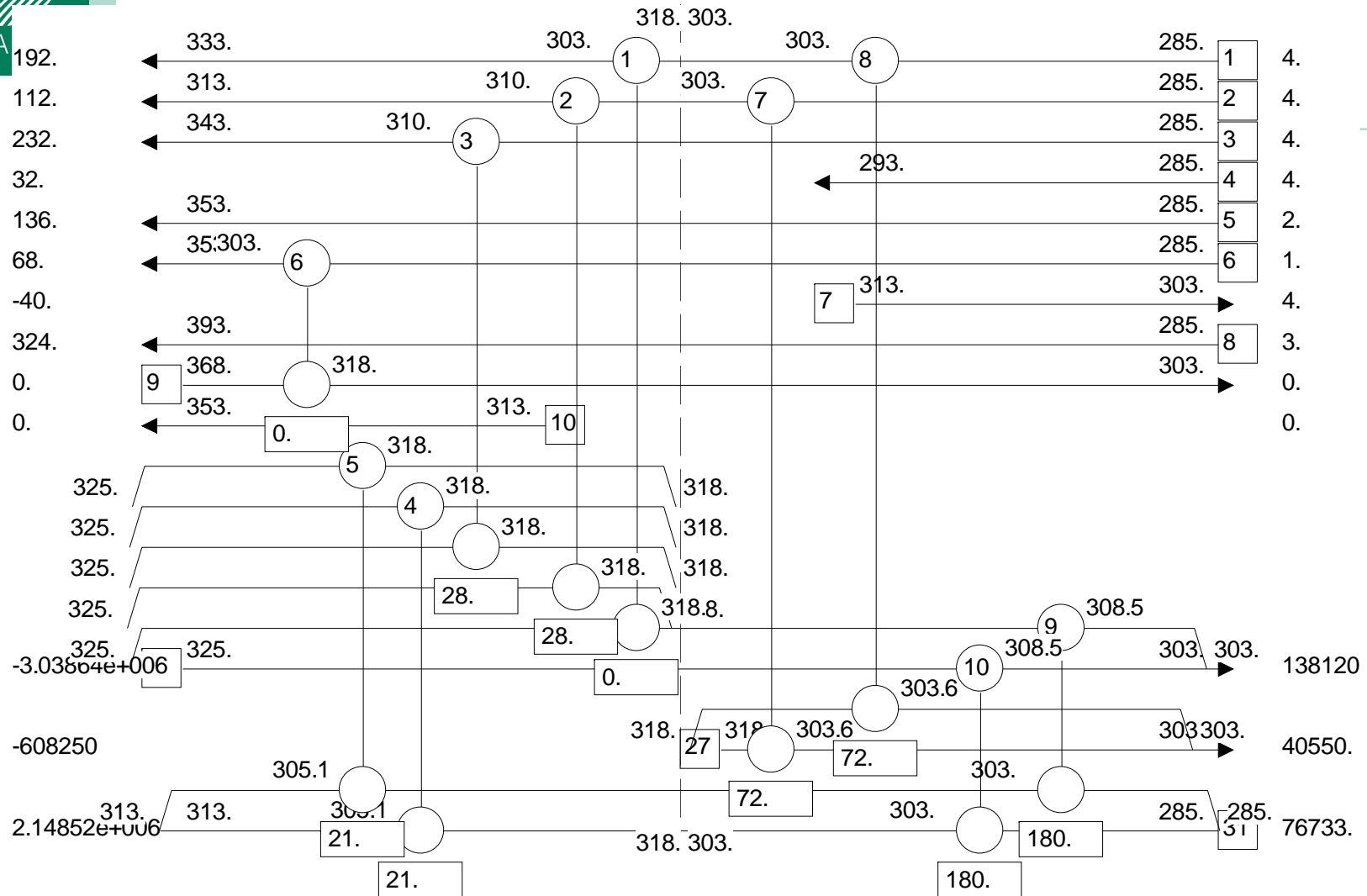
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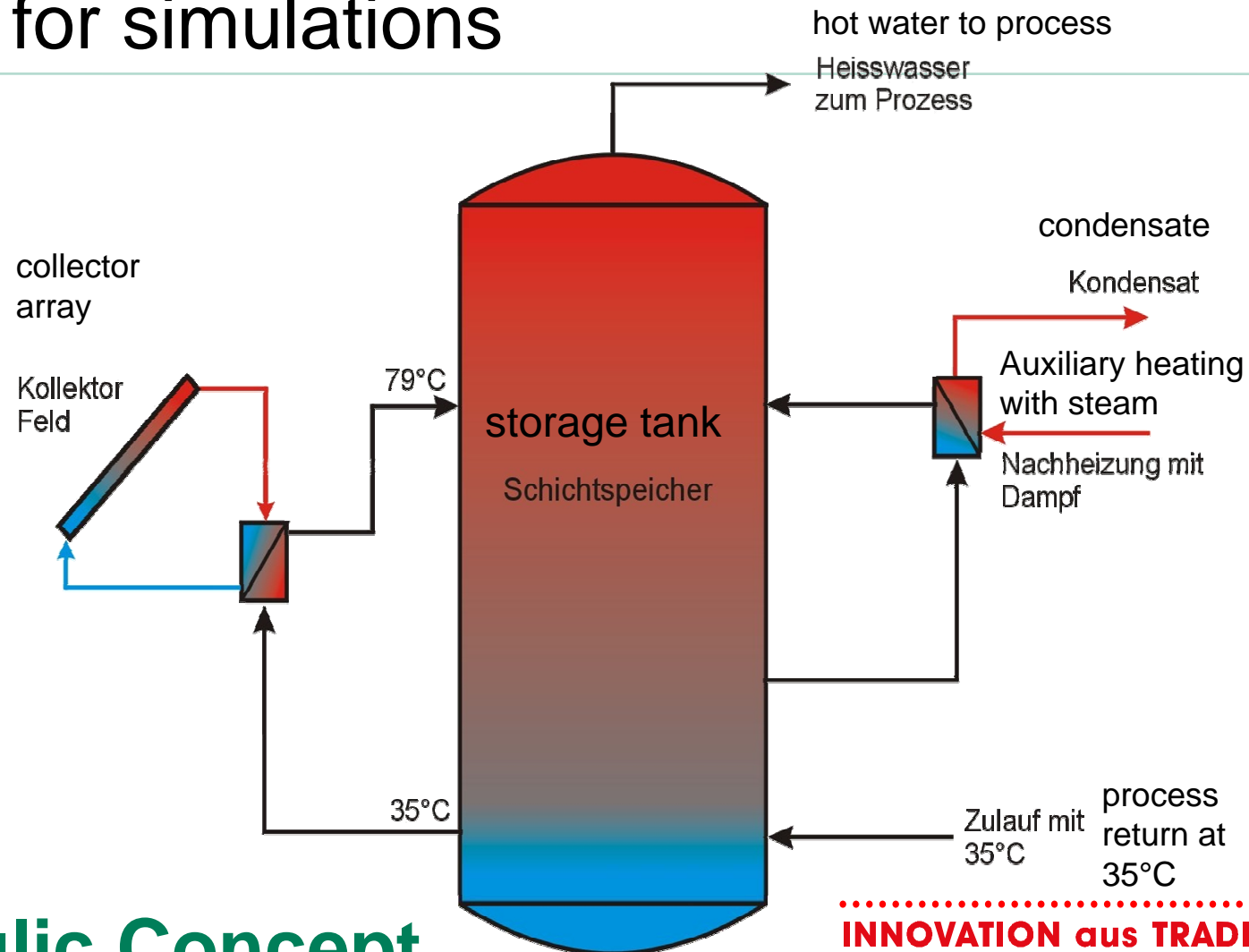
# Wolford: Energy Flows Sankey





