MSc Program

Renewable Energy in Central & Eastern Europe

The Use of Solar Thermal Energy in Production Processes of Pomurske mlekarne in Slovenia

A Master's Thesis submitted for the degree of

"Master of Science"

supervised by

Dipl.-Pad.Ing. Werner Weiss

Dr. Janez Petek

Dipl. Ing. Boštjan Baboc

0827588

Maribor, 21.11. 2011

Affidavit

I, **Boštjan Baboc**, hereby declare

1. that I am the sole author of the present Master Thesis, " **The Use of Solar Thermal Energy in Production Processes of Pomurske mlekarne in Slovenia**", 136 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

Maribor, 21.11.2011 ______________________________

Date Signature

Abstract

Current environmental issues and impacts on the environment are being discussed on a daily basis in different part of world and sectors, too. One of the biggest polluters is the industry sector, which consumes a lot of energy and emits huge quantities of greenhouse gas emissions.

Worldwide industries consume more than 30% of all primary energy consumption. The share is quite big, if we consider that more than 95% of that energy is produced from fossil fuels, which are not renewable.

The focus of this master's thesis is placed on the industrial processes heat system through the examination of the possibilities of the use of solar energy in milk production processes in the biggest milk production company in Slovenia.

The outline of the study will:

- Present the overview of worldwide use of solar thermal energy;
- Discover the potentials of the use of solar energy in industrial processes;
- Present an analysis of processes and utility systems in the milk production company and discuss how to integrate solar heat in the existing company processes;
- Present the economical assessment of such investment for Pomurske mlekarne.

At the end, the master's thesis provides clear answers and opens new possibilities of achieving new movements in the industry sector.

As soon as the fossil fuel price exceeds the oil pick price from the past, the interest of investment in solar energy in the industry sector will increase by more than 200%, in comparison to the present situation. We know that solar energy is free energy with an inexhaustible energy potential.

New efficient technologies and new generations will guide the new sunny future.

Table of contents

List of Tables

List of Figures

List of Abbreviations:

EJ	Exajoules
YJ	Yoctojoule
Mboe	Millions of barrels of oil equivalent
MWth	Thermal megawatt
kWth	Thermal kilowat
m2	Surface
AR	Glass anti reflection
CPC	Compound parabolic concentrator collectors
LCF	Linear concentrating Fresnel Concentrating Collector with
CCSta	Stationary Reflector
HT	Higher tariff
LT	Lower tariff
UHT	Ultra High Temperature
CIP	Cleaning In Place
Hot water	HW
IR	infrared radiation
UV	ultraviolet rays
TCW	tap cold water

1 Introduction

The motivation of this master’s thesis is to find the potentials of the use of solar energy in industrial processes in the Slovenian market and other former Yugoslavian countries. Before the 1991 break-up, Yugoslavia was the main industrial country in the today’s Eastern Europe.

Today, Slovenia has high and good quality industrial sectors in expansion for local and worldwide customers. In the national energy balance sheet for final energy consumption the industry represents 30%. This information shows that industry in Slovenia has a big share in the quantity and rate of greenhouse gas emissions, which shows that environmental pollution is visible and perceptible.
We should not neglect the fact that more than 80% of consumed energy is generated from non-renewable energy sources.

The research and the results given in the thesis will provide a practical outlook of the potentials of investing in such solutions in the industry.
Until present, there are not many solar thermal process heat systems installed in Slovenia. To accelerate the integration and understanding of such an investment, the industry should receive support from government, accessibility studies about this topic (with good practice examples) and increase in the price of fossil fuels.
One further topic is involving a national producer of solar thermal equipment in order to facilitate and improve the integration and production of such solutions, and to open of new job positions in the future.

Last but not least, Slovenia has to achieve the EU goals until 2020 with regard to having a 25% share of renewable energy sources.
In order to achieve the goal, the government has to find the right solutions for the industry sector to support and promote the use of solar energy in their processes.

The main questions which come up are:
What is the potential of using solar thermal energy in industry?
Which is the adequate solar collector technology to be used for processes systems?

How to integrate a solar system in the existing and operating process and what impact will it have?
Will such investment be sufficiently profitable for the company?

The author’s writing of the master’s thesis is based on his own professional experience in the field of solar energy and is based on related literatures with regard to the data used:

- Energy audit and rational energy consumption study for Pomurske mlekarne d.o.o., author: STENG-national cleaner production centre Ltd. (2010)
- Handouts: Renewable Energy in Central and Eastern Europe, 2008-2010 edition
- Publications: IEA Task 33 Solar Heat for Industrial Applications.
- Publications: POSHIP the potential of solar heat in industrial processes.
- Publications: SO-PRO solar process heat project.
- TU Vienna’s library and past master thesis from this sector.

2 The world wide use of solar thermal and it's applications

2.1 Solar Energy a potential for use

The worldwide primary energy consumption is approximately **470 EJ –exajoules** (470x10^{18} J**, 0.00047 YJ**) **or 11.190 mboe**. More then **80%** of this energy is produced from fossil fuels. This means that we use a very small share of the available renewable energy sources as primary energy and this is only around 13%. Our planet has available an estimated quantity of fossil fuel energy of **350.000 EJ** (**0.35 YJ** – yottajoule or **6.10E+07 Mboe**). These numbers clearly show us that fossil fuels are limited. The sun radiates to the earth a yearly amount of **3.8 YJ** of usable energy. In one year we receive from sun more than 10 times energy that we have available from our limited supply of fossil fuels. The table and the following illustrations give a clear picture of the figures for the potential of RES.

Table 1: Comparison between world consumption, estimated fossil energy and available solar energy

Primary energy worldwide demand	**0.00047 YJ**
Fossil energy estimated	**0.35 YJ**
Emited solar energy year	**3.8 YJ/year**

The sun is a virtually unlimited source of energy for all the world but there are some technical limitations for its use.

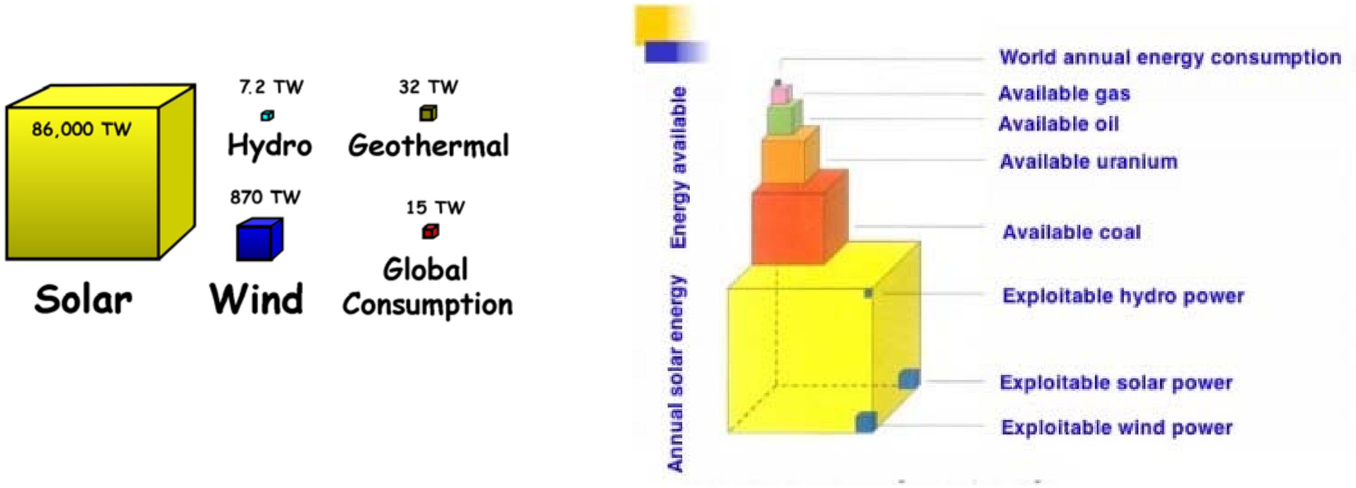


Figure 1: Potential of solar energy comparison with other RE sources (Ape, 2008)

2.2 Why use solar energy?

There are many reasons to choose solar energy that can be grouped into different categories:

- Environmental impact
- Financial benefits
- Energy independence
- Benefits to users

Environmental Impact

Many people decide to use solar energy because of the positive impact on the environment (no greenhouse emissions, no fossil fuel consumption, etc.). People understand that solar energy is a sustainable and clean energy by comparison to fossil fuels and it can be simply utilised for heating, cooling, lighting and electricity.

Financial Benefits

One of the reasons for the popularity of solar energy is the financial benefit for end users. The goal is to reduce costs with a solar based system for various purposes, also the reduction of costs have a further benefit on real estate value (aesthetic, economic and environmental issues) Many new customers wish to buy, rent or live/work in sustainably run homes or offices. Green buildings are an issue of both today and tomorrow. With regard to economy and the social sector solar energy can provide/create new jobs based on what is also a long-term sustainable development.

Energy Independence

Investing in solar energy is long term investment not only financial but also for energy independence. The Ukraine / Russia crisis clearly illustrated how dependant the west is on fossil fuels. With solar energy it is possible to produce heat, cooling and electrical power allowing an independence from the utility companies and from fossil fuel prices.

If we build zero energy (passive) homes or even positive energy buildings we can become independent and secure consumers for the present.

2.3 What is solar thermal energy?

One of oldest forms of using the sun is to transform this solar thermal energy to produce heat. We can say that this is more than a thousand year old knowledge-technology. Solar thermal energy can be utilize in a variety of ways, for drying, cooling or for production of electricity energy. A constant development of the technology provides an opportunity to find new solutions of how to use this inexhaustible source of energy more efficiently, with lower costs and sustainability.

2.4 Solar heat worldwide

2.4.1 Solar thermal capacity in operation worldwide

By the end of 2008 worldwide the total capacity of solar thermal systems in operation was the equivalent of 151.7 GWth which corresponds to 217 million square meters[1] (To define the nominal capacity of the area of installed collectors this assumes a factor 0,7 kWth/m2). From this total capacity the predominant collectors produce 131.8 GWth from flat-plate and evacuated tube collectors then 18.9 GWth comes from unglazed plastic collectors and the smallest share of 1.2 gWth was from the installation of air collectors.

The main users are China (87.5 GWth), Europe (28.5 GWth), US and Canada (15.1 GWth) in total these countries capacity is 131.1 GWth (a share of 86.3%), the remainder is 20.6 GWth or 13.7% shared by Japan, Australia, New Zealand, Asia, Middle East and Africa.

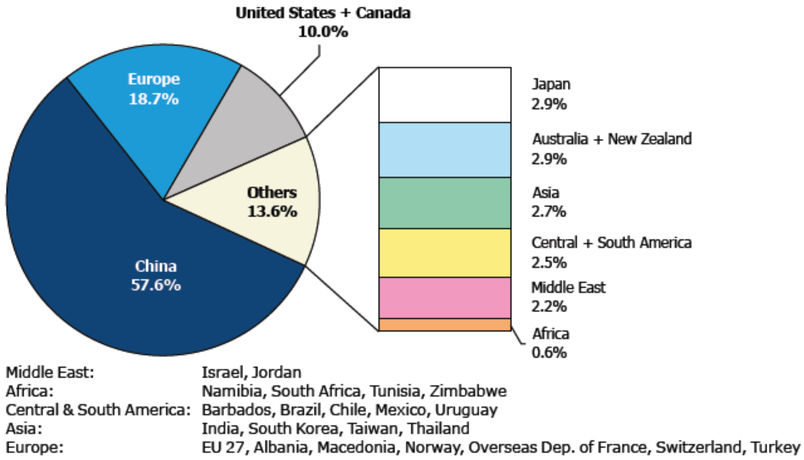


Figure 2: Share of total collector installations (Solar heat world wide -SHC 2010)

ountry	Water Collectors*			Air Collectors*		TOTAL [MW_th]
	unglazed	glazed	evacuated tube	unglazed	glazed	
Albania		40.1	0.2			**40.3**
Australia	2,870.0	1,372.4	26.2			**4,268.6**
Austria	436.9	2,305.2	32.9			**2,775.0**
Barbados		57.5				**57.5**
Belgium	32.8	145.0	14.4			**192.2**
Brazil	562.0	2,443.3				**3,005.2**
Bulgaria		21.2				**21.2**
Canada	507.7	63.8	3.9	110.3	0.9	**686.6**
Chile	1.0	12.4				**13.4**
China		7,170.3	80,329.7			**87,500.0**
Cyprus		561.1	1.3			**562.5**
Czech Republic	10.2	83.1	16.1			**109.4**
Denmark	14.4	285.5	3.6	2.3	12.6	**318.4**
Estonia		1.3				**1.3**
Finland	8.2	16.3	0.8			**25.4**
France	70.2	1,214.0	22.2			**1,306.4**
Germany	504.0	6,507.7	715.0		23.5	**7,750.2**
Greece		2,709.0				**2,709.0**
Hungary	1.9	33.5	3.4			**38.8**
India		1,756.3	15.6		11.4	**1,783.3**
Ireland		39.9	13.3			**53.2**
Israel	18.7	2,641.0		0.3		**2,660.0**
Italy	17.7	840.0	174.7			**1,032.4**
Japan		4,040.4	71.1		309.3	**4,420.8**
Jordan		449.7	175.4			**625.1**
Korea		999.5				**999.5**
Latvia		4.8				**4.8**
Lithuania		2.9				**2.9**
Luxembourg		14.6	0.5			**15.1**
Macedonia		15.4	0.5			**15.9**
Malta		23.8				**23.8**
Mexico	347.6	376.2				**723.8**
Namibia		4.5	0.3			**4.7**
Netherlands	252.6	240.0				**492.6**
New Zealand	4.6	82.9	6.8			**94.2**
Norway	1.2	8.2	0.2		0.8	**10.5**
Poland	0.9	193.3	51.4	2.0	1.7	**249.3**
Portugal	0.9	238.5	8.5			**247.9**
Romania		52.1				**52.1**
Slovak Republic		67.4	7.7			**75.1**
Slovenia		83.1	2.8			**85.9**
South Africa	489.8	180.8	12.2			**682.8**
Spain	60.5	1,021.4	67.2			**1,149.1**
Sweden	73.5	164.5	28.7			**266.7**
Switzerland**	148.3	357.0	21.0	591.5		**1,117.7**
Taiwan	1.3	1,154.2	32.9			**1,188.4**
Thailand		53.7				**53.7**
Tunisia		195.9	4.4			**200.3**
lphaTurkey		7,445.8				**7,445.8**
United Kingdom		218.5	40.8			**259.3**
United States	12,409.0	1,477.3	430.2	0.1	113.5	**14,430.0**
Uruguay		3.4				**3.4**
Zimbabwe		12.1	0.02			**12.1**
TOTAL	**18,845.8**	**49,501.8**	**82,335.9**	**706.4**	**473.8**	**151,863.7**

* If no data is given: no reliable database for this collector type is available
** Unglazed air collectors in Switzerland: this is a very simple site-built system for hay drying

Figure 3: Total capacity in operation at the end of 2008 [MWth] (Solar heat world wide - SHC 2010)

2.4.2 Distribution by Application

The dominant systems worldwide (mostly in Europe, China and Japan) are flat-plate and evacuated tube collectors used to provide hot water and for space heating. In the large markets like US and Australia the dominant application are unglazed plastic absorbers for swimming pool heating. With a share of **54.2 %** of the global market the dominant collector type is vacuum tube collectors, with **32.6%** market share followed flat-plate collectors. The small share of **12.4%** of the market place are unglazed plastic collectors and with 0.8% share are air collectors.

For evacuated tube collectors the dominant market are in China and Jordan in all other countries the flat plate collector remains the dominant collector type. In countries like Germany, Poland, US, Italy, Spain and UK there is a notable growing market share of evacuated tube collectors. In countries like Sweden and South Africa the market share of evacuated tube collectors have become almost equal to the share of flat plate collectors.

The solar systems in use can be divided into pumped or thermo-syphon systems. In US, EU and Australia the systems installed are mainly pumped solar thermal systems in other markets like China, Brazil and Japan the predominant systems are thermo-syphon (Figure 4).

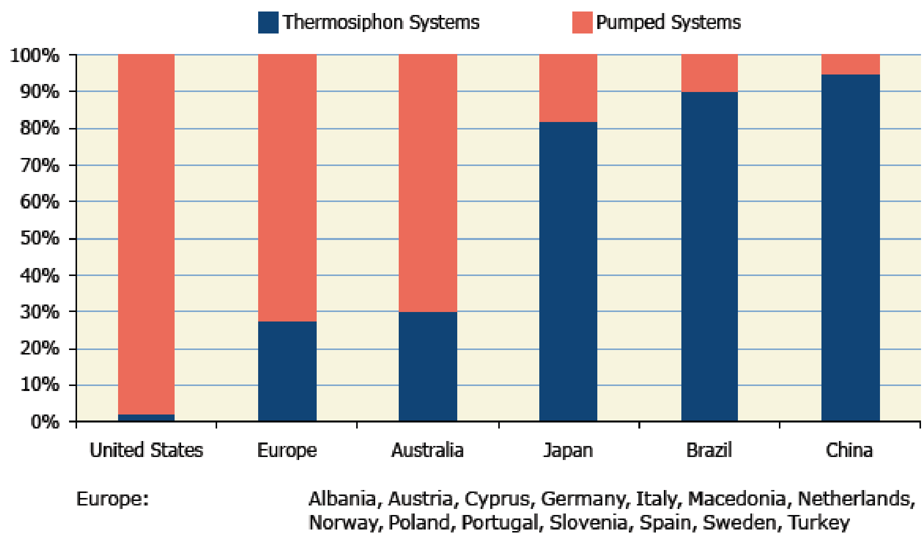


Figure 4: Distribution of different solar thermal systems by economic regions in 2008 (Solar heat world wide -SHC 2010)

On the EU market there is offered a wide range of solar thermal applications for hot water preparation, space heating for single/multi family houses, hotels and large scale plants for district heating or also for the growth of new applications in industrial processes.

Today in the EU there are approximately **150 large** scale systems (up to $500m^2$, 350 kW_{th}) in operation with total installed capacity of **160 MWth**. For district heating the biggest plant is located in Denmark with **13MWth** (18.300 m2) and the largest solar system for an industrial process is installed in China with **9 MWth** (13,000 m2) for textile company.

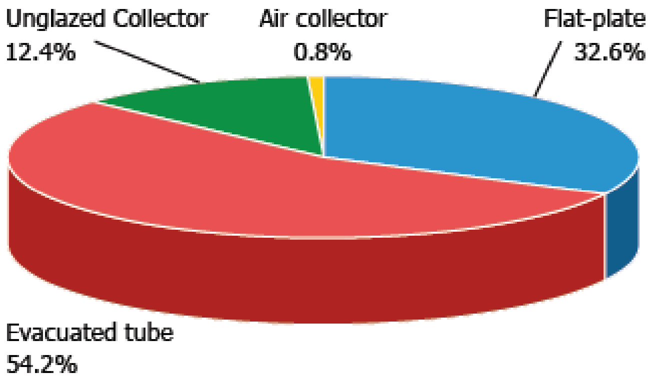


Figure 5: Total instaled capacity of different type of solar collectors in operation worldwide in 2008 (Solar heat world wide -SHC 2010)

2.4.3 Leading countries

2.4.3.1 Flat-plate and evacuated tube collectors

The leading countries showing the total installed capacity of evacuated tube and flat-plate collectors at the end of the year 2008 are: China (87.5 GWth), Turkey (7.5 GWth), Japan(4.1 GWth) and Greece (2.7 GWth). If we compare the market share per 1000 inhabitants the leading countries are Cyprus (527.2 kWth), Israel (371.3 kWth), Austria (285 kWth), Greece (252.6 kWth), Germany (87.7 kWth), Australia (66.6 kWth) and China (66.4 kWth).

2.4.3.2 Unglazed plastic collectors

The leading country with largest installed capacity of unglazed plastic collectors are US with 12.4 GWth, Australia (2.9 GWth), Brazil (0.6 GWth), Germany, Canada and South Africa with around 0.5 GWth and Austria with 0.4 GWth.
If we compare the share of installed capacity per 1000 inhabitants the picture is totally different with the leading country of Australia (136 kWth), Austria (53.2 kWth), US (40.8 kWth), Switzerland, Canada and Netherlands with installed capacities between 15 and 20 kWth.

2.4.4 Installed capacity in 2008

In 2008 worldwide the new capacity installed was 29.1 GWth corresponding to 41.5 million square meters of solar collectors. Compared to 2007 the grow of new installations is 34.9%, which shows a significant growth compared to the year 2006/2007 which was 18.8% (nearly a double growth). The main attribute of such big growth is derived from governmental law for efficiency in the use of renewable energy and special green subsidies for installed capacity. For example in China the law now prohibits the use of electricity for the production of hot water. In many other EU countries there are subsidies available for each installed 1m2 of collectors, which motivates investors to think and act green.
If we compare glazed and unglazed collector installation we can see that a new capacity of 27.5 GWth (or 94.6% of all new capacity in 2008) glazed collectors was installed. The growth rates for glazed collectors in China was (+34.8 %), Europe (+62.5%) and in US (+41.8%).
If we further compare the growth with the year 2007 for different types of collector we can see that market share for flat plate collectors increased by +42.7% and for evacuated tube collectors for + 35.4% and for unglazed the highest growth of +183.2%.
Worldwide the most dynamic markets for water collectors (all types) were in some EU countries. If we compare installed capacity for 2008 with 2007 the increase is seen in Macedonia (+105%), Germany (+116%), Slovenia (+115%), Ireland (+122), Poland (+90%), Belgium (+79%) and Cyprus (+158%) As well as the EU markets a big increase can be observed in Jordan (+344%), Canada (+128,5%) and Tunisia (+100%). We can also observe a decrease in the market of Slovak Republic (-47%), Taiwan (-12,7%) and Israel (-7%).