# Pinch Analysis Wolford: heat exchangers

# Simplified scheme for simulations



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## Hydraulic Concept

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# Economics Boundary Conditions

Calculation of Cash Flows:



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Parameter	Alternative 1	Alternative 2	Alternative 3
Specific investment costs [€/m²]	320	270	270
Operating costs [€/a]	141	259	382
Gas price [€/m³]	0,24		
Electricity price [€/kWh]	0,06		
Energy cost escalation rate [%]	4		
Operating cost escalation rate [%]	2		
Discount rate [%]	4		
Expected life time of plant [a]	20		
Grants [%]	50		

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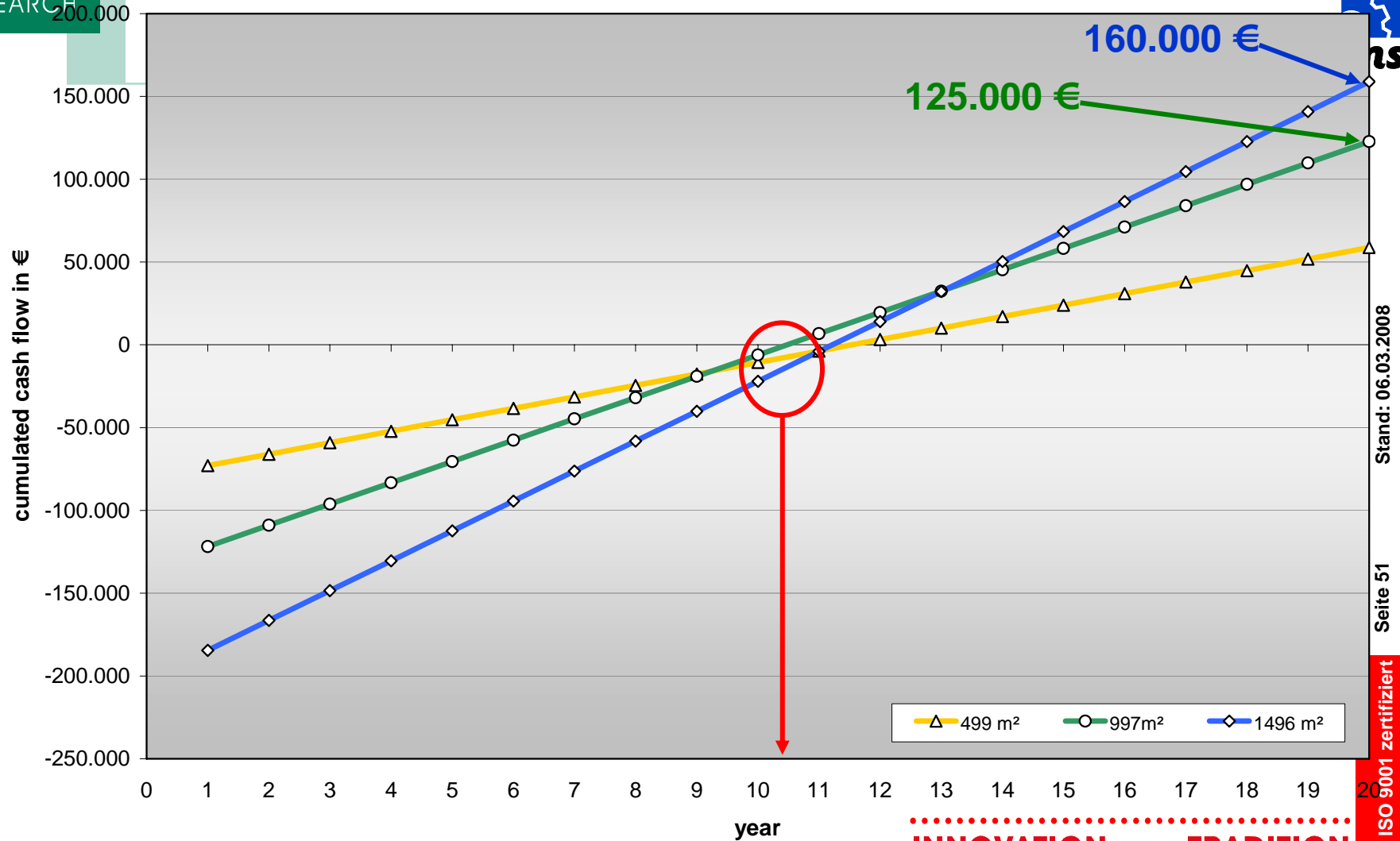
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# Results - Economics