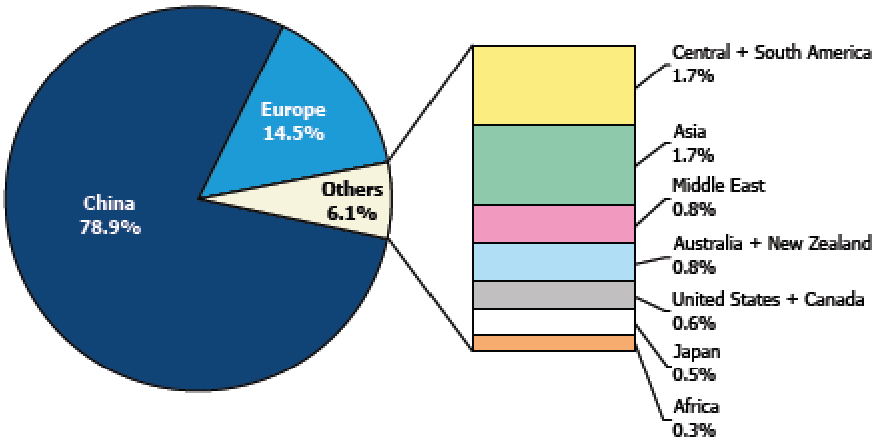


Figure 6: Share of new installed glazed collector by regions in 2008 (Solar heat world wide -SHC 2010)

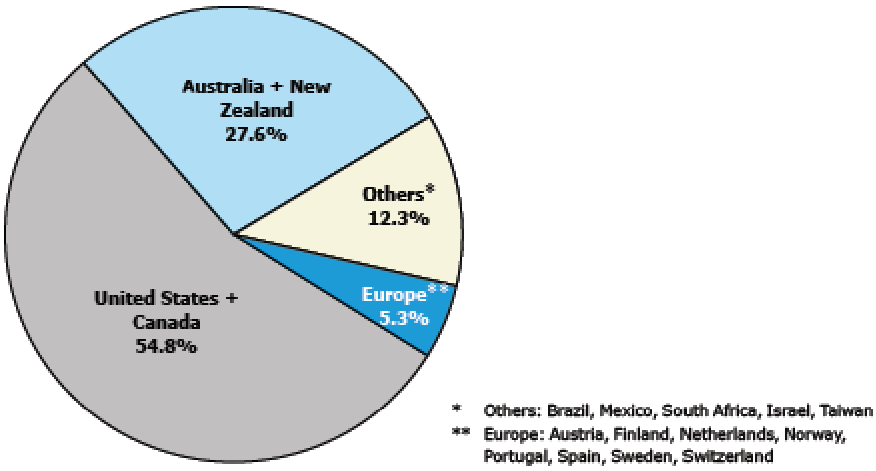


Figure 7: Share of new installedun glazed collector by regions in 2008 (Solar heat world wide - SHC 2010)

2.4.5 Market development from 2000-2008

If we compare the glazed collector market development for the year 2000 to 2008 we can see worldwide a 4 times higher growth of new installations in 2008 and this was doubled between 2004 and 2008. Between 2000 and 2008 the worldwide average annual growth was 20.1%.

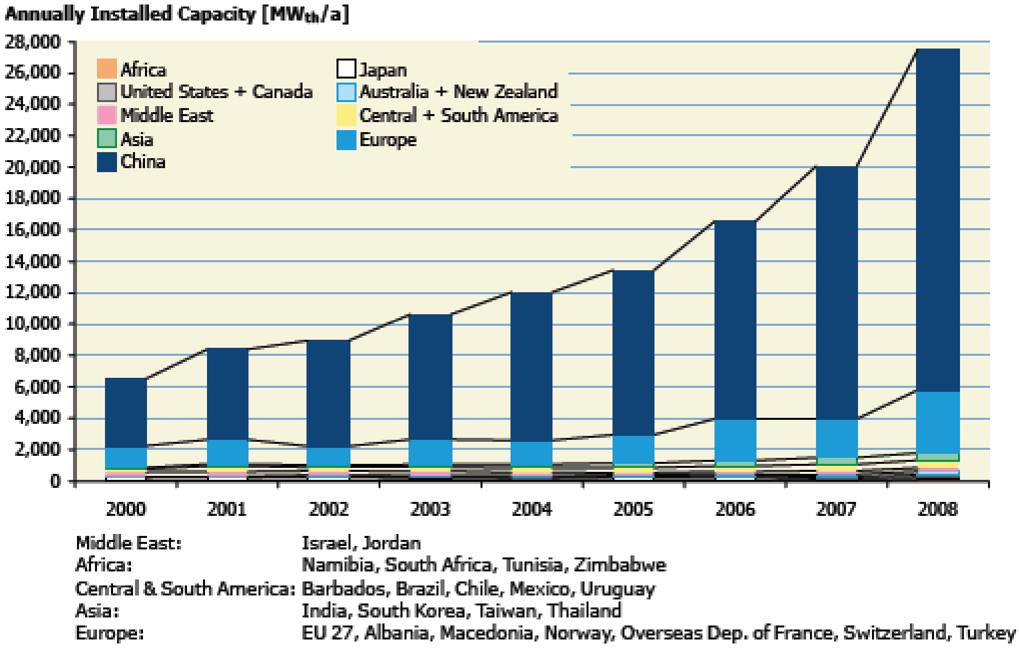


Figure 8: Solar collector market development from 2000 to 2008 (Solar heat world wide - SHC 2010)

For unglazed collectors the market development from 2000 to 2008 is steady (see figure) and we can see an increase of new installations from 2004 to 2006. The highest new share of installed capacity was recorded in central and South America and also in South Africa. Other markets remained stable.

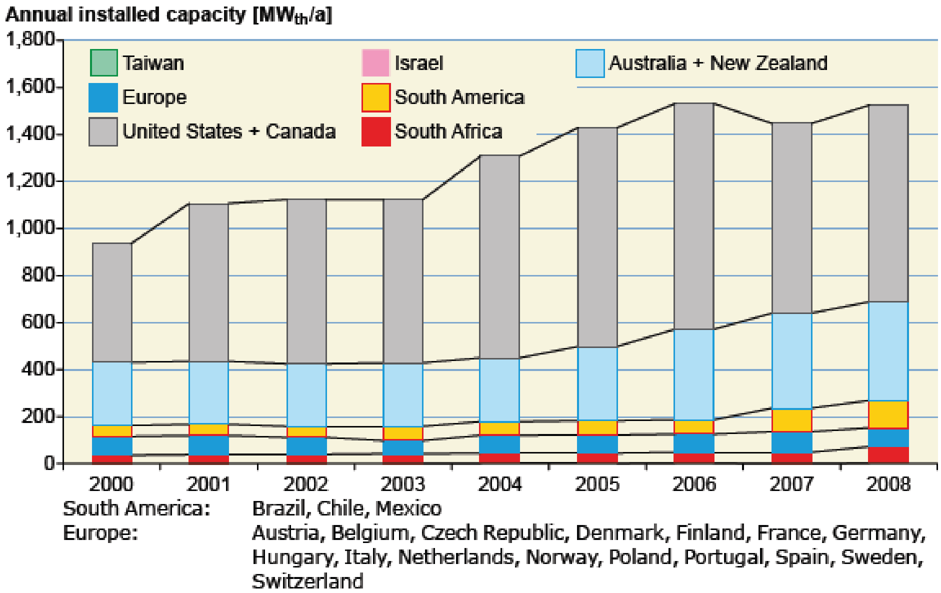


Figure 9: Overview of installed unglazed water colletor from 2000 to 2008 (Solar heat worldwide -SHC 2010)

2.4.6 Contribution of solar collectors to the supply of energy

By the end of 2008 in 53 countries recorded the annual collector yield of all solar thermal systems is 109.713 GWh (394.98 TJ). On an annual level these yields of produced energy is an oil equivalent of 12.4 million tons and an annual avoidance of 39.4 million tons of CO2.

All these values have been calculated from only the water based systems (air collectors are excluded).

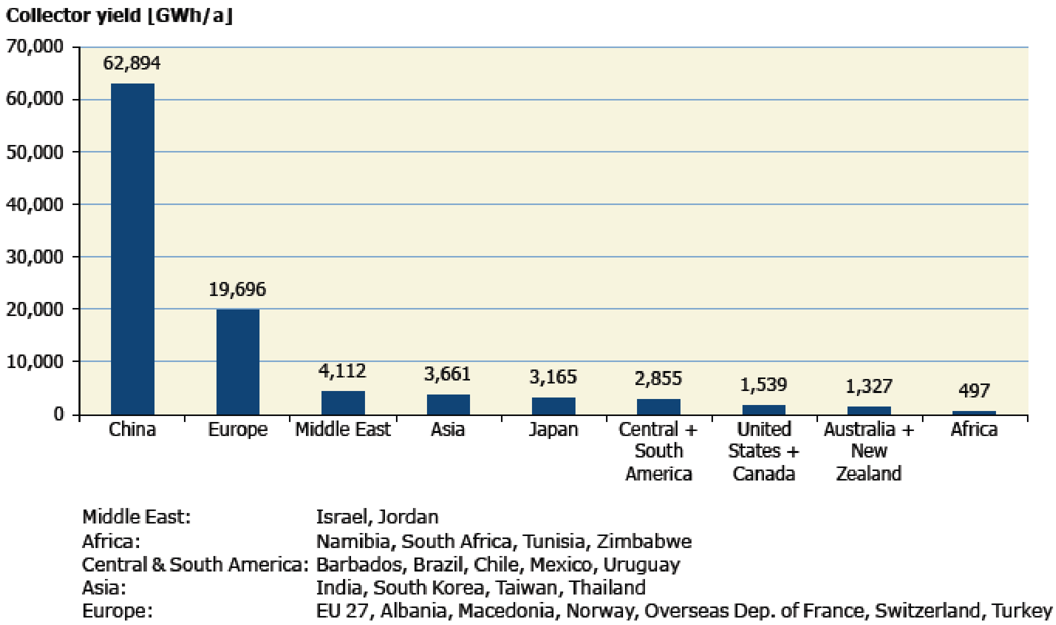


Figure 10: Average annual collector yield for glazed flat-plate and evacuated tube solar collector in 2008 (Solar heat worldwide-SHC 2010)

2.4.7 Employment

From collected data based on detailed country reports the jobs in the fields of production, installation and maintenance of solar thermal systems is estimated to be 260,000 worldwide. If we calculate that the worldwide average annual growth of solar thermal installation is around 20.1%, we can assume that every year we can expect around a 10% increase of new employment around the world.

2.5 Solar collector description

2.5.1 Flat plate collectors

2.5.1.1 Operating Principle

The flat-plate collectors use direct and diffuse solar radiation, for satisfactory working they do not require tracking of the sun, the maintenance is low and the systems are inexpensive and mechanically very simple. The working principle is very simple the solar radiation enters the collector through a transparent cover and enters into the absorber where the absorbed radiation is converted to thermal energy. For the transfer of the collected heat from the absorber sheet to the absorber pipes we need a good thermal conductivity where the heat is finally transferred to the solar (system) fluid. In practice the heat carrying fluids used are a water/ glycol mixture with anticorrosion additives, which also protects the collector from frost damage. The main losses in the collector are optical and thermal which the industry and new developed technologies are trying to reduce. To improve standard flat-plate collectors some of the main losses need to be reduced. (See illustration)

The optical losses can be controlled by the selection of type of glass cover. In practice low-iron solar glass is used with a transmission of 90% of the solar radiation. Where the producer utilises anti-reflective coatings the transmission can be increase to 93- 96%. The illustration below shows the 10% of absorbed solar energy are optical reflection losses (8%) and 2% is absorbed in the glass plane. The absorption coefficients of the absorber can reach 95%.

Thermal losses are caused because of circulating (convection) air between absorber and cover, which thus carries heat from the absorber to the glazing. The absorber sheet may produce a reflection of up to 8%. Further radiated infrared radiation energy, which, like the thermal energy, is transferred to the environment and this is around 6%. Regarding the type of insulation used the in collector there is also emitted thermal loss at the rear of the collector, which can be up to 3%.

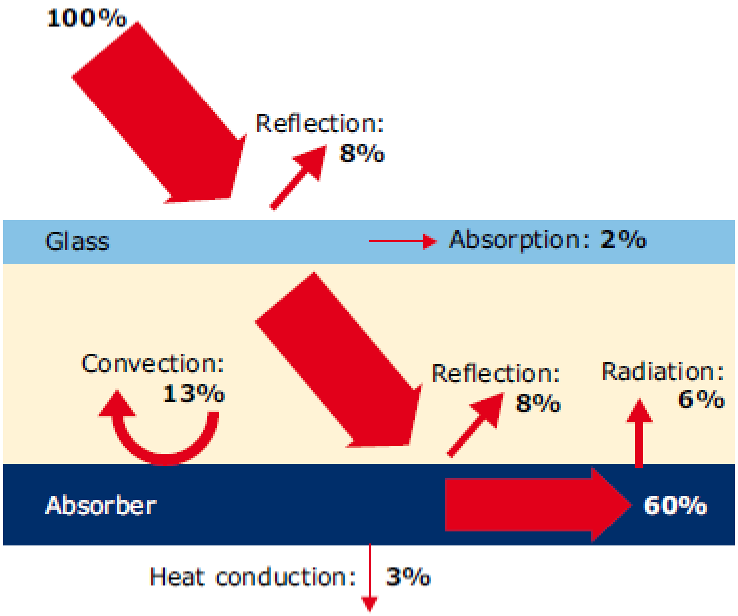


Figure 11: Main losses of a basic flat-plate collector during operation (IEA-SHC task 33/IV)

2.5.1.2 Construction principle

The most suitable flat-plate collector available on market is composed of:

- Frame,
- Transparent cover,
- Manifold,
- Rear panel,
- Insulation,
- Tube absorber,
- Selective coating.

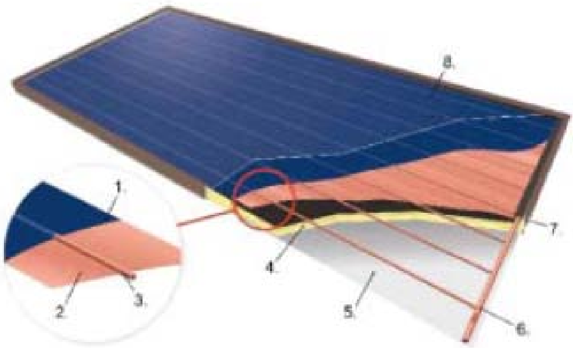


Figure 12: Basic structure of flat plat collector (IEA-SHC task 33/IV)

One of the main elements is the solar glass-transparent cover, which has to be of low iron, high transmission, high-temperature stability and with low thermal expansion.

One of the basic and most common materials used in solar collectors for the absorber pipes and sheet is copper. Because of its high price and the unstable copper market today production companies also use aluminium for absorber sheets due to its lower and more stable price.

To avoid heat and thermal losses due to high temperature from the rear of the collector to the environment mineral or rock wool is commonly used.

To protect and ensure the safety of the inner parts as well as provide stability of the collector against environmental impacts aluminium, wood, steel or synthetic materials are most commonly used the for frame production.

2.5.1.3 The current stage of development for flat-plate collectors

The normal operating temperature for a low loss classic flat-plate collector is around 80°C, at higher temperatures they have big heat losses compared to evacuated tube collectors. To become more economic and efficient at higher temperature levels these weakness can be reduced by the use of:

- Inert gas fillings in collector
- Double or triple glazing
- Vacuum flat-plate
- Combination of vacuum and multi layer glazing.

The illustration shows the efficiency curves of a standard flat plate, single, double and triple glazed used with anti reflection (AR glass) glazing. Note that curves around 0°C show an advantage for a standard collector and 1AR single anti reflection glazing collector compare to the older type but for temperatures above 120°C there is an advantage using 2AR and 3AR types (from 10-20% higher efficiency).

Currently there are two on today's market.

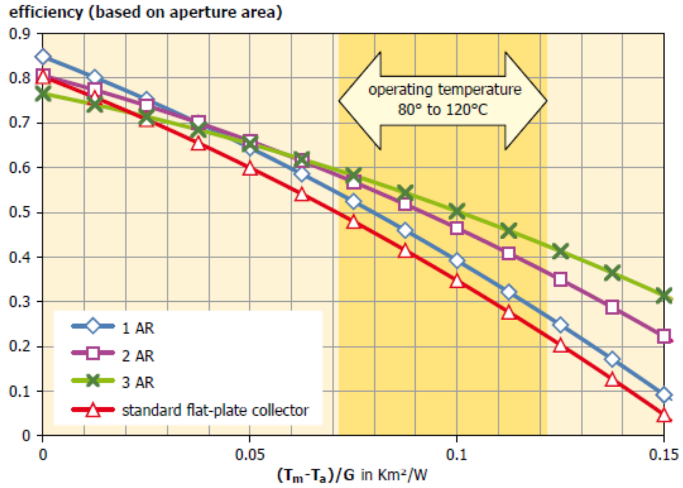


Figure 13: Efficiency curves for 3 different type of flat-plat collector (IEA-SHC task 33/IV)

2.5.2 Evacuated tube collectors

2.5.2.1 Operating principles and construction description

There are different types of evacuated tubes available on the market for solar collectors. One of the most popular collector types is the "twin-glass tube" or "thermos flask tube" so called Sydney tube showed the in picture below.

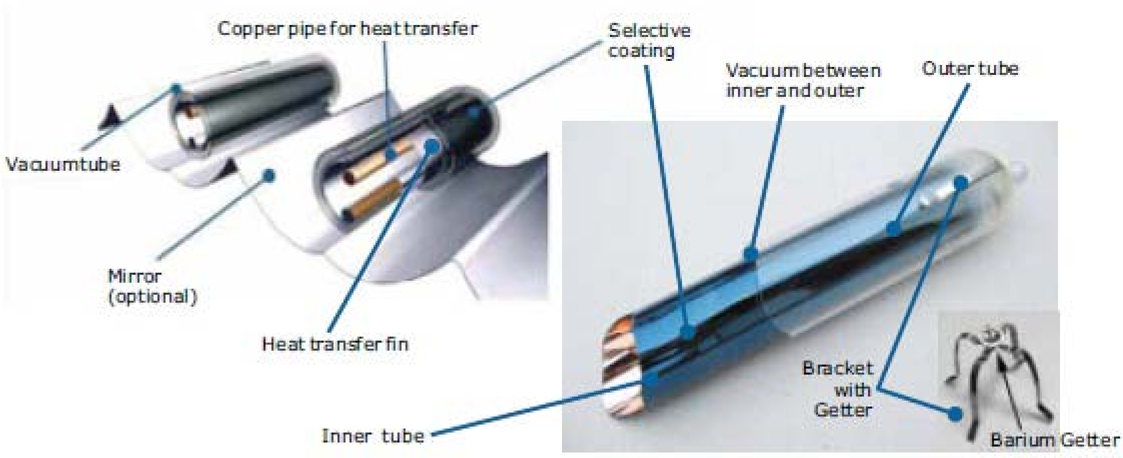


Figure 14: Basic structure of Sydney evacuated tube collector (IEA-SHC task 33/IV)

There are similar technical attributes for different types of evacuated tube collectors like:

- The glass is in the form of tube in order to resist atmospheric pressure due to the vacuum.
- All collectors are connected to the header pipe at the upper end of tubes.
- All evacuated tubes have very low conduction and convection losses due to the vacuum.
- All collectors are designed and manufactured with a row of parallel glass tubes.

More or less all types of evacuated tubes use a so-called barium getter to determine the condition of tube. These barium layers have two roles, one is to eliminate gases (CO, CO2, H2O ..) during operation and the second is a visual indicator of vacuum status. (If the barium layer becomes white it indicates a loss of the vacuum. See figure).

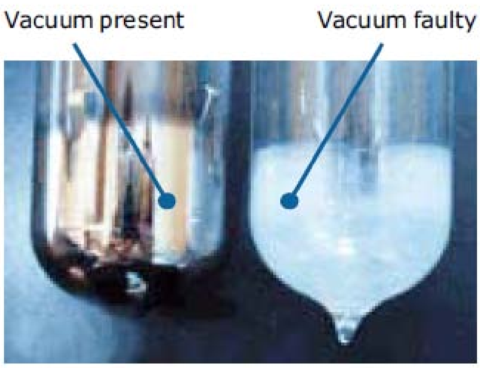


Figure 15: Indication for vacuum status in tube (present or faulty) (IEA-SHC task 33/IV)

In practice are two main types of evacuated tube collectors:

- Direct flow tubes,
- Heat pipe tubes.

2.5.2.2 Direct flow tubes

The whole interior is evacuated it is used with a single glass tube with diameters between 70 and 10mm. For this type the absorber is coated with a selective surface and is placed inside the vacuum (the inlet and outlet fluid pipes are attached to the absorber).

The illustration below shows the traditional type with separate tubes for inlet and outlet fluid.

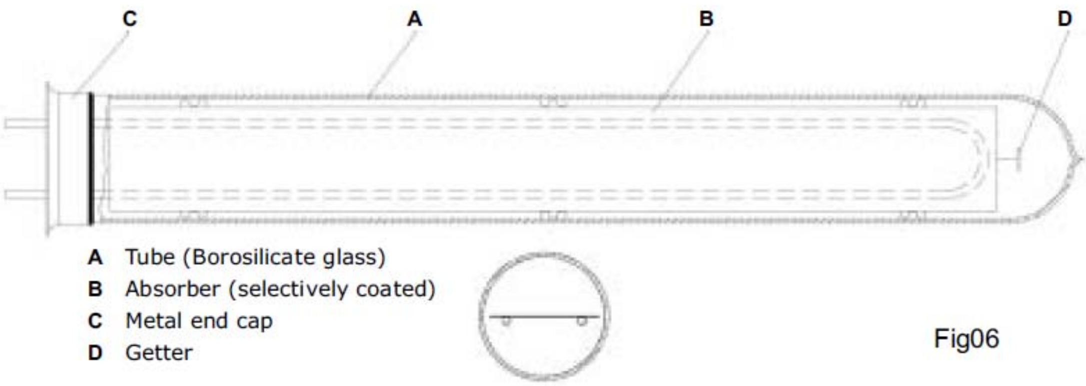


Figure 16: U-tube with direct flow pipe and flat absorber (IEA-SHC task 33/IV)

The other type has concentric inlet and outlet pipes which have the fluid outlet pipe connected directly to the absorber. The fluid inlet pipe is located inside the fluid outlet pipe so the fluid flows back between outer surface of the inner pipe and the inner surface of the outer pipe. These construction types offer the possibility of rotating the whole tube to find the optimal orientation and achieve the highest efficiency.

Currently on the market is a new type of concentric pipe called a Lenz tube (shown in picture below). The Lenz tube consists of a copper inlet fluid pipe and a glass outlet pipe. For maintenance the vacuum can be made without connection between glass and metal. To achieve a better heat transfer a graphite layer is used between absorber and outlet pipes.

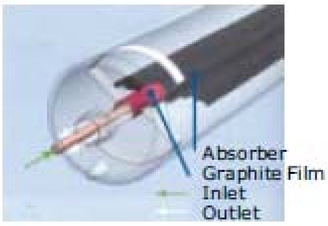


Figure 17: Concentric pipe - Lenz tube (IEA-SHC task 33/IV)

The most frequently used type of evacuated tube is the Sydney tube. Basically is composed of two fused together glass tubes and between the two tubes is the vacuum. Normally the upper side of inner tube is coated with selective absorber. The heat is removed via the copper u-tubes inside the inner pipe. These u-tubes are inserted into an aluminium cylindrical heat transfer fin. In the case of some unexpected damage to the tubes, they can be easily replaced, because there is no connection between the thermo flask tube and heat conductor or header of the collector.

2.5.2.3 Heat pipe tubes

Between heat pipe and direct flow tubes the difference is that the solar loop and carrier fluid inside the copper heat pipes are not connected. This type of collector is used with two different methods of connection:

- Dry
- Wet

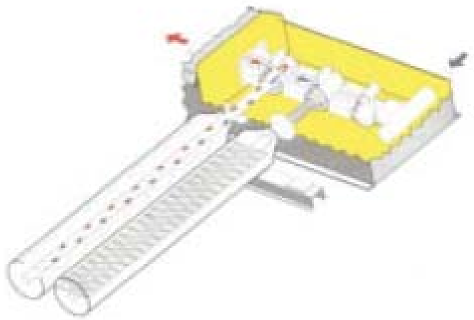


Figure 18: Dry connection het pipe (IEA-SHC task 33/IV)

With the dry connection the heat is transferred from the material of the header tube to the condenser. With this technique the installation and repairing of tubes, by comparison with the direct flow pipes that are brazed to the header, is much easier and cheaper. For the wet connection the principal is that solar fluid flows directly around the condenser of heat pipes. If there is a need to change the tubes of a wet connection this is more difficult than the dry type. Inside the heat pipe is reduced pressure to maintain the state of internal liquid. Over the variable temperature the water and a special additive vaporizes inside the heat pipe. At the top of the heat pipe the heat from vapour is transferred (taken out) to the solar system. This process is renewable because the vapour condenses back to liquid form and returns to the bottom of the heat pipe.

For efficient operation and good heat transportation in heat pipe should be fulfil some requirements:

- The minimum angle of collector must be 20°
- Avoid condensable gasses (they can form an air pocket in heat pipe)
- Use of mixture water/glycol with anti corrosion additives in solar loop
- Avoid stagnation temperature (try to keep temperature under 170°C and to have constant consumption reduce stagnation temperature).
- The stagnation temperature depends on the correct amount of solar fluid and airtight pressure inside the pipe. One technical solution can be the use of memory metal which at a certain temperature separates the fluid from condenser. The direct flow

vacuum collector requires good protection because the stagnation temperature can reach 300°C.

2.5.2.4 Current stage of development and applications

The largest market for evacuated tube collectors is China which has a 90% share of this market. They are also used in many other countries: Germany, Italy, Spain, Australia,.. The popularity of evacuated tube collectors increased 4 years ago and the demand from households is increasing as volume manufacture and other factors influence a reducing market price.

The most know usable application are for preparation of hot water or fro combi systems (space +hot water heating).

2.5.3 Compound parabolic concentrator collectors (CPC collectors)

The basic principal of this type of collect is to concentrate the solar radiation onto an absorber and thus produce an increased surface temperature. This increases the efficiency by comparison to the classic flat plate collectors with their lower operating temperatures. CPC collectors are able to produce greater output from both direct and diffuse radiation and their efficiency can be enhanced by mounting them at a calculated efficient angle to the average elevation of the sun.

2.5.3.1 Most Suitable Application and Current Stage of Development

With CPC collectors there are two types of application:

- Low concentration collectors (with large acceptance angle)
- High concentration collectors (with small acceptance angle)

2.5.3.2 Low concentration devices

Non evacuated collectors

Low concentration devices are appropriate when the collector will be stationary (similar to a flat-plate collector). If the concentration factor is increased and effective methods to control heat losses are added, the resulting collectors have a lower heat loss factor, approaching that of evacuated tube collectors. The resultant collector should perform very well in promising solar applications, such as absorption cooling, desalination and industrial processes because it can deliver heat around and above 100°C. Non-evacuated CPC collectors can be manufactured at the cost of good conventional flat-plate collectors. These can be mounted and employed in the same way as flat-plate collectors, and will provide the same reliability and greater efficiency.

They can be expected to deliver useful heat with efficiencies no lower than 50% at temperatures up to 160°C. This kind of efficiency can certainly be achieved if the installation is not totally stationary but adjusted 2 or 3 times per year in order to increase the effectiveness an gain a more idealised installation.

Figure 19: Commercial non evacuated CPC low concentration collector - SolarFocus (Solarfocus brochure 2010)

Evacuated Tubes with CPC reflector

Reflectors of the CPC type are often applied behind vacuum tubes. In this case, the reflectors often take the shape of a partial involute.

Today, with more efficient tubes and reflector materials that are able to withstand direct exposure to the environment it is possible that this principle can be re-examined as it could produce energy with temperatures of 150ºC to 200ºC even where utilised with a totally stationary collector.

Figure 20: Commercial evacuated tubes with CPC reflector U-pipe type: SU-C series Zhejiang Shentai Solar Energy Co., Ltd. (Shentaisolar.com 2010)

2.5.3.3 High concentration devices

High Concentration CPC collectors would be totally impractical as they would need to be extremely tall. By comparison, focussing concentrators are comparatively small. Even so CPC concentrators can be very useful where high concentrating collectors can be utilised. Some collectors that are currently available use this principle, where a second-stage CPC type concentrator further concentrates the radiation emerging from a linear primary concentrator of the Fresnel type.

2.5.4 Parabolic Trough Collectors

Parabolic trough collectors concentrate the sunlight before it strikes the absorber which is facing towards the reflector and thus away from the sun. The mirrored surfaces are curved in a parabolic shape and extend lengthwise with a constant cross-section into the shape of a trough. This focuses the sunlight onto an absorber tube positioned at the focus of the trough running along its length. A heat transfer fluid is pumped through the absorber tube of the collector where the solar energy is transformed into heat.

Parabolic troughs are collectors designed to reach temperatures over 100ºC and up to as much as 450ºC. They also maintain high collector efficiency as a result of having a large solar energy collecting area (aperture area) but a small collector surface where heat may be lost to the environment. In this document the concentration ratio refers to the ratio of the aperture area and the absorber surface. It is this concentration ratio that determines the temperature to which the heat transfer fluid can be heated in the collector. The optical efficiency of parabolic trough collectors, that is the percentage of the theoretical 100% of the suns rays being focused onto the collector, (this efficiency assumes an operating temperature equal to the ambient temperature) is always lower than that of flat-plate or evacuated tube collectors.

Figure 21: Parabolic trough concentrators (NREL)

Possible fields of application for small parabolic trough collectors:

• Industrial processes where heat at a temperature higher than approximately 100°C - 130°C (depending on climate conditions) is needed. They can be used to generate steam either for direct steam generation or using an indirectly fired steam generator. The steam can be fed into steam heat distribution systems that are widely used in industry.

• Driving absorption chillers, whether single or the most promising, double-stage machines. Double-stage machines have a higher efficiency than single-stage absorption chillers and due to their lower operating temperature they are used for most solar cooling applications.

2.5.5 Linear Concentrating Fresnel Collectors

2.5.5.1 Description of the Construction Principle

Linear concentrating Fresnel (LCF) collectors use groups of flat tracking mirror strips to reflect direct sunlight onto a stationary thermal receiver. The main advantages of these linear concentrating collectors is that they are relatively simple construction, have a low profile and thus low wind loads, utilise a stationary receiver (making connections for thermal fluids simpler) and a require a large ground area. This last fact means that the installation can be incorporated into areas that require shade, for example car-parks.

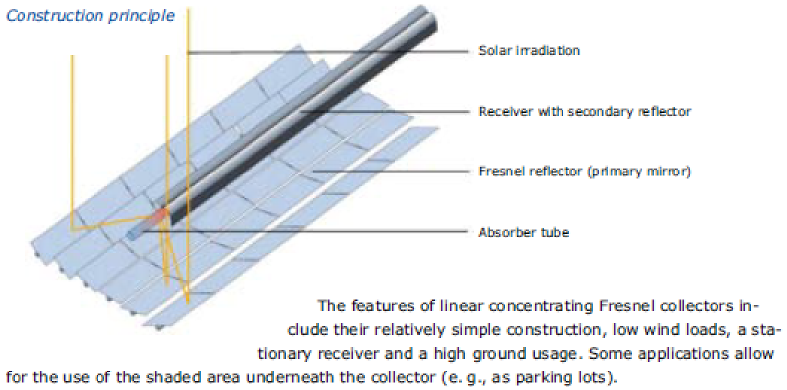


Figure 22: Construction principle of LCF (IEA-SHC task 33/IV)

Linear Fresnel collectors have been developed to enable large-scale solar thermal power generation that can provide thermal capacities from many tens and up to many hundreds of MW. They are commonly employed in remote plant applications.

On a smaller scale linear Fresnel collector can be designed to meet the special boundary conditions for the generation of industrial process heat:

• Collectors can be used for processes of a thermal capacity of around 50 kW and up to several MW.

• Collectors are easily to mounted on flat roofs as a result of even weight distribution and low wind resistance. This also allows very high surface coverage so that the heat can be produced close to where it is needed and to where space is not so freely available.

2.5.6 Concentrating Collectors with Stationary Reflector

The Concentrating Collector with Stationary Reflector (CCStaR) is also described as a Fixed-Mirror Solar Collector (FMSC). This collector is based on a reflecting cylindrical concentrator that creates a linear focus for any sun incidence angle. The position of this linear focus follows a circular path and therefore allows for more simple tracking of the sun by moving the receiver instead of the reflector.

The CCStaR collector concentrates direct solar radiation in order to increase the working temperature of the transport fluid. Although theoretically it is possible to reach concentrations of 40 to 50 suns, the averaged optical efficiency in this range of concentration ratios is about 60%, and is only achievable with flat mirrors. Therefore, the specific current development described here aims at about 15 suns. The envisaged working temperature range is from 80°C to 140°C. According to current estimations the average annual efficiency at 120°C would be between 40% to 50%, referred to direct incident radiation for a latitude of 39°.

It has been identified that the expected working temperature range for existing CCStaR reflectors is between 80°C and 140°C. This allows quite a range of industrial applications, particularly in the food industry (pasteurizing, boiling, sterilizing), textile (bleaching, dyeing) and also in a variety of processes in the chemical industry. Another suitable application is solar cooling and air conditioning because the operation range of the collector allows its use in both single and double-effect absorption devices.

Figure 23: Concentrating Collectors with Stationary Reflector CCStaR (Tecnologia Solar Concentradora)

3 Potential of solar thermal heat for industrial applications

3.1 Industrial applications for solar thermal energy

By the end of 2008 worldwide there was a total of solar thermal energy operations equivalent to 151.7 GWth (217 million square meters). Historically and today the market focuses on providing solar systems for large operations of hot water preparation and space heating. Industrial applications started to show interest as a result of:

- An increase of fossil fuels prices
- New policies relating to green gas emissions and energy efficiency in industrial sectors.

The industrial sector in the EU consumes 28% of the total final primary energy consumption and is also a big consumer of fossil fuels (the share is around 77%). 50% of all heat consumption for industrial processes are divided into three different temperature ranges:

- Low (<60°C),
- Medium (60-150°C),
- Medium high (150-250°C).

This data provides an overview from which to estimate the potential use of solar energy to produce heat for industrial processes within those temperature ranges.
Around 25 MWth (35,000m2) represents the total capacity in operation worldwide that is around 90 operating solar thermal plants used for industrial process heat.

3.2 Main results

This 25 MWth reported as the operating capacity of solar thermal plants in industry is a very small fraction (0.02%) of the total solar thermal capacity installed worldwide, which is equivalent to 118 GWth. It must be seen this comparison is not strictly correct from a methodological point of view. The global figure of 118 GWth is the result of a worldwide survey, but 24 MWth is the output of a number of existing plants in 21 countries rather than a systematic review of the installed plants currently in operation supplying industrial processes.

Whist the comparison is not scientifically valid the difference between the total solar capacity and the plants generating industrial heat is extremely large. With such a small current contribution, the potential for a greater use of solar thermal energy for the provision of heat to industrial applications is totally relevant.

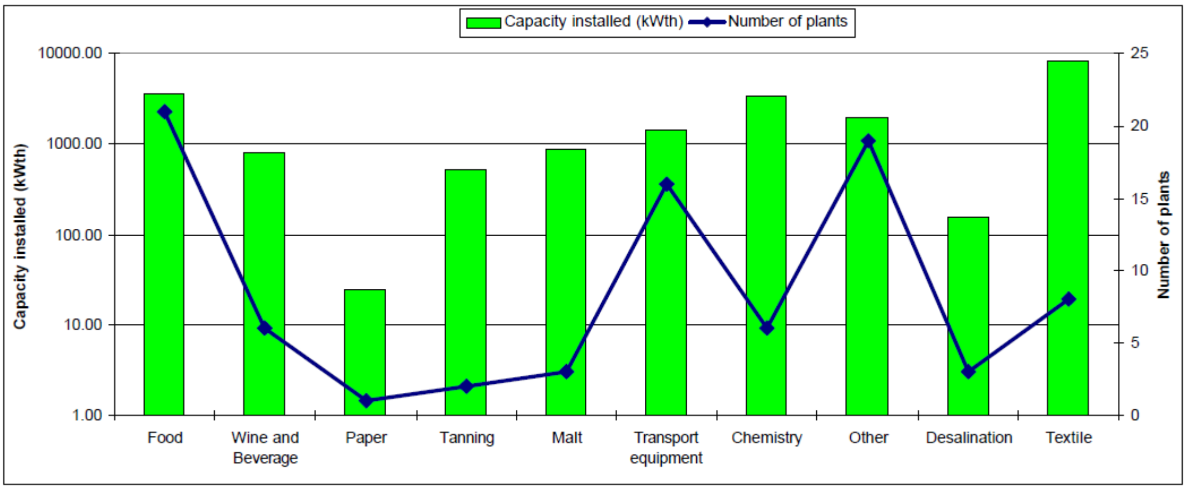


Figure 24: Total installed capacity of solar industrial process heat plants in 2007 - by industry sector. (IEA-SHC task 33/IV)

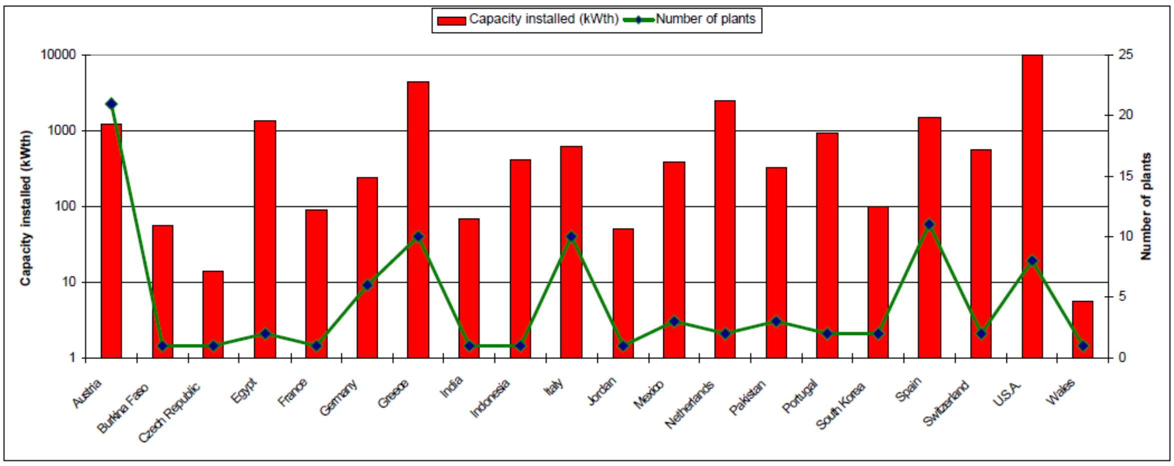


Figure 25: Total installed capacity of solar industrial process heat plants in 2007 - by country. (IEA-SHC task 33/IV)

The initial results of studies for the potential of solar energy carried out in several countries around the world can be summarised4 with key outcomes categorized by:

1. Industrial heat demand by temperature range;

2. Most suitable industry branches and processes for solar thermal use;

3. Potential of application for solar thermal technologies in industry for several countries and at European level.

3.2.1 Industrial heat demand by temperature range

The current data on the breakdown of the demand for industrial heat over the various temperature ranges have, as yet, not exhaustive in many countries. The analysis of the performed potential studies has thus been useful to overcome this lack of information. The recent study "ECOHEATCOOL"5 reports that about 30% of the total industrial heat demand is required at temperatures below 100°C and 57% at temperatures below 400°C. More interestingly in several industrial sectors, such as food, wine and beverage, transport equipment, machinery, textile, pulp and paper, the share of heat demand at low and medium temperatures (below 250°C) is around, or even more than 60% of the total figure. However the pulp and paper sector uses primary heat recovery systems and, as a result, the theoretical potential may be high but the practical implementation of a solar thermal plant installation is not suitable in many cases.

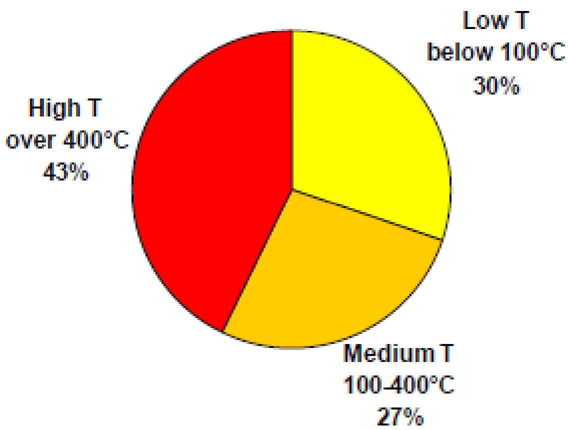


Figure 26: Share of industrial heat demand by temperature range (IEA-SHC task 33/IV)

As identified in the illustrations above, the ECOHEATCOOL and POSHIP studies, while following quite different methodologies, have come to results which are fully comparable. It is important to note that In particular the result of estimates carried out in the reported potential studies for solar process heat, for example in the POSHIP project, are comparable with the figures hat have been obtained from industry statistic. In conclusion, it should be noted that quite often industrial processes exploit medium temperature heat by using steam as a carrier even though lower working temperatures would be sufficient. Therefore, in order to make a valid feasibility study for the introduction of solar thermal energy in a specific industrial process, it is necessary to look at the actual temperature needed by the process itself and not at the temperature of the heat carrier currently in use. Such an approach must be used not only for determining the implementation of solar thermal plants, but also for lowering the current process energy consumption.

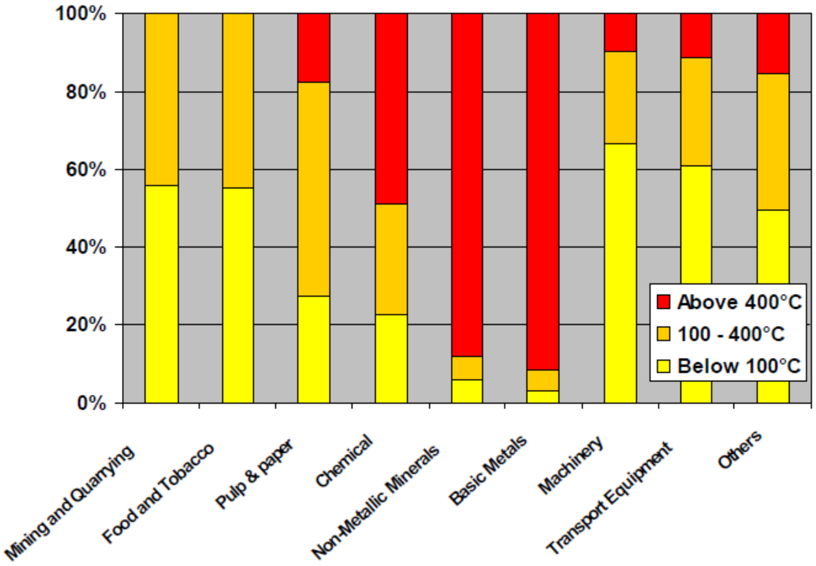


Figure 27: Share of industrial heat demand by temperature level and industrial sector. (IEA-SHC task 33/IV)

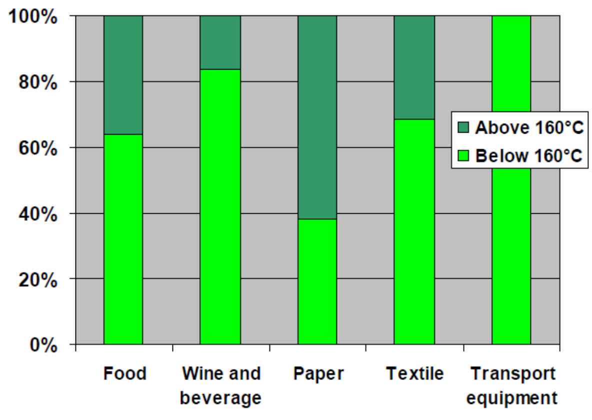


Figure 28: Share of industrial heat demand by temperature level and industrial sector. (IEA-SHC task 33/IV)

3.2.2 Industrial sectors and processes

A further valuable factor illustrated by this survey is the definition of the most suitable industrial sectors, where solar thermal heat could be effectively used. In these sectors, the heat demand is significant and more or less continuous throughout the year. Furthermore the temperature level required by some of the processes is compatible with the efficient operation of solar thermal collectors. **The key sectors are food (including wine and beverage), textile, transport equipment, metal and plastic treatment, and chemical**. **The areas of application with the most suitable industrial processes, include cleaning, drying, evaporation and distillation, blanching, pasteurisation, sterilisation, cooking, melting, painting, and surface treatment**. Finally, among the most promising applications **space heating and cooling of factory buildings should be included as well**.

The relevance of each sector in regard to solar thermal market development also depends on the local industrial profile, for example, breweries represent an important industry in Austria and Germany, while dairies are important in Italy and Greece. Table 1 provides an overview of the industrial sectors considered in the potential studies. It is therefore important to carefully take into account the different sectors that have been included in order to compare the outcomes of these studies as well as other technical and non-technical country specific parameters that could directly affect the global figures.

3.2.3 The potential for solar produced heat energy in the European Union

The results of the potential studies for various European countries are shown in Figure 29. The PROMISE study has estimated the potential for solar process heat in Austria as reaching 5.4 PJ/year, while the Iberian Peninsula (Spain and Portugal) and the Italian studies show a potential of 21 PJ/year[9] and 32 PJ/year[10] respectively. The study carried out for the Netherlands shows a much lower potential (<2 PJ/year). These results are due to the scope of the analysis being limited as hot water production up to only 60 °C was assessed in only twelve industry branches. The studies available for other countries such as Germany, Greece and Belgium cannot be directly compared because they are either regional studies or included only a few specific sectors, and as a result provide an incomplete picture.

Industry sectors	Austria	Iberian Peninsula	Italy	Netherlands	Greece	Germany	Wallonia (Belgium)	Victoria (Australia)
Food products	x	x	x	x	x		x	x
Wines and beverages	x	x	x	x			x	x
Beer and malt		x	x	x		x	x	x
Tobacco products		x	x		x		x	
Textiles and textile products	x	x	x	x	x		x	x
Leather and leather products		x	x		x			
Pulp, paper and paper products		x	x	x	x	x	x	x
Chemicals and chemical products		x	x		x		x	x
Machinery and equipment								x
Transport equipment and auxiliary transport activities	x	x	x		x	x		
Other sectors	x				x		x	x

Figure 29: The potential study of overview in industrial sectors for different country (IEA-SHC task 33/IV)

The Australian study was only carried out in the state of Victoria and includes both the commercial and service sectors thus it too cannot be used for comparison purposes. If only the industrial applications are considered, the final potential figure is 9.47PJ/year. These results are not included in the summary table below because the goal of the survey was to calculate the potential at the European level. In Table 2, the potential for the use of solar thermal in the industrial sector in various countries is reported in terms of delivered energy (PJ/year), capacity (GW_{th}) and collector area (Mio m_2). In order to obtain the share of heat demand that could be covered by using solar thermal energy these potential figures are also compared to the corresponding industrial heat demand.