Initial point: Total investment – grants + operating costs<sub>1</sub> – gas savings<sub>1</sub>



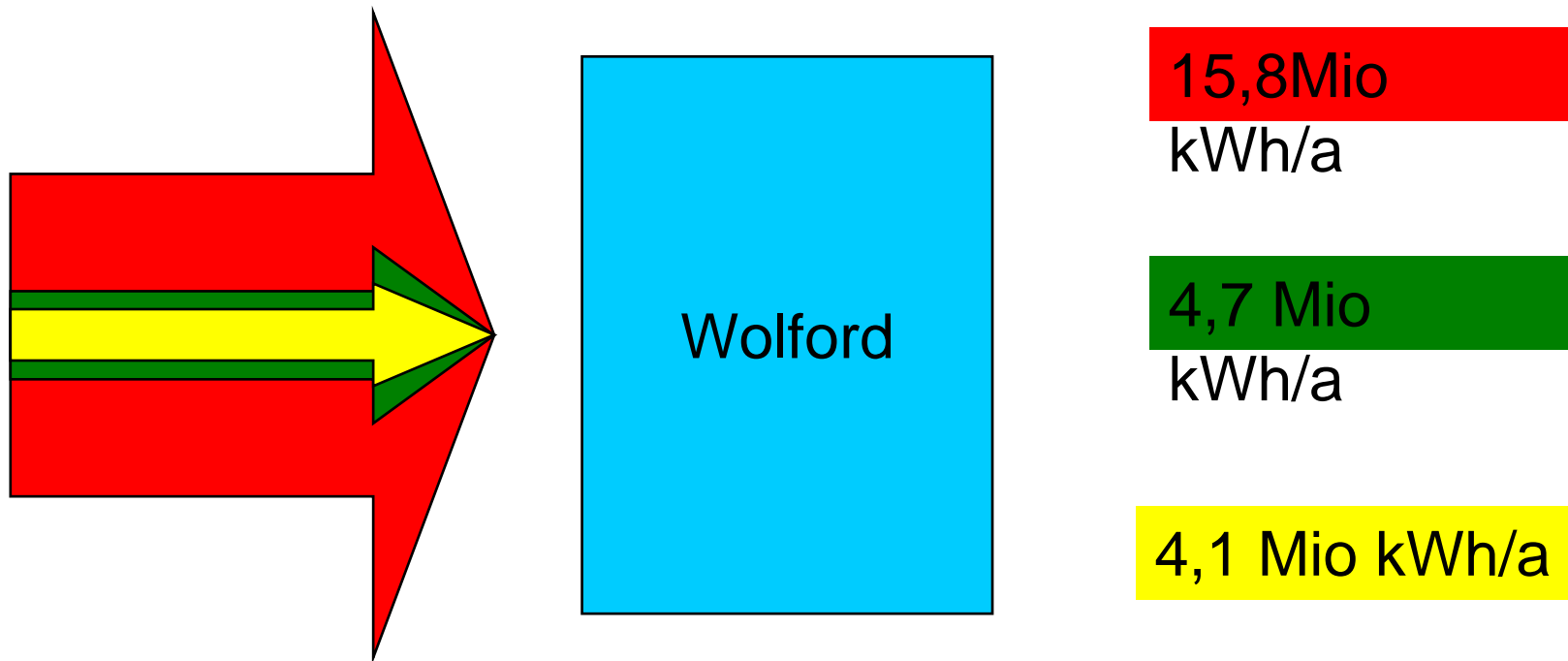
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# Total Energy Consumption



Energy saving app. 75%

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## TCA without funding (Wolford)