The reported results show that **solar thermal energy systems could provide the industrial sector with 3-4% of its heat demand in Austria, Italy, Portugal, Netherlands and Spain**. **Extrapolating this result to the European Union (EU 25)**, and assuming an average share of 3.8%, **the potential for solar thermal energy applications in industry for heat production reaches a value of 258 PJ/year.**

The corresponding potential figures in terms of capacity and area have been calculated taking into account two possible yield values for solar plants: 400 kWh/m_2 year and 500 kWh/m_2 year.

Country	Industrial final energy consumption	Industrial heat demand (Final energy to heat demand conversion factor: 0.75)	Solar process heat potential at low & medium temperature	Solar process heat/ Industrial heat demand	Potential in terms of capacity	Potential in terms of collector area	Source of the data used for calculation (*)
	[PJ/year]	[PJ/year]	[PJ/year]		[GW_{th}]	[Mio m^2]	
Austria	264*	137	5.4	3.9%	3	4.3	Eurostat energy balances, year 1999; PROMISE project
Spain	-	493*	17.0	3.4%	5.5 - 7	8 - 10	POSHIP project
Portugal	-	90*	4.0	4.4%	1.3 - 1.7	1.9 - 2.5	POSHIP project
Italy	1,653*	857	31.8	3.7%	10	14.3	Eurostat energy balances, year 2000
Netherlands	89*	46	1.95	3.2%	0.5 - 0.7	0.8 - 1	Onderzoek naar het potentieel van zonthermische energie in de inustrie. (FEC for 12 branches only)
EU 25	***12,994****	***6,881***	***258.2***	***3.8%***	***100 - 125***	***143 - 180***	Eurostat energy balances, year 2002

Figure 30: The solar process heat potential and industrial heat demand in EU25 (IEA-SHC task 33/IV)

3.3 Expected impacts

The real task here is to try to estimate what could be achieved if these technologies were used to their full potential. Certainly such an implementation could include:

A significant contribution to the renewable energy targets for the European Union

Such an increased use of these new technologies would result in the creation of jobs

The EU countries have recently adopted an energy policy that aims at securing energy supplies and helping to increase competitiveness, at the same time there is a desire to but save energy and promote the use of climate friendly energy sources.

The present targets set are to reduce the EU's greenhouse gas emissions **by 20%** by the **year 2020** and further to establish a binding overall goal of 20% of energy being derived from renewable energy sources by the same year; at present this is only 6.5%. Detailed targets are still to be agreed at both EU and national levels but already some outline suggestions have already been prepared.

ESTIF the European Solar Thermal Industry Federationhave produced the ambitious target for the use of solar thermal energy. It requires its development to have, by the year 2020 to have reached a level of 320 GW_{th} of installed systems, this equates to about 1 m_2

per capita which should produce 19.7Mtoe/year of energy[11]. According to the European Solar Thermal Technology Platform (ESTTP), the goal for 2030 is to have installed a total capacity of 960 GW_{th} by 2030.

Assuming that 10% of the calculated potential for solar heat in industrial applications were to be actually implemented by 2020, **a total capacity between 10 and 12GW_{th} in industrial applications would give a contribution of 3 - 4% to the overall target of 320GW_{th}.**

If these predictions were to be achieved **the industrial use of solar thermal energy could offer a market volume of 1000 MW_{th}/year, which would equate to a 50% growth over to the current European annual solar market volume**. From this level of expansion the jobs created could be significant; an estimated 10,000-15,000 new jobs could be created by 2020. This is a meaningful number and would certainly be a significant share of the occupational target for the overall solar thermal sector. According to the European Solar Thermal Technology Platform such an increase could produce 224,000 full time jobs by 2020.

3.4 Derivation of estimated outcome

For each country and study of energy generation very different methodological approaches were used. Spain and Portugal used a bottom-up procedure taking the results of 34 case studies and applying them as a theoretical norm for the whole industry sector. In Austria, a top-down approach was used where case studies were used simply to validate the results of earlier calculations which had been based on theoretical assumptions. The Italian methodology assumed the available surface of thermal collection as the main criterion for the solar potential assessment. In spite of these very different methodologies, some common results were identified that could be used to performing a number of new potential studies:

- Initially it is necessary to clearly define the most relevant and suitable industrial sectors for each country under study.
- Assess the industrial heat demand by sector and by temperature range, focusing on low and medium temperature ranges.
- Calculate the technical potential including all the cases where the installation of a solar thermal system is assumed to be technically feasible; this step should take into account at least the following limitation factors:

- available surface on roofs or façades
- characteristics of the heat demand
- heat demand at low temperature; here it is crucial to distinguish the heat carrier supply temperature (e.g., the steam temperature) and the working temperature actually needed by the process; if supply temperatures, which are most of the times much higher than working temperatures, are taken into account, the assessment of the potential for application of solar thermal in industry could be widely underestimated
- technical possibility of coupling the solar thermal plant with the process
- type of process (batch or continuous)
- temperature of heat usage
- availability of process heat storages (e.g. pools)
- chances for heat recovery
- availability of competing technologies

- It is important to evaluate the techno-economic potential, where all the technical conditions are met and then to further assess its economical feasibility; this step should include:

- energy costs: historical trend and an estimated forecast for the future
- investment, operation and maintenance costs
- financing schemes from the public sector
- estimations should be made of the main economic parameters for the calculations (pay back time, Internal Rate of Return, cost of kWh, etc.)

3.5 Conclusion and recommendations

Even though solar thermal energy is currently used mainly for providing hot water to households and pools, the survey conducted clearly highlights that given its relevance in total final energy consumption, **the industrial sector cannot be ignored**. Further, a significant share of its heat demand is needed in the low and medium temperature range. This is particularly true for certain industrial sectors (food – including wine and beverage, textile, transport equipment, metal and plastic treatment, chemical) and in each case for several processes (cleaning, drying, evaporation and distillation, blanching, pasteurisation, sterilisation, cooking, melting, painting, surface treatment). Studies based on both industry statistics and on individual case studies performed in order to assess the solar thermal energy potential in industrial applications reached remarkably consistent results regarding the share of low and medium temperature heat required by the industrial operations which have been illustrated above.

An analysis of the survey results from individual country studies also shows that, even though utilising significantly different methodologies, the figures obtained are remarkably similar—**solar thermal could provide the industrial sector with 3 - 4% of its heat energy demands**. From this it seems reasonable that these individual national figures could be extrapolated to the European level, suggesting that — **solar thermal energy could conceivably provide as much as 258 PJ/year of thermal energy to the EU25 industrial sector or an installed capacity of 100 - 125 GW_{th} (143 - 180 Mio m_2)**. Even if these assumptions are viewed in a conservative light regarding the penetration of the use of solar thermal energy in the industrial sector, it makes a significant contribution towards reaching the 2020 targets that have been set by the European Union.

The two main target areas of this document provide a clear message for the solar thermal energy both for national and European companies: there is a relevant, promising, suitable and to date virtually unexploited market sector that would be suitable for the application of solar thermal technology. The message is thus: **take a detailed survey of the most suitable and most representative industrial sectors in your country and exploit this energy potential**. With regard to policy makers and national and EU institutions, it is of utmost importance that **current policies for renewable development should carefully consider, take into account, and promote with clearly identified measures and policy tools, the industrial applications of solar thermal energy**. In order to encourage and support the development of a market for industrial applications of solar thermal energy the main recommendations are that policy makers should:

Make economic incentives available for industries willing to invest in solar thermal energy. The incentives should be targeted at reducing payback periods and could be provided by a range of schemes. Low interest rate loans, tax incentives, direct financial support, third party financing, etc. Currently it seems that such supporting measures have only been taken at local or regional level.

Carry out demonstration and pilot solar thermal plants in industries, including advanced and innovative solutions, like small concentrating collectors.

Organise workshops and arrange campaigns to provide information to the various industrial sectors that are relevant in order to make them aware of the several important issues:

- The real cost of heat production and the present use of conventional energy sources and their impact on the costs of the total industrial operation and its management
- The benefits of using appropriate solar thermal technology.

It is vital to support further research and innovation to improve the technical sophistication of these energy systems to further reduce costs, especially with regard to applications operating at higher temperatures.

Finally, regarding making future improvements the vital analysis outlined here, new and more complete studies are needed within the European Union in order to assess the detailed potential at both national and EU levels in the various industrial sectors that are appropriate and to expand the current data available to solar thermal companies and policy makers.

4 Integration of the solar heat into the production processes in the Pomurske mlekarne

4.1 Description of the Company

4.1.1 Activity and Programme

The principal activity of the Pomurske mlekarne dairy is dairying. The production programme includes a wide range of dairy and other products:

- Milk
- Creams
- Butters
- Fermented desserts
- Cottage cheese and spreads,
- Chocolate milk and iced coffee,
- Cappuccino,
- Processed, semi-hard and hard cheeses

It’s not easy singling out a specific product from such a varied range; however, the company is proud of top-quality Slovenian cultured butter, which has received many awards from expert juries and was also warmly received by consumers.

Pomurske mlekarne was also the first company to offer Slovenian consumers low-fat milk with added vitamins, which received a recognisable regional name »Lejko mlejko« (light milk in Pomurje dialect). Further down the list of health-friendly products is »Fyto mlejko« – milk with added plant sterols, which helps maintain a healthy level of cholesterol in the body. It is also the first and the only Slovenian product with phytosterols!

Dairy's yoghurts, cottage cheeses and creams have also established their position in the market, and by acquiring the majority share in the Ljutomer Mleko promet dairy in 2004, the company also expanded activities in the area of top-quality cheeses.

Ljutomer Emmental, a classic cheese, has been popular and appreciated for decades, while Zbrinc is also gaining ground due to the increasing popularity of Italian cuisine.

Processed cheeses and spreads Slovenka along with Bučko z lučko, processed cheese for the youngest, complete the cheese offer.

Whatever product by Pomurske mlekarne you choose, you will always get the best from the white treasures of unspoiled nature.

4.1.2 Pomurske mlekarne Today

Today, the Pomurske mlekarne dairy is one of the pillars of food industry in the north eastern part of Slovenia and one of the pillars of the Slovenian dairy industry generating about 80 million litres of milk per year. Milk production meets all European quality and hygiene standards. For these and many other reasons, Pomurske mlekarne products are marketed under the slogan “white treasures of unspoiled nature”.

The dairy production takes place at two locations; in Murska Sobota and Ljutomer. While milk powder, butter, sterilised and fermented products and cottage cheese are mainly produced in Murska Sobota, Ljutomer exclusively produces the renowned Ljutomer cheeses. 70% of the total production is sold in the Slovenian market and 30% in other markets, particularly non-EU markets and the North American market.

The dairy is mainly dedicated to the production of milk and also to processing, primarily in terms of product quality. The results of these efforts are the certificate for the export of products to the most demanding foreign markets obtained a long time ago, quality certificate ISO 9001 and environmental management certificate ISO 14001.

The basic objectives of the Pomurske mlekarne dairy include:

- To provide consumers with natural, top-quality and healthy dairy and other food products in compliance with the European standards and technology;
- To preserve and develop ecologically intact natural environment, which enables the production of top-quality farm produce for further processing;
- To facilitate the growth and development of local economy;
- To create new jobs;
- To contribute to the stability of the society;
- To take care of the personnel;

- To ensure commercial adjustability to home and foreign users.

Pomurske mlekarne strives to achieve the above goals through the following strategy:

- By buying and processing fresh milk and other raw materials produced in line with the European standards;
- By implementing state-of-the-art milk processing;
- Technology and employing qualified personnel;
- By optimising the production capacity, decreasing expenses and providing the consumers with quality products at reasonable prices.

4.1.3 Current Quality and Environmental Policy

The basic orientation and most important value of the Pomurske mlekarne dairy is its commitment to quality operation, superior product quality and safety. Therefore, our knowledge and experiences help us turn milk into “white treasures of unspoiled nature”, while continuously guaranteeing satisfaction of our customers, suppliers, staff and company owners.

The Pomurske mlekarne personnel continuously expands their knowledge to provide assurance of the highest quality and traceability of products and services as well as environmental protection. The company acts in compliance with statutory provisions and standards in all fields. High environmental awareness is one of the key elements of the culture of our personnel and contract partners.

We contribute to environmental protection through control and continuous improvement and search for new technological processes that:

- Reduce the wastewater burden on the environment;
- Reduce the consumption of energy products;
- Reduce the pollution of the environment with cleaning agents;

By consistent waste separation waste products can be re-used through recycling.
We try to create a pleasant working environment and give our personnel many challenges and motivation to achieve the established policy of quality and business excellence.

Progressing towards business excellence we aim to:

- Optimise business processes to achieve the highest level of quality;
- Constantly improve the defined quality of our products and services;
- Provide continuous education and sufficient motivation for all our personnel;
- Quickly correct any deviations from the set quality and do everything to prevent the deviations from re-occurring;
- Continuously reduce the number of customers claims and process deficiencies;
- Constantly search for new business partners who know how to listen our wishes and demands.

The Pomurske mlekarne personnel act in an environmentally responsible manner by continuously improving important environmental aspects, preventing pollution and monitoring and fulfilling the statutory and other requirements. We undertake to fulfil and constantly improve the recommendations provided in the quality and environmental policy. Being an open company, our policies are accessible to the public. The established quality standards and the received prizes and awards further confirm quality and safety of our products.

4.1.4 Introduction of Technology of Production Processes

Production processes in the company Pomurske mlekarne d.d.:

- Centrifuging for regulating percentage of fat and removing impurities in milk
- Pasteurization for eliminating or preventing formation of unwanted micro-organisms in milk
- Fermentation for the production of yoghurts and other fermented milk products
- Sterilization – UHT for the production of low-viscosity liquid products
- Cooling in various milk treatment procedures
- Evaporation or concentration of milk
- Drying of concentrated milk for the production of milk powder
- Filling and packaging of dairy products

Table 2.1 shows the quantity of processed raw milk in the period between 2007 and 2009. **Table 2.2** shows the number of employees.

Table 2: Quantity of processed raw milk (Steng - 2010)

Year	Milk production (t)
2007	40,900,011
2008	67,907,435
2009	68,230,474

Table 3: Number of employees (Steng - 2010)

Year	No. of employees
2007	122
2008	112
2009	104

4.1.5 Spatial Arrangement of Facilities with Marked Intended Purpose of Main Buildings

Figure 31 shows the spatial arrangement of buildings and their intended purpose.

Figure 31: Spatial arrangement of buildings

4.1.6 Total Energy Use

For production processes and heating, the company Pomurske mlekarne d.d. requires:

- Electricity
- Natural gas
- Compressed air
- Ice water
- Cooling water
- Technological and sanitary water

Table 4 shows use of energy and water in the period 2007 to 2009.

Table 4: Total energy consumption (Steng 2010)

Year	Electricity (kWh)			Natural gas (Sm^3/a)	Water (m^3/a)
	HT	LT	Total		
2007	1,948,096	1,659,536	3,607,632	1,659,742	113,498
2008	1,920,208	1,836,096	3,756,304	1,925,221	97,096
2009	1,924,928	1,851,488	3,776,416	1,763,187	101,824

4.2 Energy Provision and Consumption

4.2.1 Prices of Energy Resources and Monthly Consumption of Energy Resources

4.2.1.1 Electricity Consumption

Consumption of active energy in the period from 2007 to 2009 is shown in **Table 5**.

Table 5: Use of electricity for all three years (Steng 2010)

Year	HT (kWh)	LT (kWh)	Total (kWh)	Costs (EUR/a)	Specific Consumption (kWh/1,000 L of milk)
2007	1,948,096	1,659,536	3,607,632	293,868	84.33
2008	1,920,208	1,836,096	3,756,304	312,357	88.32
2009	1,924,928	1,851,488	3,776,416	317,104	84.23

Table 5 above shows that active energy consumption in 2008 increased by 4.1% in comparison to 2007 and that active energy consumption in 2009increased by 0.5%in comparison to 2008. In total, the consumption in 2009 increased by 4.7%in comparison to 2007. This indicates an average2.3% annual increase of electricity consumption in the

company, which is significantly below the predicted electricity consumption for Slovenia within the following 10 years.

The data about the electricity consumption was obtained by the Contracting Authority in the form of invoices of Elektro Maribor d.d. for supplied electricity. Charts of obtained data on electricity consumption in the company by headings HT(higher tariff), LT(lower tariff) and their comparison for individual discussed years are shown on the following figures: **Figures 32, 33** and **34** show the data obtained on electricity consumption by headings HT and LT and their comparison.

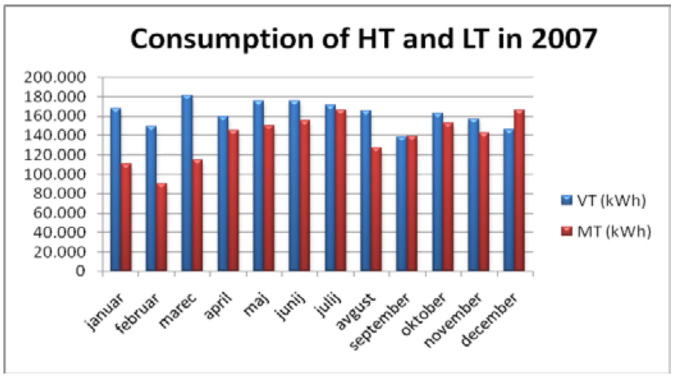


Figure 32: Electricity consumption in 2007

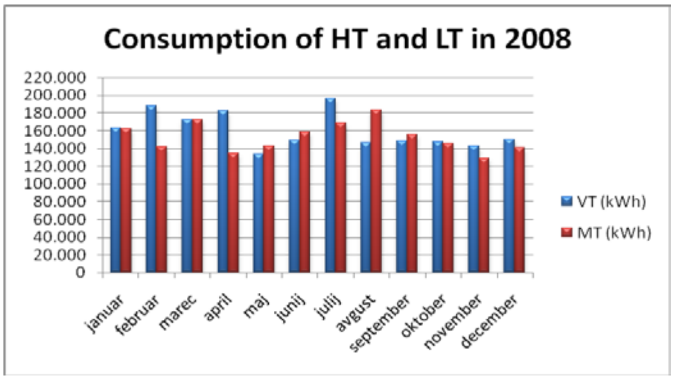


Figure 33: Electricity consumption in 2008

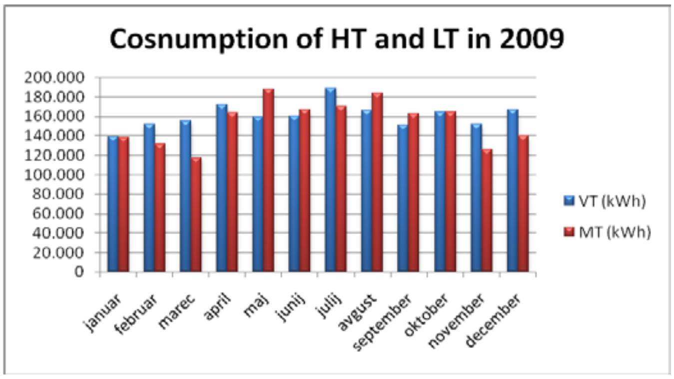


Figure 34: Electricity consumption in 2009

4.2.1.2 Natural Gas Consumption

Table 6: Natural gas consumption for the period between 2007 and 2009

Year	Consumption (m^3/a)	Costs (EUR/a)	Specific Consumption (kWh/1000 L of milk)
2007	1,659,742	463,526	367.18
2008	1,925,221	717,029	429.97
2009	1,763,187	524,574	373.64

Throughout the period, the price of natural gasvaried (**Figure 35**). In January 2007 the price of natural gas was 0.2174EUR/m^3 and remained approximately the same throughout the year. In January 2008 the price of gas was 0.2507EUR/m^3, while in December same year it was already 0.3795EUR/m^3. In January 2009 the price was 0.3314EUR/m^{3}and it slowly decreased as the year went on, to finally fall on 0.1845 EUR/m^{3}in December 2009. Ecological tax and excise duty remained the same.

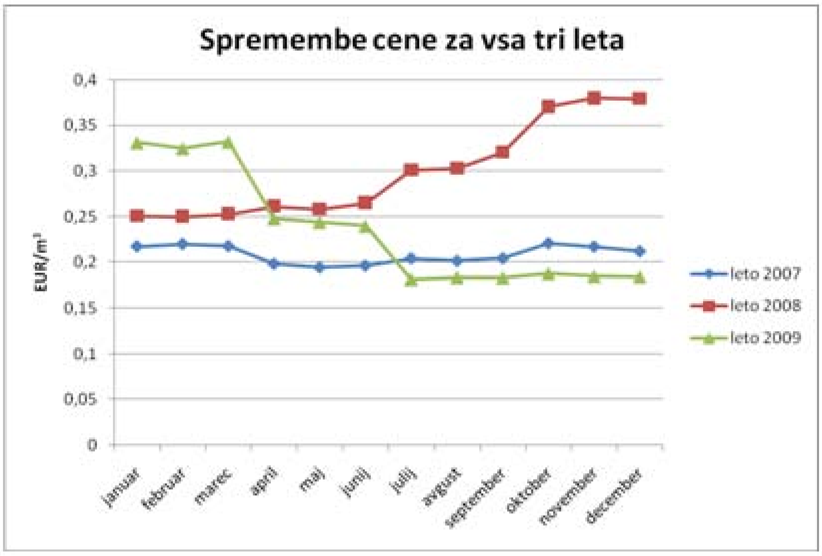


Figure 35: Changes in prices of natural gas through all three years (Steng 2010)

Due to changes in prices, the costs in 2008 are significantly higher than in 2007 and 2009, even with regard to consumption, which was approximately the same between 2008 and 2009, which can be seen in **Figures 36** and **37**. **Figures 38** and **39** show consumption and costs of purchase of natural gas on an annual level.

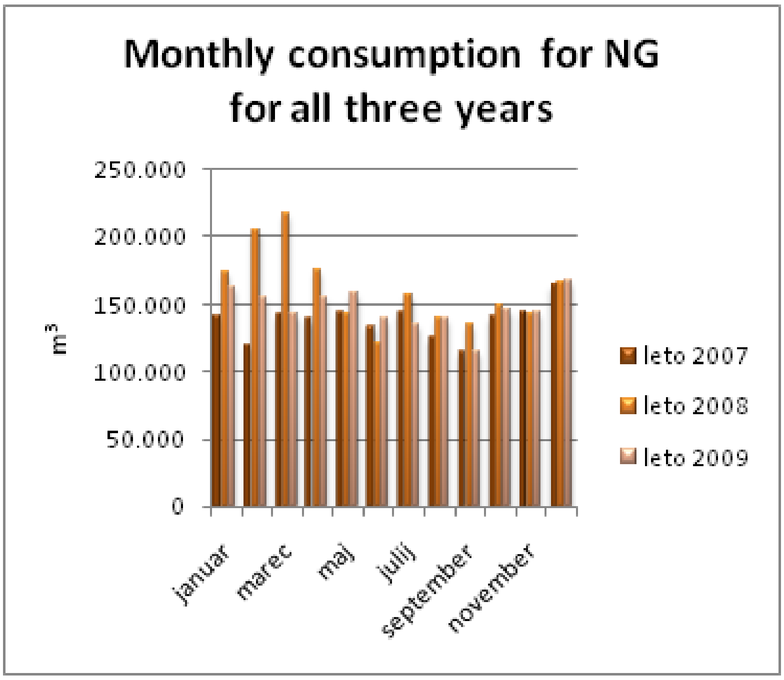


Figure 36: Monthly consumption of natural gas(NG) for all three years

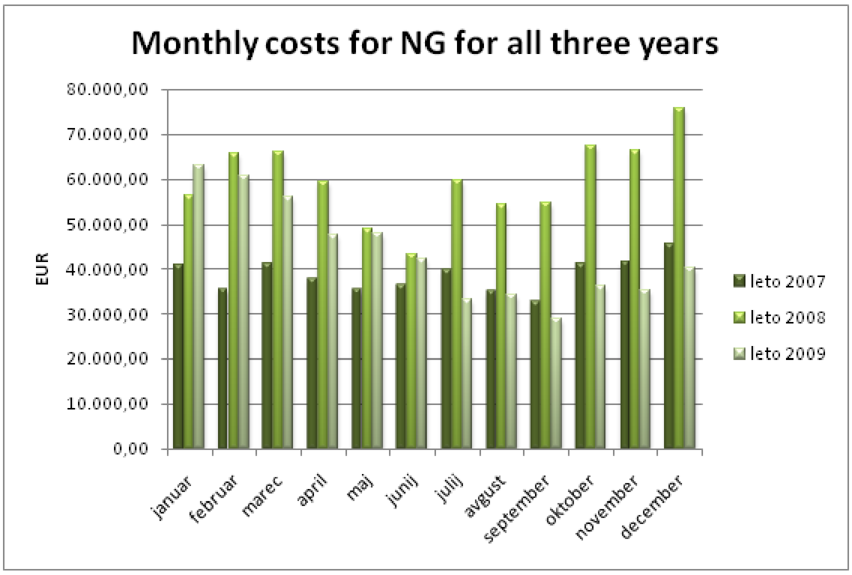


Figure 37: Monthly costs of natural gas for all three years

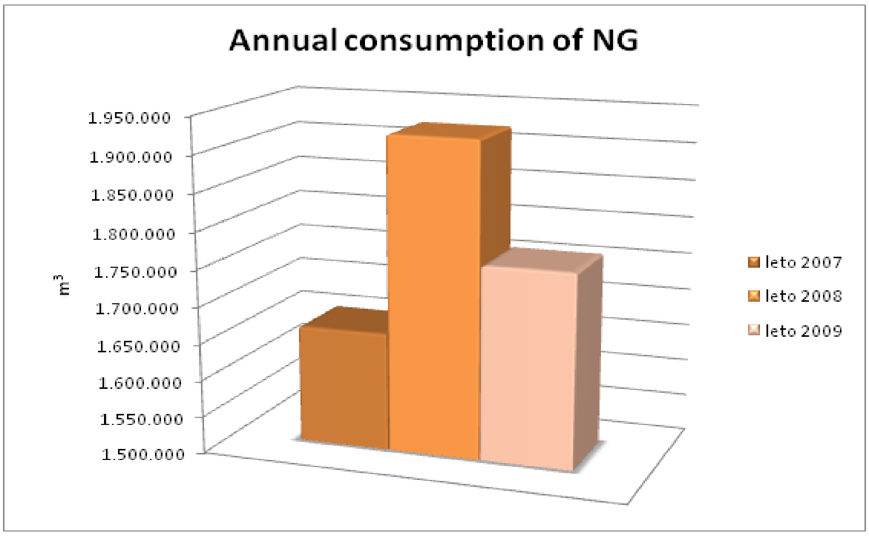


Figure 38: Natural gas consumption in the period between 2007 and 2009

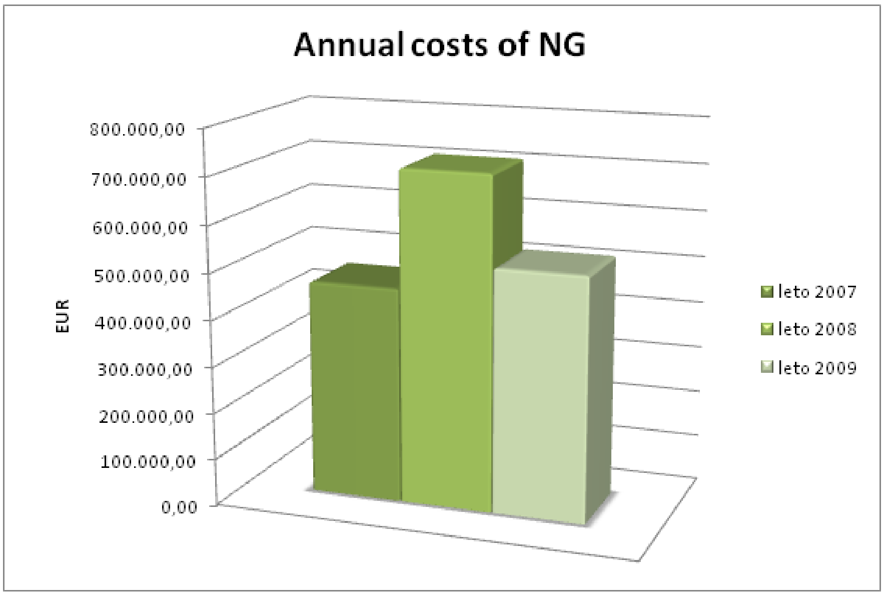


Figure 39: Costs of natural gas in the period between 2007 and 2009.

4.2.1.3 Water Consumption

Table 7 shows water consumption in the period between 2007 and 2009. Costs shown in the table 7 present the sum of the price of water, maintenance allowance, water fee, waste water discharge and treatment. The fact the price changes irrespective of the consumption is the result of major changes of prices for the discharge of sewage and waste water treatment. **Figures 40** and **41** show monthly consumption and costs, while **Figures 42** and **43** show annual consumption and costs of water.

Table 7: Water consumption in the period between 2007 and 2009

Year	Consumption (m^3/a)	Costs (EUR/a)	Price (EUR/m^3)	Specific consumption (L/L of milk)
2007	113,498	228,256	2.01	2.60
2008	97,096	247,866	2.55	2.28
2009	101,824	207,803	2.04	2.26

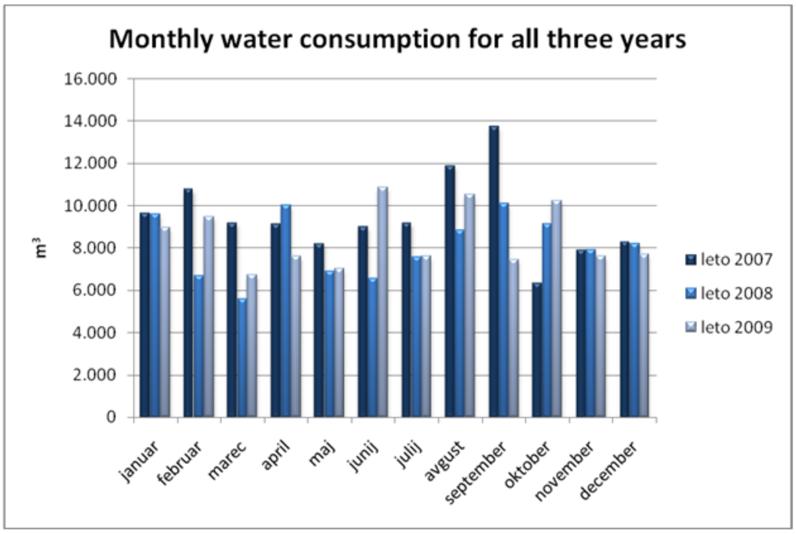


Figure 40: Monthly water consumption for all three years

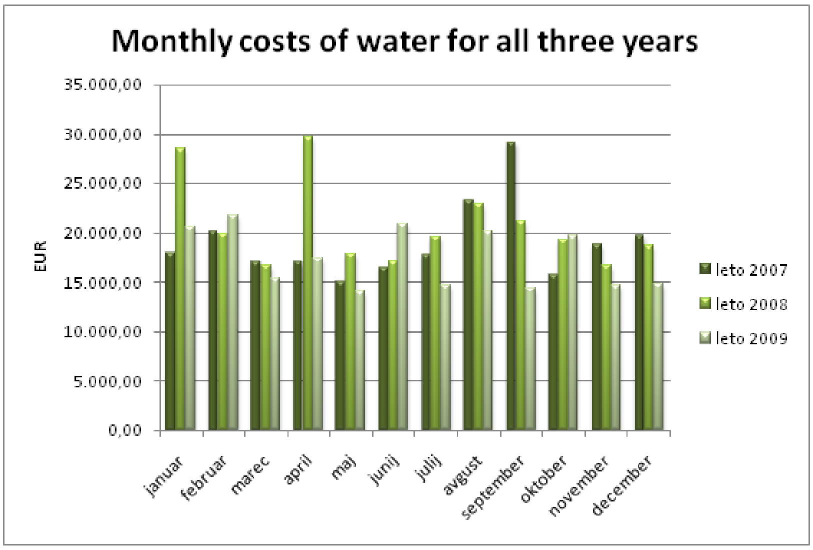


Figure 41: Monthly costs of water for all three years

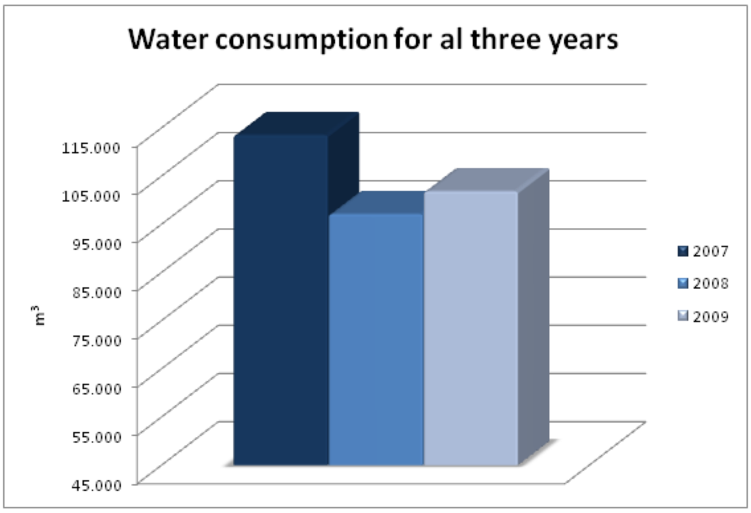


Figure 42: Water consumption in the period between 2007 and 2009

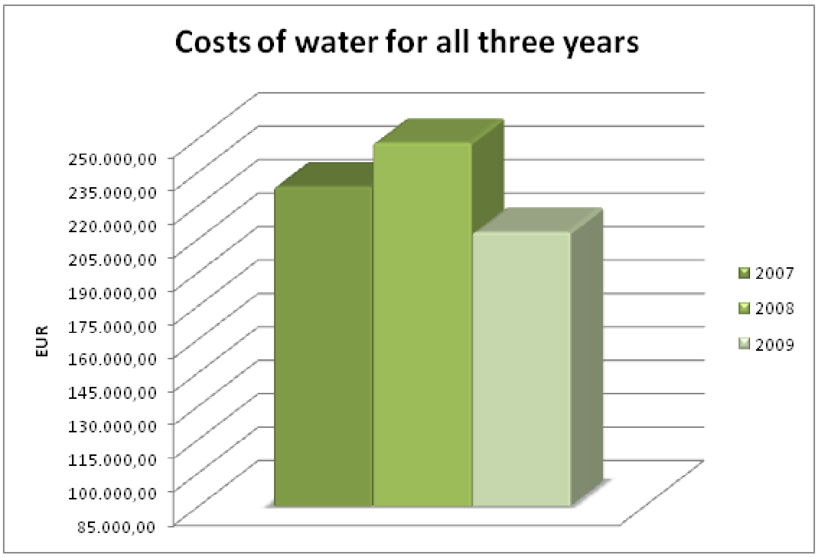


Figure 43: Costs of water in the period between 2007 and 2009

4.3 Analysis of Processes and Utility Systems

4.3.1 Production Processes

Table 8 shows the quantity of processed milk and consumption of steam and water by production processes. The values are taken from the mass and energy balances.

Reception and Preparation of Raw Milk

Milk is pumped from tanks through a balance tank to the heat exchanger, where it is cooled to the temperature between 4°C and 6°C and then pumped into fresh milk storage tanks. From there milk is transported through pipelines into the production processes.

Pasteurization

Milk is pumped from fresh milk tanks into the centrifugal process. Preliminary, in the plate heat exchanger the milk is heated to the temperature between 50°C and 60°C for better separation of milk. Centrifuging is a process of milk refinement, skimming of milk and whey, concentration of cream, whey proteins and lactose. This is followed by milk standardization in the compomaster, where on the basis of the weighing of masses of both raw materials (skimmed milk and cream) milk is prepared with the content of milk fat ranging from 0.05% to 3.5% and cream with the content of milk fat ranging from 30% to 42%. This is followed by pasteurization, which destroys pathogens microorganism and inactivates enzymes. Pasteurization is performed in accordance with the HTST procedure (medium or short-time pasteurization) at a temperature ranging from 81°C to 83°C with an effective residence time of 15 seconds. After that milk is cooled down to the temperature of between 4°C and 6°C. Cooling takes place in a pasteurizer with non-pasteurized milk and then with ice water – cooling is counter-current. Cooled milk is stored in tanks, where it waits for further processing. **Figure 44** shows the pasteurization process flow diagram.

Figure 44: Pasteurization process chart (Steng)

Lactic Acid Fermentation (Production of Yoghurt and Butter)

Cooled pasteurized milk is added milk powder. Then in the plate heat exchanger milk is heated to the temperature ranging from 60°C to 70°C. This is followed by homogenization at a pressure of approx. 200 to 300 bars. This procedure reduced the diameter of fat globules and inhibits secretion of fats on the surface. Thermal processing at *T* = 105°C for 120 seconds improves conditions for the activity of a “starter” culture. In the plate heat exchanger milk is cooled down to a temperature of between 42°C and 43°C. In an isolated tank started cultures are added. Various sorts of bacteria are used for various decomposition processes of milk sugar, and this is what creates a specific aroma and texture of a product.

Fermentation is an anaerobic process, which takes places at a temperature of approx. 20°C to 40°C. After completed fermentation the yoghurt is filled in cups and stored in the ripening chamber at a temperature of 10°C to 20°C, then it is cooled down in the cooling room to a temperature to approx. 2°C to 6°C (**Figure 45**).

Figure 45: Yoghurt production process chart (Steng 2010)

Pasteurized cream is stored in ripening tanks, and then it is heated in the plate heat exchange to a temperature of churning in the butter making machine. Ice water for cooling of mixture is supplied through a double shell. A mixture of butter grains and buttermilk is separated on the rotating strainer. Cooled buttermilk is returned to the separator in order to cool butter grains. Butter grains freely fall into the first kneading machine, where the rest of buttermilk is drained off. Depending on the technological procedure, fermentation culture is added. Butter is finally treated in the second kneading machine, where water is added, if necessary. This results in a homogeneous mass. Vacuum chamber with nozzles is located between the two kneading machines, butter passes through them in order to press out excess air. This is followed by packaging and storage in the cooling room.

Curd Making

Coagulation temperature is the main condition for coagulating milk and takes place at a temperature between T = 30°C in T = 40 °C. Heating is performed in the plate heat exchanger or cheese tank. Two methods of renneting are known, i.e. *enzymatic method* by means of rennet's and *acid method* by means of starter cultures. Cooled pasteurized milk is heated in a plate heat exchanger to a temperature of 26°C and pumped into cheese vessels, where starter cultures are added to achieve acidity level from 42°SH to 50°SH* in 16 to 20 hours. The milk coagulates and when the acidity level of coagulum is reached, it is cut to a specific size of cheese grain. Whey is pumped from cheese vessels to a landfill site in order to be transported for animal feed. Curd is stored at T = 8°C and then packed and stored in a cooling chamber at T < 8°C (**Figure 46**).

Figure 46: Curd production process chart.

Sterilization – UHT (Ultra High Temperature)

Sterilization is a thermal processing procedure, which is used to destroy all micro-organisms and their spores as well as to inactivate enzymes. UHT sterilization can be indirect in tubular heat exchangers or direct with direct injection of steam into milk or cream. It is performed at a temperature of approx. 135°C to 150°C for 4 to 8 seconds.

**Acid level – SH (Soxhlet – Henkel) is the number of millilitres of 1 molar solution of NaOH, used for neutralization. 20 ml milk.*

Production on the APV line

For direct sterilization pasteurized milk is pumped on the plate heat exchanger, where it is heated to a minimum temperature of 82°C. Milk heated that way is pumped in the infusion chamber. In the chamber milk at first disperses and then in jets, which form a type of a cylinder, flows inside the chamber. The lower part of the chamber is heated through a double wall to a temperature of approx. 120°C and 121°C. At this temperature occurs the lowest secretion of milk stone and denaturalization of proteins in contact with milk heated to a temperature of approx. 135°C and 145°C and with metal surface of the paralizer. On the so-called cooling ring of the chamber a thin film appears on the condensate, which prevents direct contact between milk and surface of the chamber. This is followed by milk pumping to the retention chamber, where milk is retained for approximately 4

Figure 47: Production on the APV line chart.

seconds. Due to fast drop, the milk is cooled to *T* = 78°C, whereby water, which was added as steam in the sterilization in the paralizer, evaporates. This is followed by homogenization in an aseptic homogenizer. It has two levels at a pressure of 215 bars and 50 bars. This results in uniform distribution of fat globules and prevents secretion of fat in the milk. Indirect sterilization means that milk is sterilized in tubular heat exchangers. Milk is heated with hot water, which is additionally warmed throughout the process with steam to reach the required temperature. After sterilization, milk is cooled down with ice water in the heat exchanger to a temperature of 28°C. Sterilization of the sealing water and water for "oiling" pistons of homogenizer takes places in the plate heat exchanger. Milk is then packed and stored at a temperature of 20°C (**Figure 47**).

Evaporation of Milk (Whey)

Cooled pasteurized milk is pumped through a balance tank, which serves for pressure balancing of milk. Then milk is pumped through the evaporation pre-heaters. In the heat exchanger milk is additionally warmed and pumped into the shell of the evaporator of the level III evaporation. After that, milk is pumped into the second heat exchanger and in the shell of the evaporator of the level I evaporation. Milk is heated to a temperature of between 64°C and 66°C. Heated milk passes through the tubular pre-heater and enters into the shell of the level II evaporator. In the tubular pasteurizer milk is pasteurized at *T* = 92°C. Pasteurized milk heats the milk pumped into the evaporator and is thus cooled down to a temperature of approx. 69°C to 71°C.

The milk passes through the upper part of the evaporator to the level I evaporation. In a thin layer milk is distributed over the walls of pipes, which are on the external part heated with steam. In the evaporation process, water evaporates from milk and is separated from milk in a cyclone. Milk passes the level I evaporation five times. Partially concentrated milk is pumped to the level II evaporation, where the same process takes place, only at a lower temperature and pressure. This is followed by level III evaporation, which takes place at an even lower temperature and pressure than the previous stage. Concentrated milk (with a specific percentage of dry matter) is separated from water in the cyclone and is pumped into two duplicators. In order to prevent concentrated milk from being retained in one duplicator for too long, the duplicator should be replaced every 2 to 3 hours.

Drying

In the tubular heat exchanger, concentrated milk is heated with steam to a temperature of approx. 70°C to 72°C. This reduces the risk of microbiological recontamination. After that concentrated milk is pumped through a filter in order to remove all bigger particles that might obstruct spraying nozzles on the drying tower. Homogenization is performed only in the production of full-fat milk powder. In the production of skimmed milk powder concentrated milk passes through a homogenizer, which is not under pressure. In the sprayer with nozzles the concentrated milk is dispersed into fine droplets, because this increases the surface for drying and drying is performed faster. Drying is performed with filtered dry air with a temperature of 174°C. This air comes into contact with dispersed globules with water evaporating from them, causing the air to cool down. In the tubular heat exchanger the air is heated with steam. Milk powder is removed to the bottom of the drying tower by means of an emptying device, which works on the principle of tapping (instantizer). Fine particles from the drying towers and instantizer that have been preliminary collected in the cyclone are returned into the drying tower through nozzles.

The bottom of the drying tower is connected to the instantizer so that the milk powder freely falls into the instantization phase. Warm air is blown into the first part of the instantizer, which continuously vibrates. Such warm air dries milk powder to reach the required moisture percentage. In the second part of the instantizer, milk powder is cooled with cool air. Fine milk powder is drained off into the auxiliary cyclone by means of over-pressure and returned into the drying tower. Prior to packaging, milk powder is sifted on a sieve. This removes any possible burnt dust particles (**Figure 48**).

Figure 48: Milk drying chart

Table 8: Consumption of steam and water calculated from mass balances

	Quantity (L/a) oz. (kg/a)	Steam (kg/h)	Ice water (L/h)	Cooling water (L/h)	Note
Reception	68,230,474		5,865		
Pasteurization:					
a) Milk	59,133,077	336	12,702		
b) Cream	9,097,397	19	1,956	3,589	
Curd making:	5,377,140	75			
a) Home-made		146			
b) Low-fat					
c) Cheese spreads		126			
Yoghurt					
production:	896,440	445		8,161	
a) Yoghurt	326,471	379		8,161	
b) Cream	1,431,240	418	8,160		
c) Fresh milk	124,997	418		8,160	
d) Buttermilk					
Butter making	2,311,481	40	1,480		
APV – new:					
a) Milk	20,698,775	1,108	12,000		
b) Iced coffee	306,840	1,071	12,000		
c) Pudding	159,253	579	6,000		
APV – old:					*Soft water from the cooling tower
a) Cream	1,343,290	422	4,031	4,192*	
b) Milk	485,972	787	7,862	7,835*	

4.3.2 Steam & Condensate System

Steam and condensate system of the company Pomurske mlekarne d.d. is composed of:

- Steam boiler room with two steam boilers (**Table 9, Figure 49**), thermal preparation and chemical preparation of water;
- Steam distribution system (steam distribution piping system);
- Steam consumers (process units, steam blowing and sterilization systems, steam blocks, heat exchangers for heating sanitary water and water for heating rooms, steam fan heaters) including steam fittings and regulation;
- System for collecting, storing and returning condensate including condensate pumps and regulation.