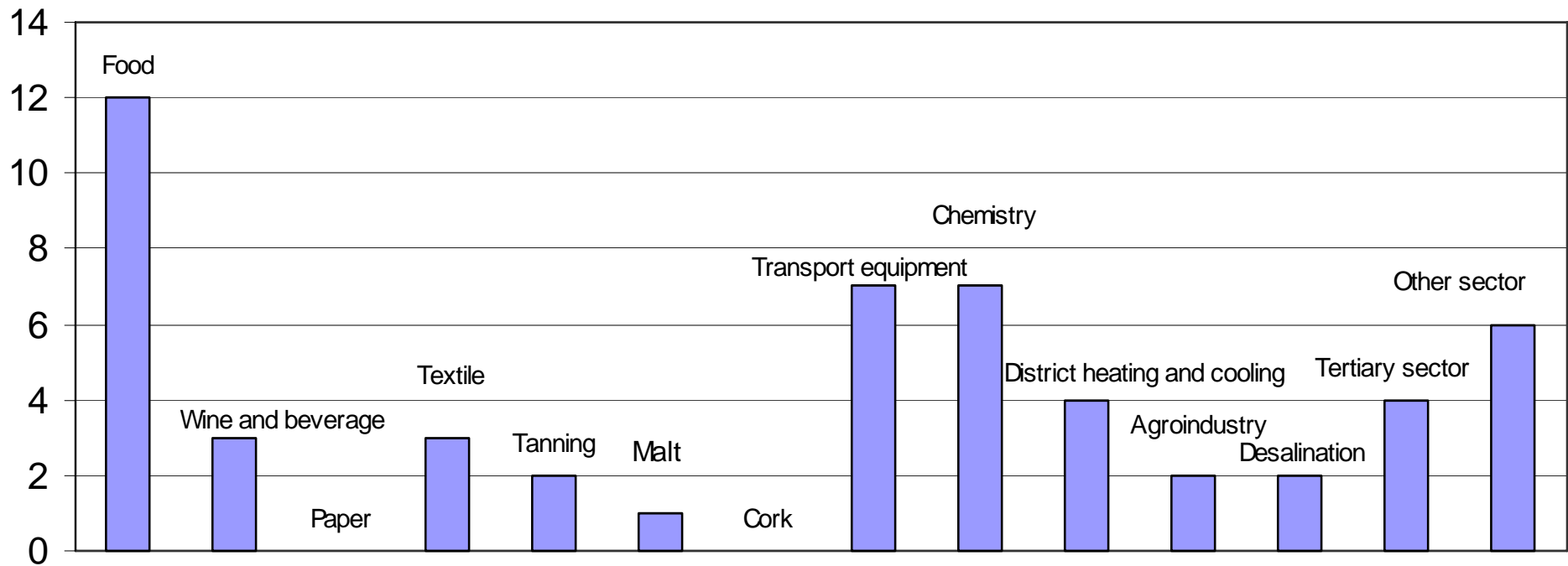
Investment Solar installation	€300.000.-
Investment heat exchange	€13.500.-
one-time charge (material,..)	€581.000.-
	<hr/>
	<b>€894.500.-</b>

**savings of operating costs per year  
(minimisation of the gas consumption) €309.168.-**

# Solar Process Heat Plants

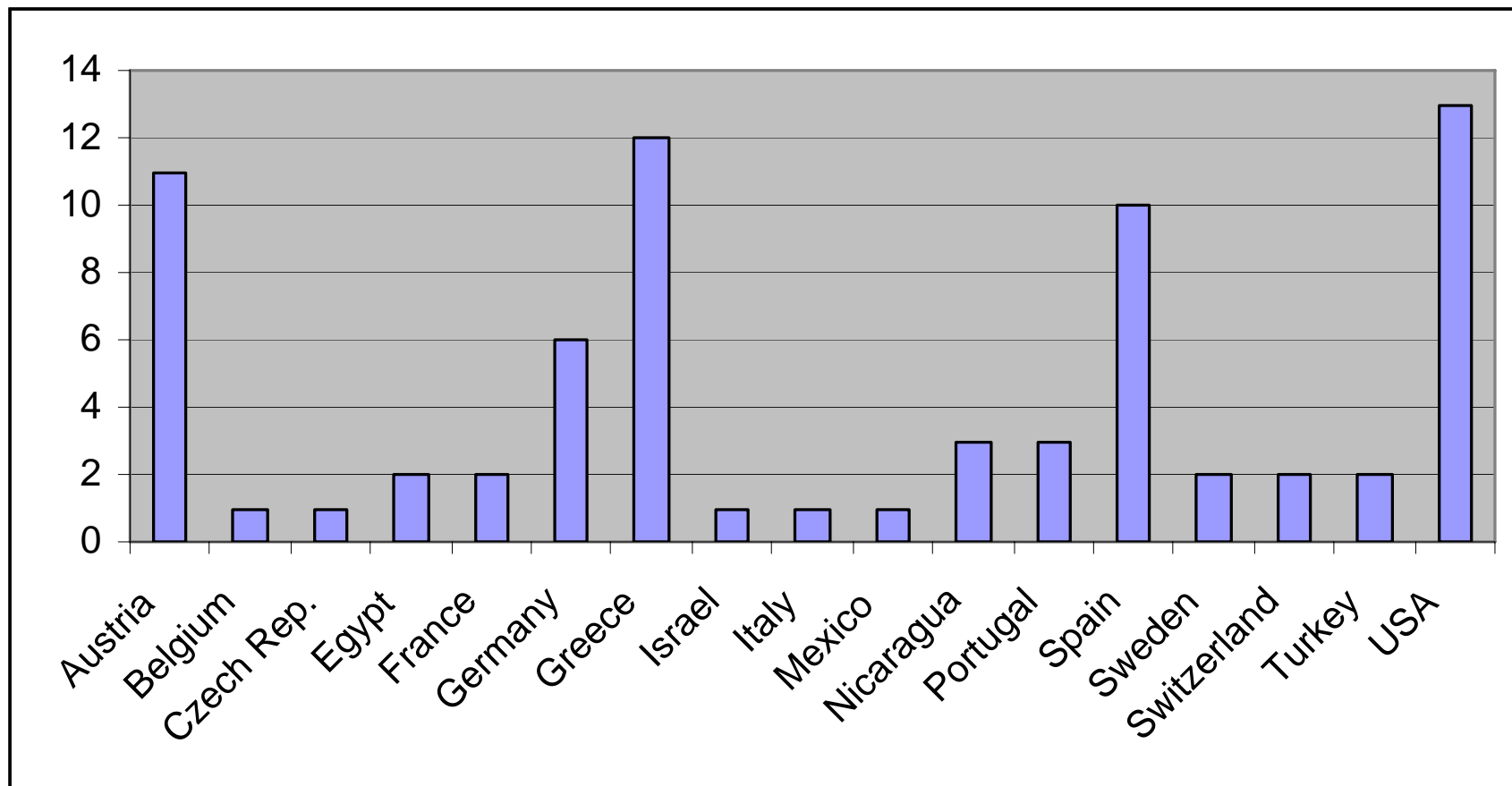
about 70 plants – 60 000 m<sup>2</sup> - world-wide identified (March 2004)

Sector distribution



# Solar heat in industry worldwide

70 installations – 60 000 m<sup>2</sup> (March 2004)



# Car wash in Austria



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Location:

**Pozo Izquierdo  
Gran Canaria  
(Spain)**

Solar field:

**48 m<sup>2</sup> (flat  
plate)**

Process:

**Sea water  
desalination**

Working temp.:

**20 – 95 °C**

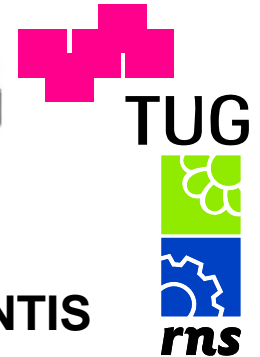
Source:

**Fraunhofer ISE**

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Plant:

**SARANTIS**

Location:

**Oinofita Viotias  
(Greece)**

Solar field:

**2700 m2 (flat  
plate)**

Process:

**Solar cooling in  
cosmetics  
industry**

Working temp.:

**90 °C**

Source:

**CRES / SOLESA**

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Plant:

**Tyras**

Location:

**Trikala (Greece)**

Solar field:

**1040 m<sup>2</sup> (flat plate)**

Process:

**dairy**

Working temp.:

**80 °C**

Source:

**CRES /**

**Solenergy Hellas**

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# Water heating by solar systems for yogurt maturing process



*Solar collectors on the roof*

## General Characteristics

Company name: Mandrekas SA

Activity: dairy

Staff: 15 employees

Location: Korinthos



*Yogurt production*

Source: Solar systems  
application in the dairy industry  
CRES, Greece

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# Mandrekas S.A.: Water heating by solar systems for yogurt maturing process

## Process hot water requirements of Mandrekas S.A

Factory operation hours: 8 hours a day, 5 days a week

Hot water consumption: 0,5 m<sup>3</sup>/day

Temperature of process water:

a) for yogurt: 30-70°C

b) for pasteurizing: >100°C

## Installation Description

The hot water from the solar collectors heats the water in the two tanks through an open circuit.

Source: Solar systems  
application in the dairy industry  
CRES, Greece

## Auxiliary heating

A steam boiler (with 600kg capacity)-LPG.

The system is in operation and the energy saving in the yogurt production process is quite remarkable.

The project was financed by 50% through the Plan for Regional Development.

## TECHNICAL CHARACTERISTICS

Provider:	Thia S.A.
Year of installation:	1993
Collector's area:	66 x 2,6 m <sup>2</sup> = 170 m <sup>2</sup>
Inclination of flat plate collector:	45 ° South
Hydraulic circuit:	water open circuit
Collector's field layout:	13 branches connected in parallel with 5 collectors per branch
Capacity of solar storage tanks:	2x1000 lt

## Solar systems for water heating for CIP washing machines and the water pre-heating in steam boilers



*CPC + flat plate collectors on the roof*



*Selective flat plate collectors on roof*

### Process hot water requirements:

Factory operation: 24 hours a day, 7 days a week

Hot water consumption: 120 – 150 m<sup>3</sup>/day

Temperatures:

a) Washing machine: 20 – 80°C

b) Other processes: 20 -130°C

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# Solar systems for water pre-heating in steam boilers



*Solar collectors on roof*

## Process hot water requirements:

Factory operation: 8 ½ hours a day, 7 days a week

Hot water consumption: 30 – 40 m<sup>3</sup>/day

Temperatures:

a) Washing machines: 20 – 80°C

b) Other processes: 20 -130°C

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

# Fruit jam, Nicaragua



# Pasteurizing of juice

Gangl, Austria



60 m<sup>2</sup> Flat plate collectors  
storage: 21,9 m<sup>3</sup> (1 x 20 m<sup>3</sup> , 1 x 1,9 m<sup>3</sup>)