Within the energy audit procedure, we prepared a precise diagram of a steam and condensate system, which is annexed to this report and serves as an aid in projecting the steam and condensate system for the process reconstruction.

Table 9: Data on steam boilers

	Steam Boiler 1	**Steam Boiler 2**
Type of steam boiler	EMO TPV12,5	EMO TPV12,5
Nominal power	8.2 MW	8.2 MW
Operating steam pressure	13.2 bar	13.2 bar
Steam boiler over-pressure protection	16.0 bar	16.0 bar
Burner	Combined ELKO/ZP	Combined ELKO/ZP
Type of burner	Weishaupt RGMS 70/2 -A	Weishaupt RGMS 70/2 –A
Burner supply power	1 MW - 10,9 MW	1 MW - 10,9 MW
Burner nominal pressure	30 mbar- 180 mbar	30 mbar- 180 mbar
Operating control	24 hours	24 hours

Natural gas flows through the external main gas valve and gas line into the utility room. Additionally, a tank of extra-light heating oil with the capacity of 4m^3 is installed on the floor next to the feed tank.

Steam boilers are equipped with automatic desalination and blow-down with the equipment of the Gestra manufacturer. The system operates conditionally, because the probe for measuring electro-conductivity of boiler water is installed in the intermediate chamber without a constant flow, so it is required to empty the chamber manually from time to time or by automatic outlet valve. Because this does not happen, users manually desalinate steam boilers. Similarly, automatic blow-down system operates only on one steam boiler and even here users normally perform a manual blow-down of steam boilers.

Figure 49: EMO Celje TPV 12,5 Steam Boiler

Steam Distributors in the Boiler Room

In the boiler room there is the main steam distributor with an operating pressure of 13.4 bars, an operating temperature of 195°C and a volume of 185 litres (**Figure 50**). The steam distributor is equipped with three steam valves DN200 (two for inflow of steam from the steam boiler, one for outflow into the distribution system) and an outflow valve DN65 for flow of steam into the steam distributor for the thermal preparation of boiler water. As can be determined on the basis of the figure and the audit, flanged fittings PN16 are installed on the distributor and on the blow-down side of boilers, instead of PN25, which represents a safety risk and is not in accordance with the norms.

Figure 50: Steam distributor in the boiler room (Steng)

The distributor for heating the feed tank and outgassing dates back to 1985, and has an operating pressure of 5 bars, an operating temperature of 152°C and a volume of 35L (**Figure 51**). It is equipped with a safety valve and an additional outflow DN40 and leads the steam pipeline into heat exchangers that are no longer used.

Figure 51: Steam distributor for feed tank

Feed Tank with Outgasser

The feed tank itself has a volume of 10,000L, and is heated to 105°C at a maximum pressure of 0.3 bars (**Figure 52**). The tank contains four feed pumps, two for each boiler with a flow of 19.7m^3/h and a pressure height of 20 bars.

Figure 52: Feed tank with outgasser for steam boilers

Steam Distribution System

The steam distribution system includes the distribution of steam to all consumers, and is composed of :

- The main steam pipeline DN200 from the boiler room into the room for the main steam sub-station in the basement next to the sterilization plant;
- The pipeline to the car wash;
- Side steam pipelines with dimensions ranging from DN100 to DN15;
- 16 steam distributors and namely:

Steam pipelines are partially thermally insulated, on many areas there is no thermal insulation, specific branches of steam pipelines are under pressure, although there are no consumers or they are not operating; 30% of steam valves don't provide sealing on the outside and steam along the valve spindle leaks into the environment. Efficiency of thermal insulation is 50%.

Steam and Condensate Balance

a) Steam boiler room

Steam and condensate balance was performed gradually:

- Steam consumption was calculated with mass and heat balance of processes;
- Consumption of steam for heating rooms was calculated on the basis of heat balance of buildings in accordance with the PHPP07 methodology;
- Consumption of steam for heating process water was calculated on the basis of measurements of water flow and temperature, and measurements of water flow and temperature from steam cleaning mixer.

Figure 53 shows the process diagram of a steam boiler room. We performed mass and heat balance of boiler rooms by means of measured parameters and calculated percentage of returned condensate (**Table 10)**. Basic steam production parameters are the following:

- Specific steam production is 11.2 kg/m^3 of natural gas;
- Thermal efficiency of boiler room is 82.8%.

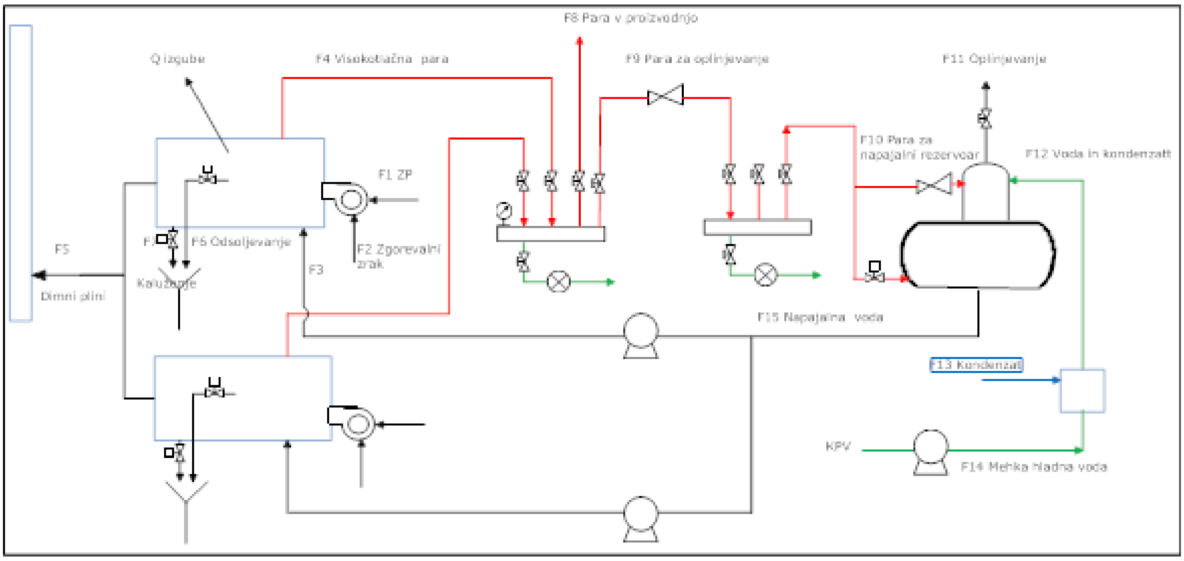


Figure 53: Boiler room system diagram

Table 10: Mass and energy balance of boiler room

	q (m^3/h)						**H (kJ/m^3)**	
Flow	**q (kg/h)**	**Q (kJ/h)**	**P (kW)**	**p (bar)**	**c_p (kJ/m^3·K)**	**T (°C)**	**H (kJ/kg)**	**h (kJ/kg)**
F1	201.3	6,938,990.5	1,927.5			20.0	34,470.00	
F2	2,311.8	61,072.9	17.0		1.3209	20.0	26.42	
F3	2,487.6	1,096,527.2	304.6	1.0		105.0		440.80
F4	2,434.8	6,794,163.5	1,887.3	13.2		195.7	2,790.44	833.40
F5	2,513.1	774,326.6	215.1	0.0		223.0	308.12	
F6	52.8	43,990.5	12.2	10.0		195.7		833.40
Qk		484,110.0	134.5	0.0				
F8	2,257.7	6,302,623.2	1,750.7	13.2		195.7	2,790.44	833.40
F9	177.1	491,540.3	136.5	13.2		195.7	2,790.44	833.40
F10	177.1	491,540.3	136.5	1.2		148.0	2,774.90	440.80
F11	2.2	5,817.3	1.6	1.0		100.0	2,676.00	

F12	2,312.6	611,080.2	169.7	0.0		63.1		264.24
Qo		276.0	0.1					
F13	1,516.2	571,085.5	158.6	1.0	4.185	90.0		376.65
F14	796.4	39,995.1	11.1	1.0	4.185	12.0		50.22

The **table 10** shows that:

- The average natural gas flow is: **201.3m^3/h;**
- The average steam flow is: **2,434.8kg/h;**
- The average consumption of steam for process, heating of water and rooms is: **2,257.7kg/h;**
- Own use of boiler room is: **177.1kg/h;**

- Level of condensate return (including technological condensate) is: **65.5%.**

In the same way we calculated the annual mass and energy balance of steam boiler room; data can be found in the **Table 11**.

Table 11: Annual steam boiler room balance

	q (kg/m^3)						**H (kJ/m^3)**	
Flow	**q (kg/a)**	**Q (kJ/a)**	**P (kW)**	**p (bar)**	**c_p (kJ/m^3·K)**	**T (°C)**	**H (kJ/kg)**	**h (kJ/kg)**
F1	1,763,187.0	60,777,055,890.0	16,882,515.5			20.0	34,470.00	
F2	20,248,462.8	534,923,889.8	148,590.0		1.3209	20.0	26.42	
F3	21,788,355.0	9,604,306,885.8	2,667,863.0	1.0		105.0		440.80
F4	21,326,024.9	59,508,993,034.7	16,530,275.8	13.2		195.7	2,790.44	833.40
F5	22,011,649.8	6,782,152,375.8	1,883,931.2	0.0		223.0	308.12	
F6	462,330.1	385,305,875.1	107,029.4	10.0		195.7		833.40
Qk		4,239,835,380.0	1,177,732.1	0.0				
F8	19,772,001.7	55,196,733,860.0	15,332,426.1	13.2		195.7	2,790.44	833.40
F9	1,554,023.3	4,312,259,174.7	1,197,849.8	13.2		195.7	2,790.44	833.40
F10	1,554,023.3	4,312,259,174.7	1,197,849.8	1.2		148.0	2,774.90	440.80
F11	19,038.2	50,946,136.8	14,151.7	1.0		100.0	2,676.00	
F12	20,253,369.9	5,351,695,796.7	1,486,582.2	0.0		63.1		264.24
Qo		8,701,948.8	2,417.2					
F13	13,278,716.9	5,001,428,723.4	1,389,285.8	1.0	4.185	90.0		376.65
F14	6,974,653.0	350,267,073.3	97,296.4	1.0	4.185	12.0		50.22

Table 11 shows that:

- The annual consumption of natural gas is: **1,763,187m³/a;**
- Annually produced steam is: **21,326t/a;**
- Annual consumption of steam for process, heating water and rooms is: **19,772t/a;**
- Own use of boiler room: **1,554t/a;**
- Level of condensate return (including technological condensate) is: **65.5%.**

b) Steam and condensate balance of all consumers

Balance was calculated on the basis of the data on production in 2009; all data and process diagrams are annexed. The annual balance of steam consumption and quantity of returned condensate can be found in **Table 12**. The table shows there are unidentifiable losses of **7,152t/a** or **33.5%.**

Table 12: Steam and condensate balance of some steam consumers.

Consumer	Building	Plant	p (bar)	q_{min} (kg/h)	q_{pov} (kg/h)	q_{maks} (kg/h)	q (t/a)	Condensate outflow
CIP Pasteurization	Building II, basement	Pasteurization basement	4.5	0	1,200.00	1,200.00	962.20	Into the sewage system
Sanitary water heater	Building III, basement	IWK, basement	2	0	47.00	414.30	411.68	Into the sewage system
CIP		APV sterilization	7	0	535.30	626.40	462.30	Into the sewage system
CIP	Building VI, basement	Curdmaking plant	3	0	533.79	795.91	561.00	Into the sewage system
CIP	Building IV, ground floor	Drying room-NIRO II	3	0	179.90	193.37	120.90	Into the sewage system
CIP	Car wash	Car wash	3	0	564.00	564.00	677.00	Into the sewage system
Head office heating	Head office	Head office building	2	0	84.52	219.64	160.25	Into the sewage system
Storage facility heating	Existing storage facility	Storage facility	5	0	20.34	77.14	115.71	Channel in the curdmaking plant
Workrooms heating	Maintenance	Maintenance	0.5		27.30	34.50	51.76	In the condensation tank NIRO
Own use of boiler room					177.44	177.44	1,554.02	-
Steam for cleaning mixers							161.00	Into the sewage system
TOTAL					**14,356.70**	**15,398.95**	**14,173.95**	
Produced							**21,326.20**	
Losses, unidentifiable							**7,152.07**	

The summary of the table above is contained in the **Table 13**, which shows that almost a half of known consumption of steam is used for washing (CIP), that's why the greatest reserves in steam savings are here, next to unidentifiable losses.

An average, steam flow means the steam flow when processes are operating. Hence, in the event of a full process operation (without heat losses), the flow of steam to be ensured by the boiler room, including heat losses (without CIP operations), is:

- Steam flow for processes: 9,586kg/h
- Own use of boiler room: 177kg/h
- Allowable heat losses (10%): 958kg/a
- Heating of rooms: 637kg/a
- Sanitary water heating: 572kg/h

Total in the non-heating season: 11,294kg/a

Total in the heating season: 11,931kg/h

Because the capacity of a steam boiler is 12,500kg/h, such capacity is sufficient in the event of a full operation, but due to safety reasons another steam boiler is on hot reserve.

Table 13: Summary of steam balance

Steam consumer	Average flow (kg/h)	Maximum flow (kg/h)	Annual consumption (t/a)	Percentage (%)
Processes	9,515.46	9,586.48	6,895.59	32.33
CIP	3,012.99	3,379.68	2,783.70	13.05
Heating of rooms	400.25	637.49	2,367.96	11.10
Sanitary water heating	47.00	414.30	572.68	2.69
Own use of boiler room	177.44	177.44	1,554.02	7.29
Steam consumption			14,153.95	66.46
Losses			7,152.07	33.45
Total			**21,326.02**	**100.00**

Steam losses occur for the following reasons:

- Heat losses of steam pipelines;
- Excess consumptions, for examples repetition of procedures, process interruptions and repeated start-ups, additional sterilization and purification of equipment and pipes;

- Excess heating of rooms;
- Losses due to leakages of steam and condensate valves on spindles, flanges, holes in pipelines (result of corrosion);
- Leakage of regulation valves or after the process has been completed steam valves stay open and steam is used in a non-active equipment, such as the drying air heater in the NIRO II dryer, yoghurt filler, room heating fan convectors in IWK, etc.

A precise analysis and overview of the situation, including outline of a steam and condensate system (plans are annexed), defines how much condensate is unduly lost and how much of it is returned to the feed system of the steam boiler. Information can be found in the **Table 14.**

Table 14: Condensate balance

	q **(t/a)**	**Percentage /%**
Returned condensate	2,226	11.26
Evaporation condensate	1,529	7.73
Contaminated condensate	375	1.90
Lost condensate	8,490	42.94
Own use of boiler room	1,554	(no condensate)
Unknown	7,152	36.17
TOTAL	**21,326**	**100.00**
Specified	12,645	
Technological condensate	12,267	

As can be ascertained from the discussions with steam boiler users, in the event of operation of the Evaporation plant, the complete returned condensate is sufficient for covering the soft water demand for the steam boiler. Therefore, in these cases we do not take tap cold water from the softening plant. But it has not been checked whether there are losses in the main condensate tank occurring due the overflow and then in the sewage system, when all processes, including evaporation, are operating. Losses of steam condensate also occur due to:

- Corrosion of a heat exchanger for heating storage areas in the in Curdmaking plant sub-station; for this reason complete condensate is drained off into the sewage system (1,160t/a);

- Inappropriate drainage of condensate from all plate heat exchangers (CIP, pasteurization, sterilization, heating of technological water, heating head office, etc.);
- Leakage in condensate pipelines (Pasteurization: 2,910t/a).

The above data was the basis for the calculation of own price of steam in Pomurske mlekarne. Own price of steam includes costs of natural gas, water, chemicals, depreciation, labour force and electricity. The structure of own price can be seen in **Table 15**.

Table 15: Calculation of own price of technological steam

	m^3/t	EUR/m^3	EUR/t
ZP	89.17	0.2975	26.5280
Soft water	0.65563	2.04	1.3375
Water for regeneration	0.065563	2.04	0.1337
Water losses			0.9193
Chemicals		0.1852	0.0121
Depreciation			0.7860
Electricity		0.0840	0.5172
Workers			30.5021
Total			**60.7359**
Price of steam without workers			**30.2338**

Key Findings:

- Automatic desalination system is not carried out efficiently;
- Feed tank with thermal outgasser must be replaced;
- We annually produce 21,326t of steam at a pressure of 13.2 bars;
- 33.5% of steam represents losses or excess use;
- 10% of technological condensate is returned, the total level of returned condensate, including technological condensate, is 65%;
- 2,800t/a of steam is used for washing (CIP), which is 13%;
- All rooms and technological water are heated with steam;
- Steam losses occur due to leakages, uneconomical operation and maintenance, worn equipment in pipelines, corrosion and ineffective thermal insulation;

- Losses of condensate also occur due to deterioration of condensing circuits, corrosion of heat exchangers, ineffective drainage of condensate from plate heat exchangers – the problem of precise temperature regulation;
- Steam and condensate circuit is deteriorated and should be replaced;
- Own price of steam is 60.37EUR/t; own price of steam, excluding the costs of steam boiler users, amounts to 30.23EUR/t.

4.3.3 Water Distribution System

All water is recovered from the water distribution system of the Municipal Utility Company. We use the following types of water:

- Sanitary water, potable water and water for sanitary purposes;
- Technological water, water used in milk treatment processes;
- Cooling water;
- Ice water;
- Water for heating rooms and process equipment;
- Washing water;
- Water for production of technological steam.

With regard to hardness, the company uses three types of water:

1. Hard water, water from the water supply system, which is directly used for the above described purposes;
2. Soft water: this is sealing water, water for steam production, cooling in circular system with a cooling tower and ice water;
3. Condensate: steam and technological.

Washing takes places with the CIP (Cleaning In Place) system automatically and manually with washing points (so-called washing mixers). Solutions in CIP are composed of an alkaline and acidic solution and rinsing water. Purification period, required quantity of water or solution (flow) and temperature regimes depend on the type of equipment or a production process (on the product). CIP cleaning systems are computer controlled. The ice water system is described in more detail in the following chapter. Ice water is used for cooling milk/cream in yoghurt plant and pasteurization plant, for cooling condensers in the cooling system of the yoghurt plant and for cooling feed pumps and samples in the boiler room.

Sanitary Water and Water for Washing Mixers

Sanitary water and water for washing points is heated with steam (p = 3 bars) to T = 70°C, which is stored in two tanks with a volume of V_1 = V_2 = 3,000L. Its annual consumption was calculated on the basis of measurements of cold water flow and water from washing mixers. The precise consumption of washing water with washing devices (mixers) cannot be calculated, because the length and frequency depend on the employee on a specific workplace, period and temperature of washing.

Measurements of water flow were carried out with the ultrasound flow meter in closed systems. The flow meter measures the shift of ultrasound signal through a medium due to flow of liquid. The principle of operation of ultrasound flow meter is shown in **Figure 54:**

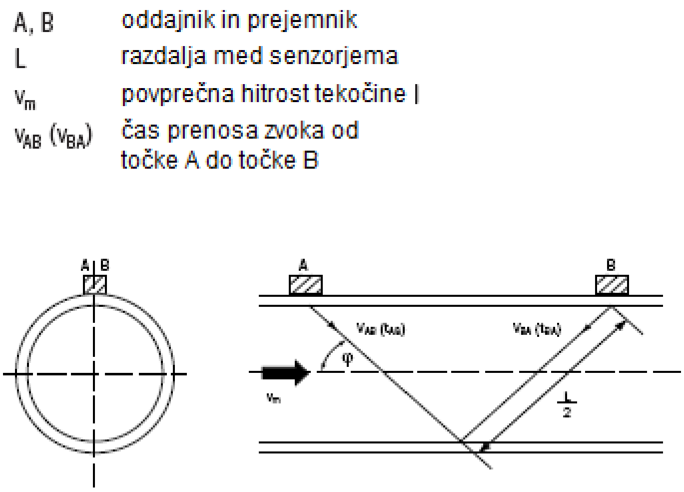


Figure 54: : Method of flow measurement in pipe with the ultrasound hand-held flow meter.

Measurements of the flow of cold water with the ultrasound flow meter was carried out on 29 and 30 September 2010, and namely on the inlet pipe of cold water of hot water buffers, while the second we also measured the consumption of hot water from recuperation of waste heat of the ice system. Measurements took place within 24 hours. The measured data served for the assessment of consumption of hot water in the company:

- Hot water flow in water heater: 10m^3 per day or 3,669m^3/a (T=70ºC);
- Hot water flow from the ice system hot water reservoirs: 3.9m^3 per day or 1,447m^3/a (T=50ºC).

Table 16 shows standardized consumption of sanitary water per employee in the food industry. It also shows the number of washbasins, showers, toilet cisterns, urinals and washing mixers within the whole company. On the basis of these data we calculated the consumption of hot and cold water and steam in the company. **Table 17** shows consumption of sanitary water and technological water for washing mixers.

Table 16: Standardized consumption of sanitary water per employee

HW consumption per employee per day (shower and washbasin)	50	L/day
CW consumption per employee per day (toilet cisterns and urinals)	30	L/day
HW consumption per employee per day (washbasin)	20	L/day
Number of washbasins and showers	87	piece
Number of toilet cisterns and urinals	18	piece
Washing mixer CW/steam	8	piece
Washing mixer CW/HW	33	piece
Washing mixer CW/HW/steam	13	piece
Number of working days	365	days
Number of employees in 2009	104	employ.

Table 17: Annual consumption of sanitary and technological water (washing mixers)

	Consumption	***T***
	(m^3/a)	**(°C)**
Sanitary water		
CW	1,139	12
HW	1,898	36
Washing mixers		
CW/steam	2,567	50
CW/HW*	4,773	44
TOTAL	**10,377**	-

*Consumption in washing mixers CW/HW/steam is included in the consumption of CW/HW washing mixers.

On the basis of measurements and calculations of mass and energy balance, steam consumption (p = 3 bars) for water heating to T = 70°C is 411t/a. Steam consumption for CW/steam washing mixers is 161t/a.

CIP (cleaning in place)

Five CIP systems are installed in the company. Systems are installed in NIRO II, Sterilization plant, Pasteurization plant, Curd making plant and Car wash. CIP Sterilization and CIP Pasteurization are interconnected and they rinsing water circles inside them after blow-down. All programmes are computer controlled and cannot be changed. On the basis of the data collected on the duration of CIP systems operations and recorded programmes, we calculated water and steam consumption. CIP Pasteurization consumption was calculated with regard to other CIP systems, because access to data was disabled. **Table 18** shows steam consumption for individual CIP systems. CIP systems computer print-outs show water consumption for an individual step. The program has no save function for energy consumption for a full period, but only for an individual step. If this function was installed or activated, it would be possible to monitor consumption of energy products within a longer period.

Table 18: Water and steam consumption in CIP systems.

Location	**Water (m^3/a)**	**Steam (t/a)**
NIRO II	2,429	121
Sterilization	4,421	462
Pasteurization	7,423	962
Curdmaking	9,477	561
Car wash	7,200	677
TOTAL	**30,950**	**2,783**

Return lines of solutions and rinsing water in cleaning pass through solution and water tanks until full or until they reach the prescribed concentration, the rest is drained off into the sewage system. Solutions and water are heated with steam in heat exchangers to the prescribed temperature for an individual system.

Water Balance

For the calculation of water balance we observed all consumed or supplied water.

The following also has to be mentioned here:

- Washing water from washing mixers was calculated on the basis of an inspection and random measurements and measured average washing period;

- Cooling water was calculated from mass and energy balances of consumers;
- Water in CIP was calculated on the basis of real data and washing periods, except CIP in Pasteurization, where data were not available;
- The consumption of ice system was measured by means of existing flow meters;
- Cooling water flow of APV Sterilization was measured;
- Consumption of boiler water was calculated on the basis of the mass and energy balance of the steam and condensate system;
- Supplement of NIRO II was calculated on the basis of water balance with combination of measurements;
- Regeneration of softening plants was calculated with regard to the type of the softening plant and volume of resin. Deviations are possible due to the manual regeneration of the softening device in the boiler room and the Sterilization plant;
- Consumption of sealing-cooling soft water was calculated with the soft water balance.

Water balance of the company Pomurske mlekarne is shown in the **Table 19**.

Table 19: Water balance of the company

Water balance	Consumption (m^3/a)	Percentage (%)	Hard water (m^3/a)	Soft water (m^3/a)
SHW and washing mixers	10,377	9.24	10,377	-
Cooling water	30,277	26.96	30,277	-
CIP	30,950	27.56	30,950	-
Foam sprayer	2,250	2.00	2,250	-
Supplementation of ice water	100	0.09	-	100
Ice water system cooling tower	5,300	4.72	-	5,300
Cooling tower APV Sterilization	244	0.22	-	244
Boiler room	7,564	6.74	-	7,564
Evaporation of whey	179	0.16	179	-
Evaporation of milk	33	0.03	33	-
Losses of sealing water NIRO II	4,177	3.72	4,177	-
Regeneration of softening plants	951	0.85	951	-
Supplementation of soft water NIRO II	5,219	4.65	-	5,219
Cooling/sealing of pumps	14,681	13.07	-	14,681
TOTAL	**112,301**	**-**	**79,193**	**33,108**
Percentage	**-**	**100**	**70.52**	**29.48**

The total water consumption in the company is 112,300m^3/a, of which 30% is soft water, the rest is hard water. The majority consumers are CIP and pre-cooling in the Pasteurization plant, and the cooling of the skimmer housing and sealing of pumps in the Sterilization plant.

Key Findings:

- The company uses water supplied by the municipal utility company Komunala javno podjetje d.o.o from Murska Sobota;
- Water is used for manual washing of production areas and equipment, automatic washing and disinfection (CIP), for cooling, sealing of pumps, skimmer and compressors, for production of steam and for sanitary purposes;
- Annual water consumption is 112,300m^3;
- The majority is used by cooling waters (27%), washing water in CIP (27.3%), sealing of pumps and cooling of skimmer (13.1%) and manual washing of rooms (9.1%);
- All cooling water (except in APV Sterilization), sealing cooling water in Sterilization and Pasteurization plants is drained off into the sewage system (except sealing soft water in NIRO II);
- Waste heat for heating hot water is exploited only in the partial system; the measured one-day value is 3.9m^3, whereas the data on annual production are not available;
- Water is heated with steam to 70ºC by means of a plate heat exchanger in IWK basement areas, away from consumers;
- Water saving potential is 30%.

4.4 Low Temperature (<100) Heat Demand and Related Industrial Processes

Table 20: Low Temperature (<100) Heat Demand and Related Industrial Processes

Processes name	Quantity consumption (L/a) or (kg/a) or (m3/a)	Input temperature level (°C)	Temperature level (°C)	Operating hours h/a	Working days/a
Pasteurization c) Milk d) Cream	59,133,077 9,097,397 **Sum: 68,230**	10	55 – 83	4,613	192
Curdmaking: a) Homemade b) Low-fat c)Cheese spreads	5,377,140	7	25- 50	1,664	69
Yoghurt plant: a) Yoghurt b) Cream c) Fresh milk d) Buttermilk	896,440 326,471 1,431,240 124,997	6	20-75 fermentation process	1,029	43
Buttermaking	2,311,481	10	20 -75 fermentation process	525	22
Sanitary water	3,650	10	35-70	8,760	365
Technological water for washing mixers	10,377	8-12	40-70	8,760	365
CIP water: - Car wash Pasteurization - Sterilization - Drying	30,950	8-12	40-55	8.760	365
Boiler cold soft water	5,767 – 7,560	8-12	105	8.760	

4.5 Medium Temperature (<200) Heat Demand and Related Industrial Processes

Table 21: Medium Temperature (<200) Heat Demand and Related Industrial Processes

Processes name	Quantity consumption (L/a) or (kg/a) or (m3/a)	Input temperature level (°C)	Temperature level (°C)	Operating hours h/a	Working days/a
APV – new: a) Milk b) Iced coffee c) Pudding	 20,698,775 306,840 159,253	 8 8 10	 70 - 139 65 - 139 65 - 139	 2,094 31 32	 90
APV – old: a) Cream b) Milk	 1,343,290 485,972	 8 8	 69 – 144.4 70 – 142.5	 522 97	 26
Drying milk: Concentrate *with hot air	7,796,400	57	70-125	8,760	365

4.6 Heat Profiles (Capacity, Temperature over the Time) per Process

Table 22: Heat Profiles (Capacity, Temperature over the Time) per Process

Processes name	**Quantity consumption (L/a)** or **(kg/a) or (m3/a)**	**Input temperature level (°C)**	**Temperature level (°C)**	**Operating hours h/a**	**Working days/a**	**Type of water**
Pasteurization: e) Milk	59,133,077 9,097,397 **Sum: 68,230**	10	55 – 83	4,613	192	Hard water
Curdmaking: a) Home-made	5,377,140	7	25- 50	1,664	70	Hard water
Sanitary water	3,650	10	70	2,920	365	Hard water
Process water, technological water for washing mixers, cleaning water	10,377	10	70	3,800	365	Hard water
Cleaning water, CIP water: - car wash	8,000	10	60	1,200	365	Hard water
Boiler cold soft water	5,767 – 7,300	10	105	8,760	365	Soft water

Three processes were chosen from the **Table 22** for further observation and analysis:

- Hot water
- CIP: Car wash
- Soft water for central heating system

Hot water (HW) Heat Profile

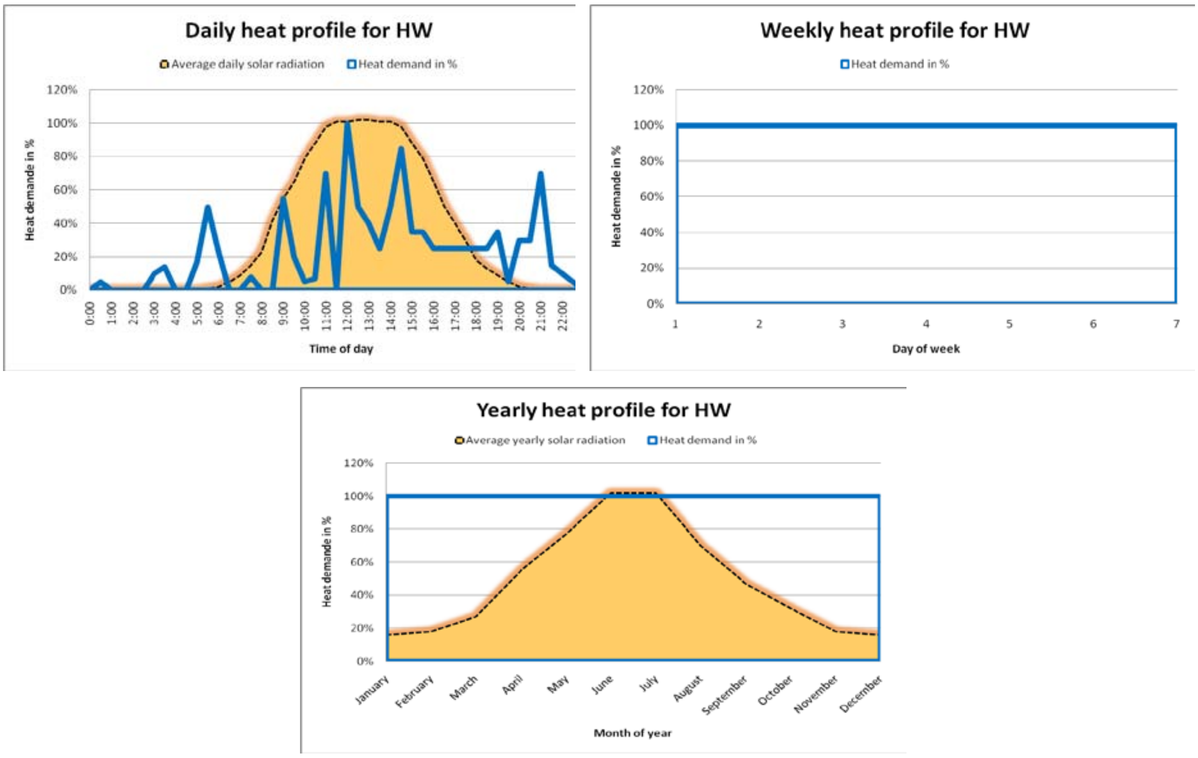


Figure 55: Daily, weekly and yearly heat profile for HW

CIP: Car wash heat profile

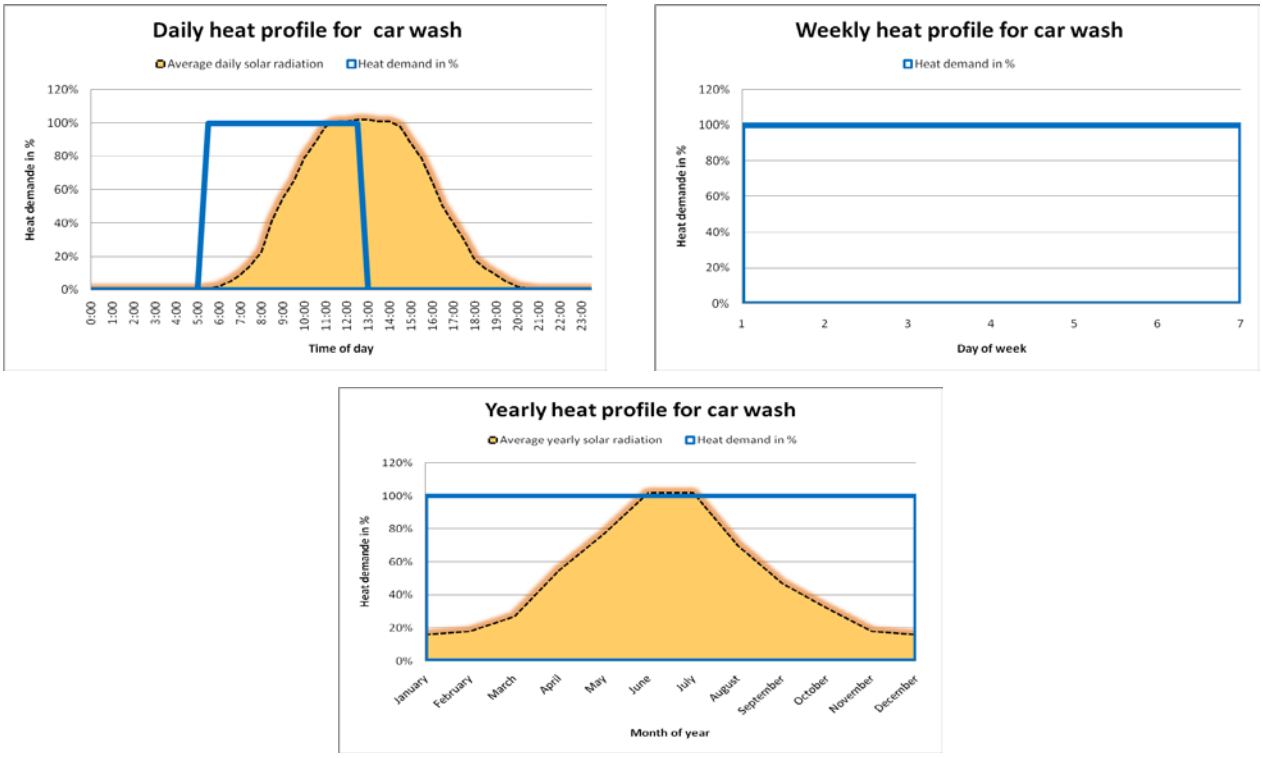


Figure 56: Daily, weekly and yearly heat profile for car wash

Soft Water for the Central Heating System Heat Profile

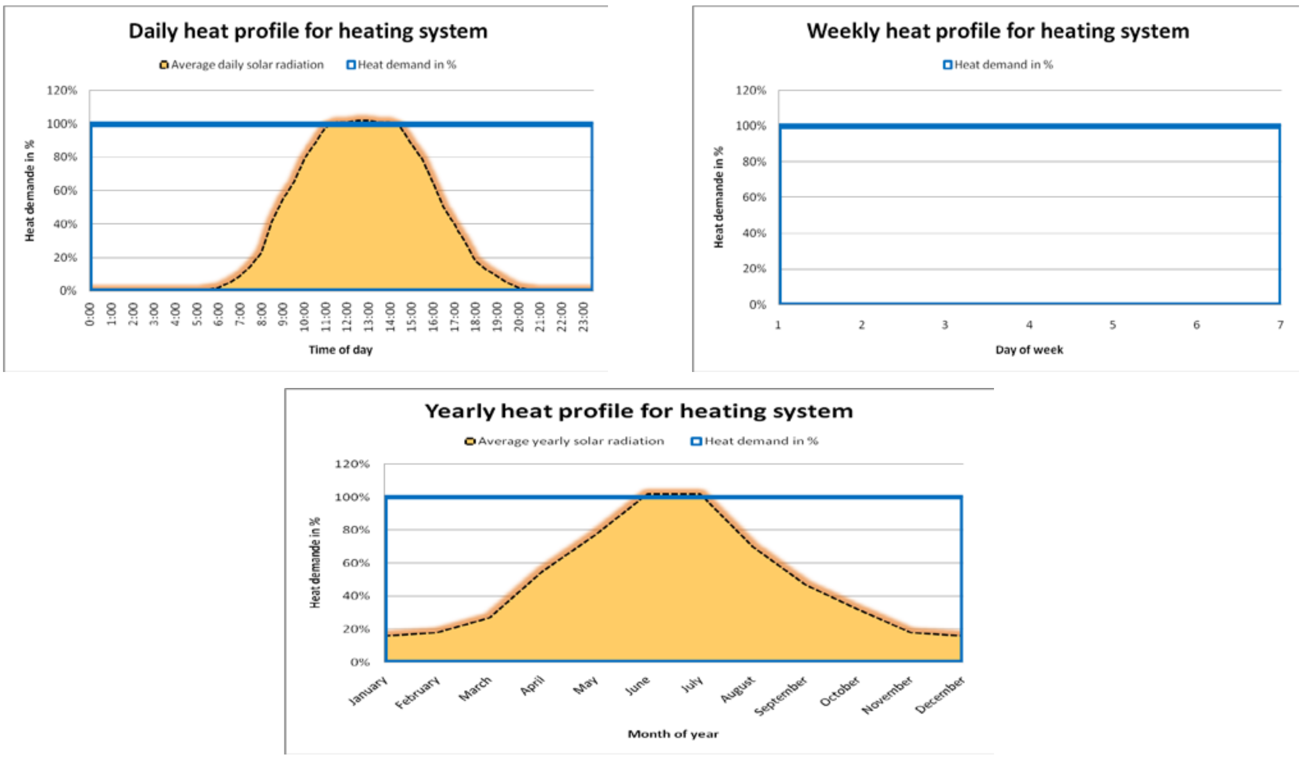


Figure 57: Daily, weekly and yearly heat profile for soft water

The charts show heat profiles for each process and present the proper picture of how the process is active by day, week and year. If the process is appropriate for use of the solar
thermal energy, there should be:

- Exposure to sun at least ¾ of the year (including summer);
- 5 working days minimum; and
- daily demand in summer should not be lower than in the rest of the year
- Temperature process levels should be lower than 100°C; the desired temperatures are around 50°C.

If we compare all 3 figures for HW, CIP and the Heating system, we can see that the daily consumption's dynamic demand is more or less constant only for the central heating system. The topic of the discussion is how to integrate heat in the existing processes and in the distribution heat system. If we check all the above points, we can say that more or less all of them are appropriate; only temperature levels are higher because of the old energy system and protocols which should be changed in the future in order to reduce losses and achieve greater system efficiency.

4.7 Possibilities of Using Waste Heat

Reduction in Consumption of Steam and Water in CIP Systems

All 5 CIP washing systems use different washing parameters and on different locations. Even washing of product pipelines into remote facilities requires additional washing and higher costs. As planned, the reconstruction of the facility will combine processes and CIP plants in order to shorten transport routes (manipulative costs), losses of products and consequently also reduce the costs of washing with CIP plants. In the area NIRO I a new, modern CIP plant will be installed, which will include the Old facility, Pasteurization, Sterilization, Curdmaking plants and Car wash. Combining CIP plants has the following advantages:

- Central and computer management of washing procedures, managing records and controlling consumption and costs;
- Reduced consumption of water, steam and chemicals;
- The possibility of use of waste water;
- Optimization of CIP procedures (optimization of temperatures and washing periods).

In the existing thermodynamic models that we prepared for the calculation of mass and heat balances of all CIP plants, we assumed that the complete consumption of water and steam in new CIP plants will remain the same. We simulated two possibilities:

- Use of hot water with a temperature of 50ºC instead of using a 12ºC cold water;
- Reduction of washing periods by 10%.

If we use hot water and washing solutions in all these phases, we will increase washing efficiency and thus reduce washing periods. The task of technologists is to optimize washing periods by monitoring cleaning parameters. Washing procedures currently used were proposed by equipment producers on the basis of good practice. There are a great number of professional and scientific articles discussing optimization of washing in the dairy industry. **Table 23** contains calculated consumptions in CIP plants and actually shows the saving potential on one side and hot water demand on the other.

Table 23: Saving potential in washing with CIP plants

Location	**Actual condition**		**Use of heated water with waste heat**		**Change in washing period by 10%**	
	Water (m^3/a)	**Steam (t/a)**	**Water *T* = 50°C (m^3/a)**	**Steam (t/a)**	**Water (m^3/a)**	**Steam (t/a)**
NIRO II	2,429	121	2,429	24.6	2,186	108.8
Sterilization	4,421	462	4,421	100.5	4,001	415.8
Pasteurization	7,423	962	7,423	290.0	6,681	866.0
Curdmaking	9,477	561	9,477	163.0	8,529	505.2
Car wash	7,200	677	7,200	142.0	6,480	610.0
TOTAL	**30,950**	**2,783**	**30,950**	**720.1**	**27,877**	**2,505.8**

Savings (**Table 7.24**):

- If we have 50ºC hot water available, then steam savings are 2,010t/a or 60,762 EUR/a;
- If we further shorten washing periods, water savings amount to 3,073m^3/a (6,270 EUR/) and steam savings amount to 72 t/a (2,177EUR/a);

Total savings possible:

62,939EUR/a.

Table 24: Possible savings of steam and water in CIP systems

	Basic consumption	Hot water use (T = 50°C)	Savings
Replacement of cold water with hot water *T* = 50°C			
Steam (t/a)	2,730	720	2,010
Cold water (m^3/a)	30,950	30,950	0
Shortened washing periods by 10%			
Steam (t/a)	720	648	72
Cold water (m^3/a)	30,950	27,877	3,073

Savings of cooling water in the boiler room

The boiler room has two installed sample refrigerators:

- Refrigerator of feed water samples and
- Refrigerator of boiler water samples.

Both the feed and boiler water flow out into the sewage system 24 hours. After performed measurements we assessed annual losses of soft and hard water and natural gas:

Soft water losses	1.,006.94	m^3/a	2,557	EUR/a
Hard water losses	1,681.92	m^3/a	3,431	EUR/a
Gas losses	26,442.87	m^3/a	7,867	EUR/a
Total			**13,855**	**EUR/a**

Savings:

Soft water	964.98	m^3/a	2,450	EUR/a
Hard water	1,639.96	m^3/a	3,346	EUR/a
Natural gas	25,341.08	m^3/a	7,539	EUR/a
Total savings			**13,335**	**EUR/a**

Amount of investment:

Refrigerator of samples for boiler and feed water Spirax Sarco SC20 with valves	2 pcs	2,600	EUR
Stainless pipes of DN15, PN25 boiler	60 m	5,040	EUR
Water pipes DN15	20 m	1,300	EUR
Shut-off valves DN15, PN25	4 pcs	1,440	EUR
Ball valves for water DN15	4 pcs	104	EUR
Total		**10,484**	**EUR**

The installation of a modern samples cooling system includes two refrigerators for samples, shut-off valves and pipework. The refrigerators are installed in existing places. Before sampling, cold water valve is opened, then the sample water valve (boiler or feed) and after some minutes of flow sampling is performed. In total, we expect the system to operate 1 hour per day. This saves hard and soft water and natural gas:

Figure 58 : Modern refrigerator of samples with shut-off valves.

Heating Technological Water with High-Temperature Heat Pump from the NH_3 Cooling System

Ice water cooling system already has an installed system for wastewater recuperation from the circuit of glycol cooling and NH_3 vapours. We calculated that with current load of the cooling system it is possible to warm 11.6m^3 of hot water to 50ºC from the refrigerator of compressor oils, and 10m^3 of hot water to 50ºC, i.e. in total 21.6m^3 per day, after reconstruction it will be possible to produce 10,950m^3/a of hot water. This waste heat is now used to heat store, some of it is also used for technological water, and it will also be possible to heat rooms with the new heating and ventilating and air-conditioning plant that is installed next to the room with the ice water system.

The other source of waste heat is air compressors. The analysis has shown that it is possible to recover 438,780kWh/a of waste heat from air compressors by installing plate exchangers for oil cooling. We can produce 8,980m^3/a of hot water with a temperature of 70ºC.