Pasteurization of fruit juice  
bottle rinsing  
production of vinegar and sider

Back-up: oil

installation: 2004

# Timber drying in Austria



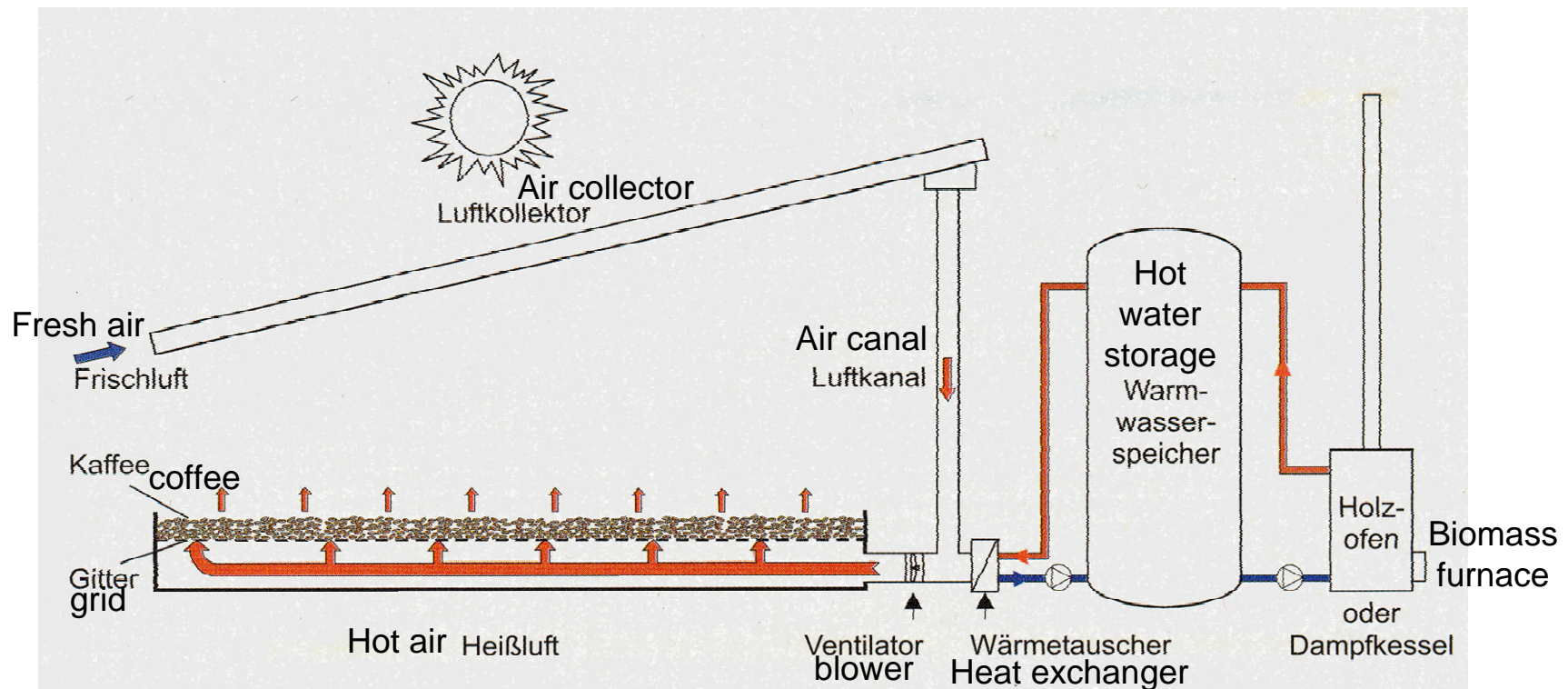
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# Solar coffee dryer



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# Drying of coffee, Zimbabwe



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# Drying of coffee in Costa Rica

Coopeldos

595 kW<sub>th</sub>

(850 m<sup>2</sup> air collector)



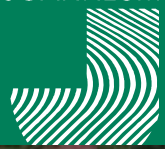


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# Rinsing water for food industry





Plant:

**Parking Service**

Location:

**Barcelona (Spain)**

Solar field:

**510 m2 (flat plate)  
(in construction)**

Process:

**Container  
cleaning (hot  
water)**

Working temp.:

**20 – 80 °C**

Source:

**AIGUASOL**

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**TUG**



**rns**

Plant:

**Parking Service,  
Transportation**

Location:

**Barcelona  
(Spain)**

Solar field:

**510 m2 (flat  
plate)**

**(in construction)**

Process:

**Container  
cleaning (hot  
water)**

Working temp.:

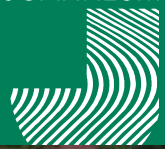
**20 – 80 °C**

Source: **AIGUASOL**

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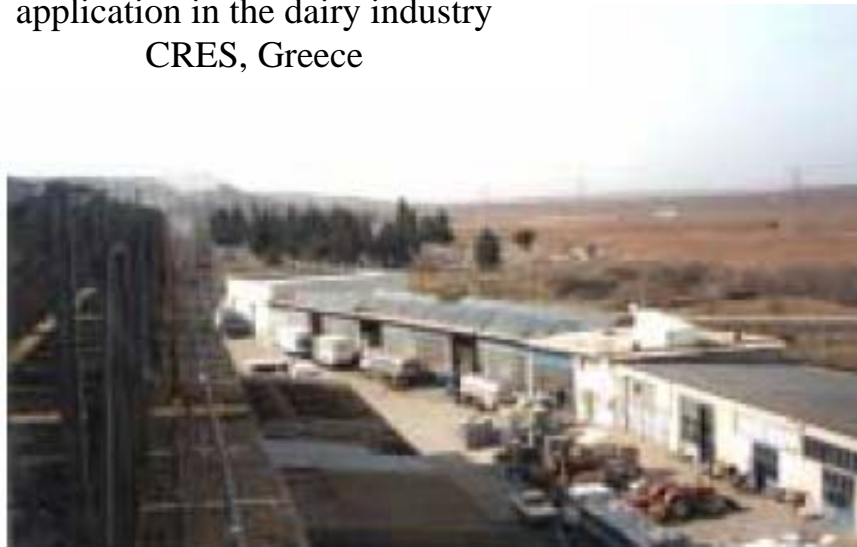


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# Mevgal S.A.: Solar systems for water heating for CIP washing machines and the water pre-heating in steam boilers

Source: Solar systems  
application in the dairy industry  
CRES, Greece



*CPC + flat plate collectors on the roof*

## Process hot water requirements:

Factory operation: 24 hours a day, 7 days a week

Hot water consumption: 120 – 150 m<sup>3</sup>/day

Temperatures:

- a) Washing machine: 20 – 80°C
- b) Other processes: 20 -130°C

## General Characteristics

Company name: Mevgal SA

Activity: dairy

Staff: 800 employees

Location: Thessaloniki



*Selective flat plate collectors on roof*

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**INNOVATION aus TRADITION**

# Technical characteristics

Provider:	Intersolar S.A
Year of installation :	1999
Collector's area :	a) $168 \times 2.4 \text{ m}^2 = 403.2 \text{ m}^2$ (selective flat plate collectors) b) $108 \times 2 \text{ m}^2 = 216 \text{ m}^2$ (flat plate collectors) c) $40 \times 2.7 \text{ m}^2 = 108 \text{ m}^2$ (CPC collectors)
Inclination of flat plate collector:	$45^\circ$ South
Hydraulic circuit:	closed loop water /propylene glycol
Collector's field layout (selective flat plate collectors):	14 parallel branches with 12 collectors per branch
Collector's field layout (CPC):	8 collectors connected in parallel
Collector's field layout (flat plate collectors):	9 parallel branches with 12 collectors per branch
Capacity of solar storage tanks:	$2 \times 2.5 \text{ m}^3$ (in series) – selective collectors $2 \times 2.5 \text{ m}^3$ (in parallel) – CPC + flat plate collectors

Source: Solar systems  
application in the dairy industry  
CRES, Greece

# ALPINO S.A.: Solar systems for water pre-heating in steam boilers

## General Characteristics

Company name: ALPINO SA  
Activity: dairy  
Staff: 110 employees  
Location: Thessaloniki



*Selective flat plate collectors on roof*

## Process hot water requirements:

Factory operation: 8 ½ hours a day, 7 days a week

Hot water consumption: 30 – 40 m<sup>3</sup>/day

Temperatures:

- a) Washing machines: 20 – 80°C
- b) Other processes: 20 -130°C

Source: Solar systems  
application in the dairy industry  
CRES, Greece

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# High temperature collector at Sarigerme Park Hotel in Dalaman, Turkey





Plant:

**EI NASR**

Location:

**Egypt**

Solar field:

**1900 m<sup>2</sup>  
(parabolic trough)**

Process:

**Saturated steam  
(173 °C/8bar) for  
processes in the  
pharmaceutical  
industry**

Working temp.:

**173 °C**

Source: **Fichtner Solar  
GmbH**

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Plant:

**BRISA**

Location:

**Carcavelos  
(Portugal)**

Solar field:

**663 m<sup>2</sup> (CPC)**

Process:

**Space heating  
and cooling**

Working temp.:

**80 °C – 90 °C**

Source:

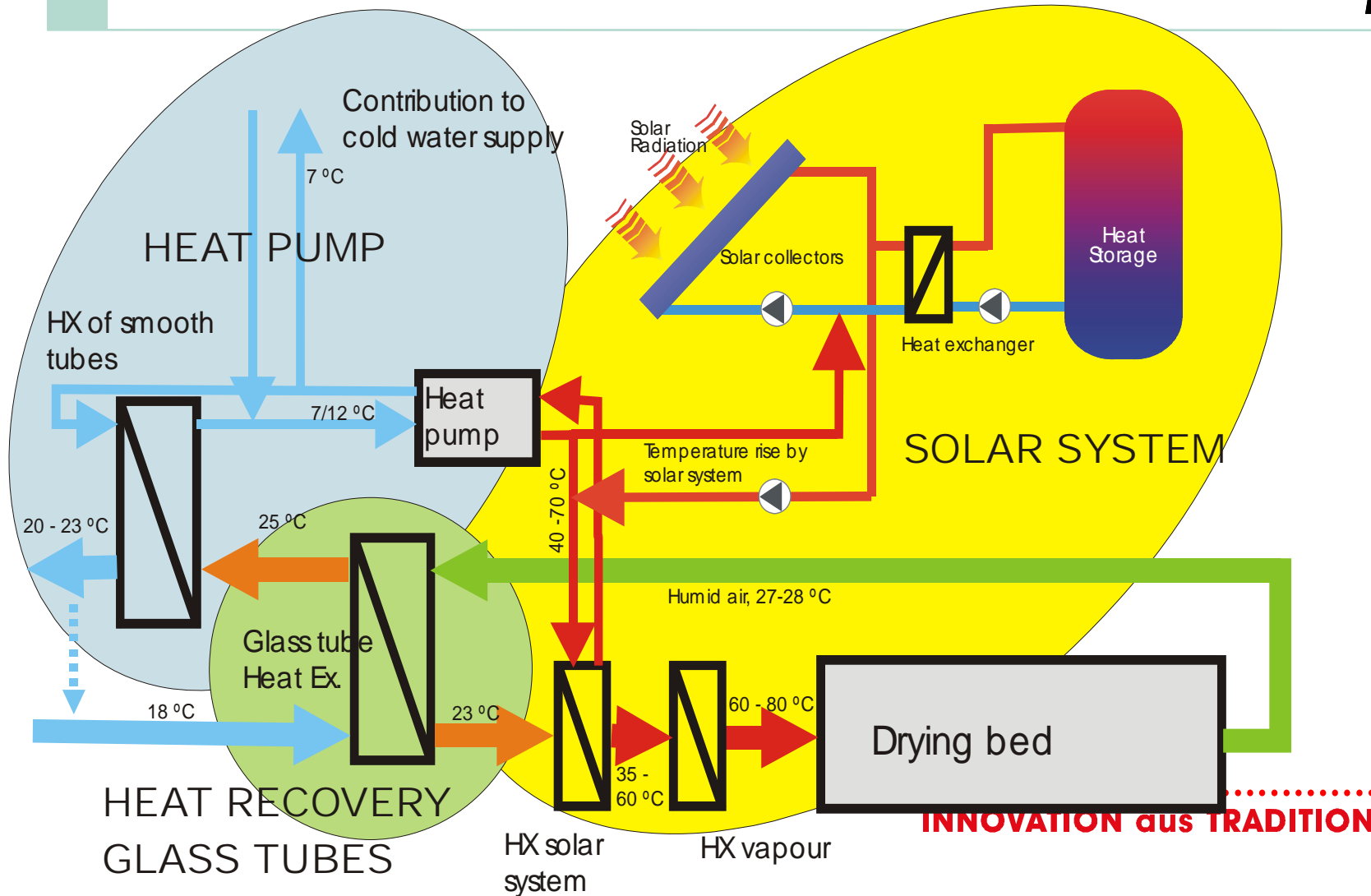
**AO SOL Ltda.**

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# Malt house Heineken Sevilla – Solar Energy and Heat Recovery



## Investment costs

Data based on collector GROSS-AREA

Collector type	Investment costs [€/m <sup>2</sup> ]
Flat plate	275
CPC	300
Parabolic trough	312.5
Evacuated flat-plate	400
Evacuated tube	437.5
Evac. tube with CPC	437.5

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## Evaluation criteria

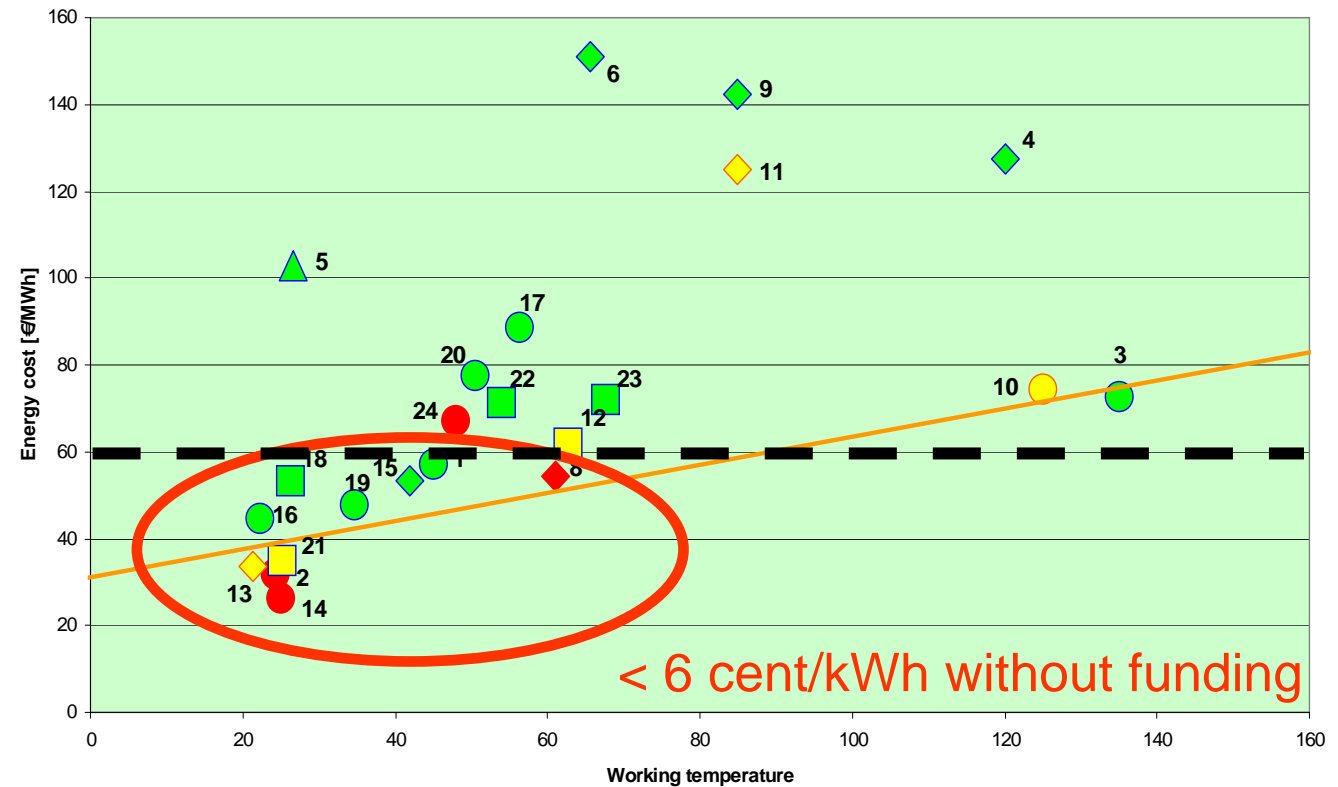
Continuity of  
the heat  
demand

Working  
temperature  
(heating-  
preheating)

Climatic  
conditions

System size

POSHIP Case Studies: energy cost vs. working temperature



Solar heat costs for the systems studied

Colors: solar radiation in kWh/m<sup>2</sup>: > 1750 (red), 1600 – 1750 (yellow), 1400-1600 (green)

Symbols: continuous demand (circles), continuous 5 days / week (rombs), seasonal(triangles).

# Concurring Technologies

- Energy efficiency
- New Technologies
- Heat integration
- Combined heat and power
- Combined heating and cooling
- more ...

# Conclusions

- In many industries there exists a great variety of low temperature processes
- Solar thermal plants will be designed to cover a part of the load only
- Solar thermal energy should go hand in hand with energy efficiency
- Many installations turned out to be economically advantageous at present energy prices
- Systems consisting of solar thermal plants and biomass can support industrial processes with 100% renewable energy.