The third source of waste heat is ice water NH_3. In NH_3 systems we would integrate heat pump ammonia/water and use it to heat technological and sanitary water. The functioning principle of such a heat pump is shown on **Figure 59.**

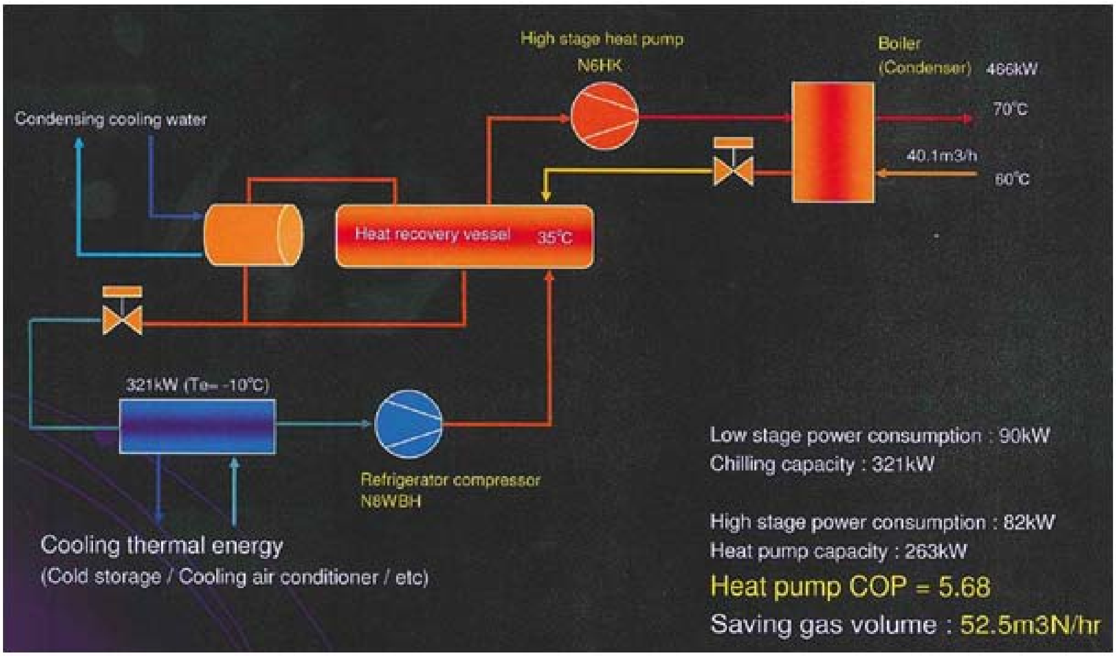


Figure 59: Operating principle of a high-temperature NH_3/water heat pump (Steng)

Heat pump is installed directly into the piping system with flow of NH_3 vapours, which connects the recuperator and evaporation condenser, because it uses the same cooler as the existing cooling system. On the secondary side HP is connected to the hot water system. With regard to the available waste heat of ice water NH_3 compressors, it is possible to install two heat pumps with the total heat capacity of 1MW. Because we don't have consumers of low-temperature heat, we propose the installation of only one heat pump, while additionally exploiting waste heat of compressors and waste heat of the ice system from the existing system.

Data on heat pump:

Pump thermal output:	518	kW
Annual operating period:	5000	h
Annual COP:	5.64	
Heat production:	2,590,000	kWh/a
HW production 70ºC:	38,413	m^3/a

Operating costs HP				
Electricity	459,219	kWh/a	38,560	EUR/a
First service			1,000	EUR/a
Regular service			625	EUR/a
Total operating costs			**40,185**	**EUR/a**

Investment costs:		
Heat pump	90,000	EUR
Construction and pipe installations	45,000	EUR
Project documentation	13,500	EUR
Total	**148,500**	**EUR**

Steam savings	4,470	t/a	135,122	EUR/a
Reduction in ZP consumption	483,221	m^3/a		
Total savings (savings – operating costs)			**94,937**	**EUR/a**

Amount of investment	*148,500 EUR*
Savings	*94,937 EUR/a*
Payback period	*2.0 a*
NSVD	*377,673 EUR*
ISD	*49.6%*

Central Hot water System

All the above given hot water recuperations are only possible if we install the central system with a 24-hour hot water storage. So it is important to fully consider the investment in the recuperation of waste heat by including the following measures:

- Waste heat recuperation from air compressors;
- Waste heat recuperation with high-temperature HP from the ice system;
- If possible, integration of solar energy in the existing system.

We performed the simulation of hot water demand for CIP washing and for the use in washing mixers, and the possibilities of recuperation of other waters that are drained off into the sewage system. Likewise, waste heat may be used for heating rooms, which are currently heated with steam. It is possible to increase the exchanging area of existing heat exchangers by adding plates and connecting them to the hot water system.

Hot water system will recover hot water from three sources; from the existing hot water recuperation system of the ice system, from the compressor station and the from NH_3/water heat pump. Cold water will be supplied as cooling water from the yoghurt plant and the Pasteurization plant, which has a temperature of approx. 30ºC – 35ºC and a surplus of waste condensate from the Wiegland evaporation plant with a temperature of 74ºC. This way all waste water that is being drained off into the sewage system will be heated and used for sanitary and washing purposes and for heating rooms. During the reconstruction project it is required to carry out an additional analysis of a low-temperature heating demand from this system.

Hot water system with waste water recuperation is shown by **Figure 60**. It comprises two heat reservoirs with the total volume of $120m^3$ and a mixing tank for the preparation of 50ºC hot water with a volume of $10m^3$. The system is supplied with waste cooling water and cold soft water. Because the temperature in reservoirs will reach 70ºC, there is a risk of scale formation. This possibility needs to be examined, although the existing heating of water to that temperature does not cause such problems. Alternatively, we can install a softening plant or a magnet plant to prevent accumulation of scale, however, in such cases water needs to be used within 24 hours. The system is additionally supplied by waste condensate from the evaporation plant, which will also supply the steam and condensate system. Because the total steam condensate will be returned, the surplus of technological condensate may be used in this system. It is also possible to integrate the water heating system with solar energy collectors.

Figure 60: Hot water system (Steng)

Amount of investment in the whole hot water system:			
Hot water reservoir	2 x 60 m^3	156,000	EUR
Mixing tank	10 m^3	13,000	EUR
Pumps with frequency regulation	3 pcs	4,000	EUR
Temperature regulation	2 pcs	8,000	EUR
Expansion vessel	1 pc	16,000	EUR
Stainless steel piping	200 m	30,000	EUR
Water softening plant	30 m^3/h	20,000	EUR
Fittings		10,000	EUR
Project documentation		12,000	EUR
Total		**269,000**	**EUR**

All savings due to the construction of the central hot water system and its heating with waste heat

Savings are a reduction in the consumption of steam for heating SHW and washing mixers, a reduction in steam consumption in CIP systems and a result of heating water with the ice water system waste heat. The amount of investment is the sum of investment in the new washing mixers, the purchase of high-temperature HP, the installation of HW in compressors as well as the investment in the total hot water system.

Amount of investment	*495,700 EUR*
Savings	*170,300 EUR/a*
Payback period	*3.5 a*
NSVD	*488,427 EUR*
ISD	*25.3%*

4.8 The Potential of Solar Thermal Energy

4.8.1 Solar Energy

Solar Radiation

In contact with atmosphere and on the surface of the Earth solar radiation is converted into heat, kinetic and potential energy. All its forms (heat, wind and water energy) have a common name – renewable energy sources. Energy that the sun radiates on the Earth is 15,000-times greater than the energy consumed by a man (**Figure 61**). And solar energy is the energy that is freely available and does not pollute the environment. Solar energy can be used for heating rooms, sanitary water, heating pools and for electricity production, lighting and other house consumers. It falls on the Earth in the form of electromagnetic radiation (shortwave radiation), of which 47% is represented by light, 46% by infrared (IR) radiation, and 7% by ultraviolet (UV) rays. Before the sun's rays reach the Earth's surface, a part of them is reflected or absorbed in layers of ozone, CO_2, water vapour and dust in the atmosphere. Hence, only 80% of solar radiation reach the surface and can reach maximum power of 1,000W/m^2. Radiation is divided to direct radiation, which comes on Earth directly with sun's rays (mostly in nice, warm weather) and diffusion radiation, which is the result of scattering and reflection of sun's rays, which increases with cloudiness. The sum of both radiations is called global radiation (**Figure 62**).

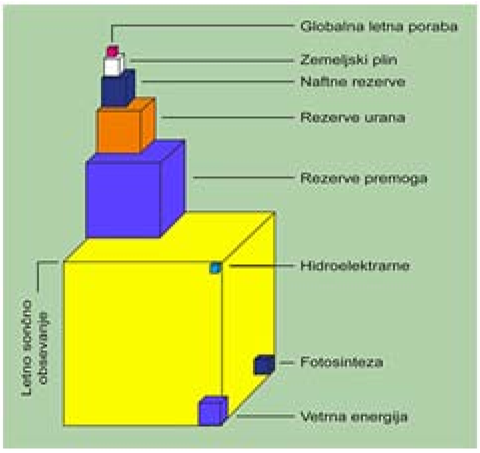


Figure 61: Solar energy potential (Ape)

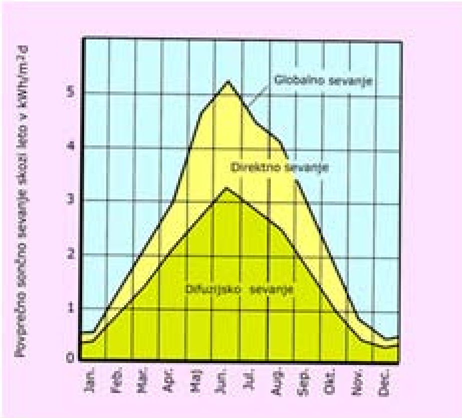


Figure 62: Image of global, diffusion and direct radiation (Ape)

Slovenia

The full potential of solar radiation for Slovenia amounts approximately to 23,000TWh, which is as 300-times as more than the amount of energy use. The latest studies show that approximately 960GWh per year is available with the existing technologies, which equals approx. the half of the Slovenia's share of electricity production of the Nuclear Power Plant Krško or well over a third of annual electricity of the Drava Power Plants. Today we exploit only approx. 28GWh, which is only 3% of the estimated technical potential. In winter time, when the demand for heating energy increases, we only get approx. 10% to 15% of total annual solar energy quantity. Information on the annual hours of solar irradiation of some Slovenian towns for 1993 show there are no significant differences in the duration of solar irradiance, except, of course, in the area of Primorska.

When we talk of solar energy, we use expressions solar radiation and solar irradiation. Solar radiation is the power of solar radiation per unit of surface, whereas irradiation is the energy of solar radiation per unit of area. Typical values of solar radiation in Slovenia range between 600W/m^2 and 1,000W/m^2. Values of yearly solar irradiation in Slovenia range between 1,000 kWh/m^2 and 1,100kWh/m^2. The sum of direct and diffusion radiation is called global, and the annual average in Slovenia amounts to approx. 1,200kWh/m^2, which complies with energy content of approx. 120L of heating oil. With regard to the type of collector, around 75% of global radiation can be converted into heat. In essence, Slovenia is a sunny country and has in comparison to Germany about 10% to 20% better sun conditions. **Figure 63** shows the average global irradiation of Slovenia.

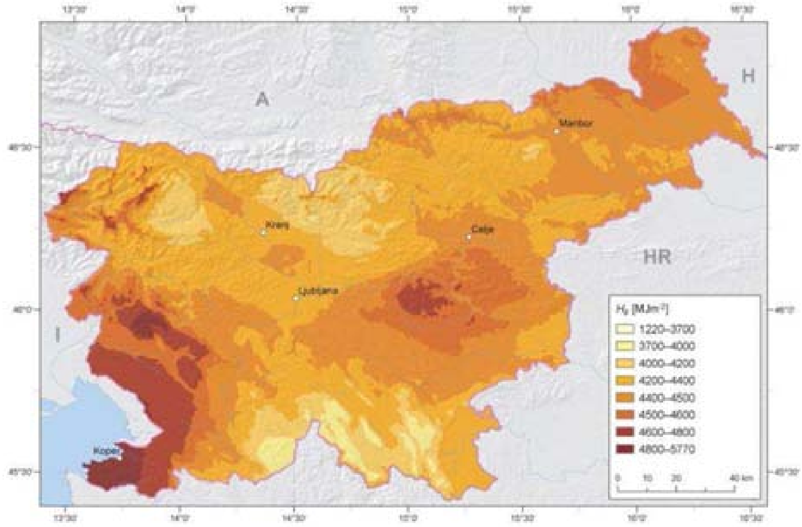
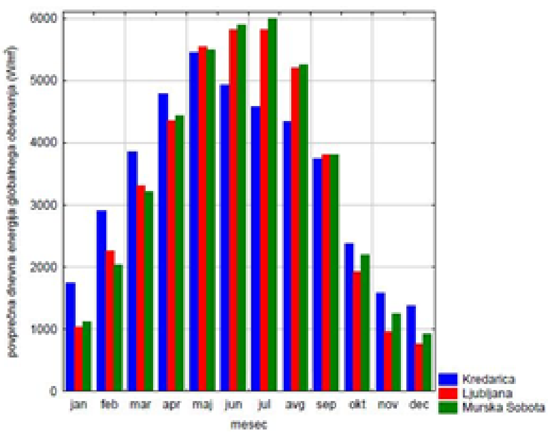


Figure 63: Average annual global irradiation (MJ/m^2).

Murska Sobota

As can be ascertained from the graph below, Murska Sobota is among Slovenian cities most exposed to irradiation (**Figure 64**). In terms of favourable prices and profitability it is second to Portorož (coastal towns). On the other side, we should not neglect the average annual temperature, which also affects the operation of the solar system. In summer time, system overheating is not a rare phenomenon and is more frequent in the coastal area than in north-eastern parts of Slovenia. The additional benefit is that excess heat is not lost in production due to system overheating (heat removal in the system affects overheating).



Povprečja mesečnih vsot energije globalnega sončnega obsevanja za merilna mesta Kredarica, Ljubljana in Murska Sobota (obdobje 1961–2000)

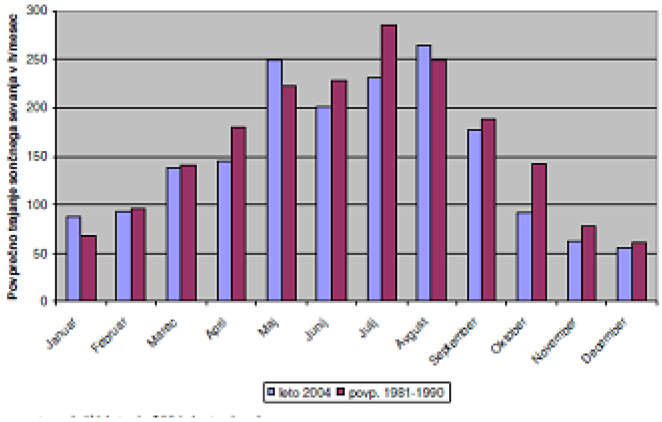


Figure 64: Average duration of solar radiation in hours/month for Murska Sobota (Ape)

4.8.2 Description of the Process and Operation of HW and TCW Processes

HW (hot water)

In the process, sanitary hot water is used for sanitary purposes of employees and for shower mixers for cleaning/rinsing floors, vessels and equipment. The process (HW) takes place throughout the year, 365 days, mostly between 6.00 and 16.00. The daily consumption is $10m^3$ of hot water, which is directly heated with a 3bar steam at T = 70°C, and is stored in two 3000L tanks. At the outlet, the temperature of sanitary water is approx. 35°C to 50°C, whereby the desired water temperature is regulated by a mixing valve. The lower three figures show HW heat profiles for daily, weekly and yearly consumption.

Hot Water (HW) – Heat Profiles

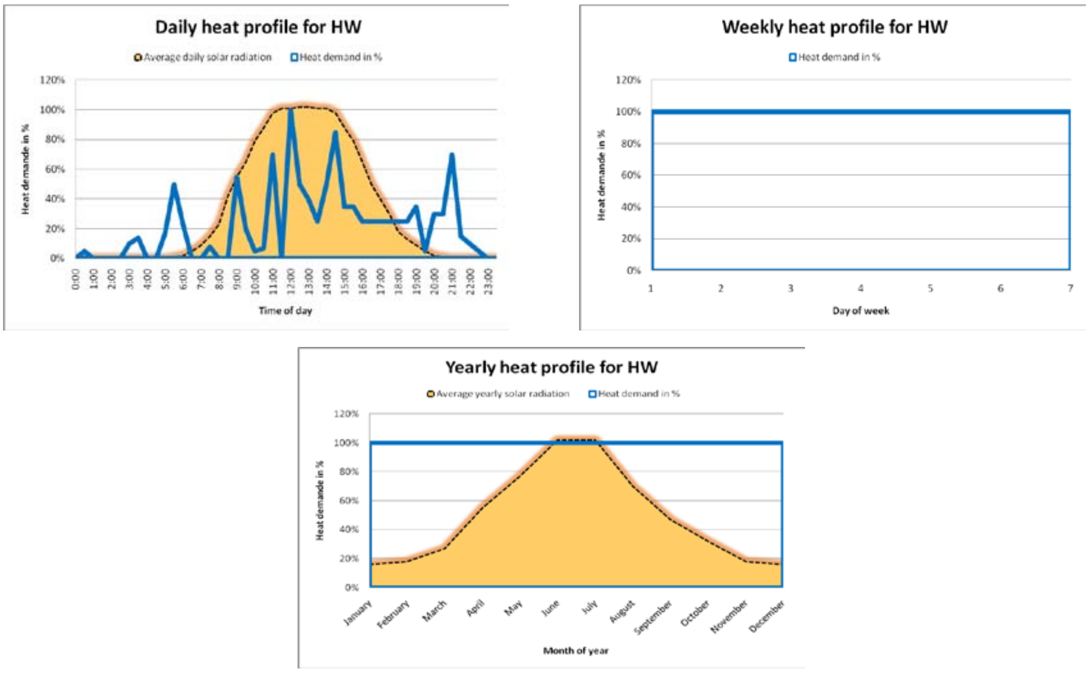


Figure 65: HW heat profiles

HW	
Used energy source:	**natural gas**
Emitted heat:	**steam 144°C / 3 bars**
Temperature for SHW:	**70°C**
Sanitary water consumption:	**3,672m^3/a**; **10m^3/day**
Energy price	
Natural gas price:	**0.298EUR/m^3**; **0.031EUR/kWh**

Boiler Water (tap cold water – TCW)

In the heating circuit of the boiler, 15.8m^3 of tap cold water (TCW) is daily replenished from the water supply network (with an average temperature ranging from 10°C to 12°C). It should be noted here that its consumption may also be doubled in the event of larger production. The process is active 24 hours, 7 days a week. The boiler heats the input TCW to T = 105°C.

Central Heating System – Heat Profile

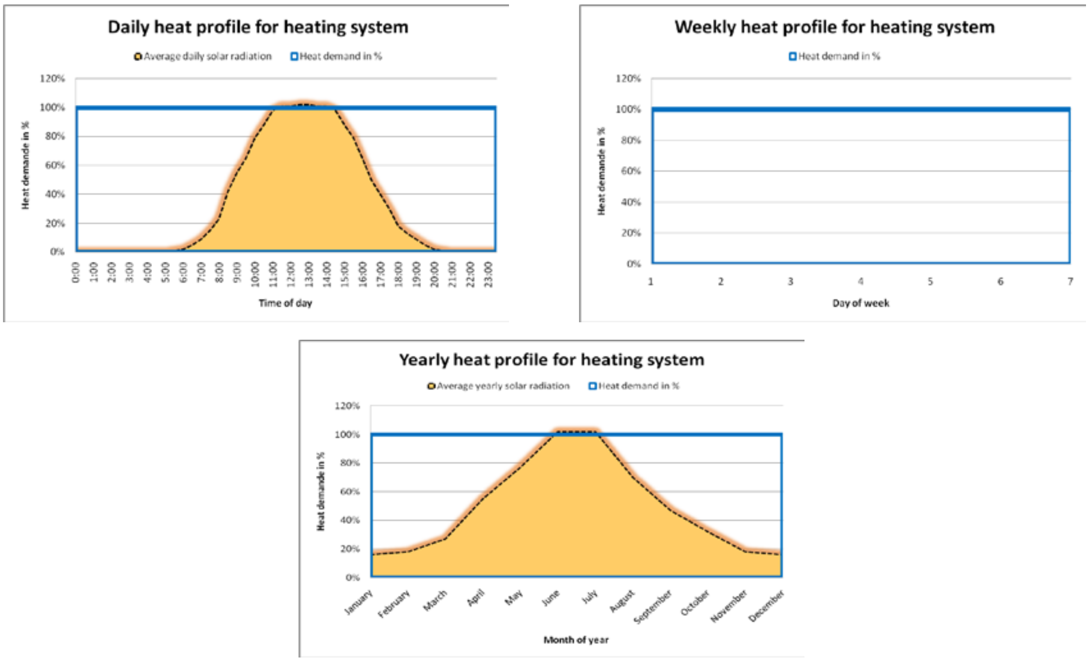


Figure 66: Central heating system heat profile

TCW	
Used energy source:	**natural gas**
Temperature for TCW:	**105°C**
TCW consumption:	**5,767 – 7,560m^3/a**; **15.8 – 20m^3/day**
Energy price	
Natural gas price:	**0.298EUR/m^3**; **0.031EUR/kWh**

4.8.3 Demand for Thermal Energy for heating HW and TCW

4.8.3.1 Heating Temperature Regime and Heat Demand for Preparation of HW

Consumption of sanitary water per day: **10m^3 (10,000L).**

$$Q = \frac{q_v \cdot c_p \cdot \Delta T}{3.600}$$ *(energy required for heating the used water per day)*

q_v = 10m^3 (10,000L)	q_v = 10m^3 (10,000L)
T_1 = 8°C	T_1 = 12°C
T_2 = 70°C	T_2 = 70°C
ΔT = 62°C	ΔT = 58°C
c_p = 4.185kJ/kg · K	c_p = 4.185kJ/kg · K
Q = 723 kWh	**Q = 676 kWh**

$Q_{aver.}$ = 699.5kWh/day

Q_{year} = 255,317.5kWh/a (theoretical consumption per year without considering losses in the heating system)

Due to losses of boiler, pipes and reservoirs additional **35% of losses** of energy must be added to the calculated value (**5%** – **10%** are system losses, the rest (**25%** – **30%**) is boiler losses).

Q_{real} = 344,678.62kWh/a

4.8.4 Heating Temperature Regime and Demands for Heat for preparation of SCW

Water consumption per day:

Version 1: **15.8m³ (15,800L)**

Version 2: **20m³ (20,000L)**

$Q = \frac{q_v \cdot c_p \cdot \Delta T}{3.600}$ *(energy required for heating the used water mass per day)*

Version 1:

q_v = **15.8 m³ (15,800L)**	q_v = **15.8m³ (15,800L)**
T_1 = 8°C T_2 = 105°C	T_1 = 12°C T_2 = 105°C
ΔT = 97°C c_p = 4.185kJ/kg · K	ΔT = 93°C c_p = 4.185kJ/kg · K
***Q* = 1,788kWh**	***Q* = 1,714.3kWh**

***Q*$_{aver.}$ = 1,751.1kWh/day**

***Q*$_{year}$ = 639,170kWh/a** (theoretical consumption per year without considering losses in the heating system)

Due to losses of boiler, pipes and reservoirs additional **35% of losses** of energy must be added to the calculated value (**5% - 10%** are system losses, the rest (**25% - 30%**) is boiler losses).

Q$_{real}$ = 862,879kWh/a

Version 2:

q_v = **20m³ (20,000L)**	q_v = **20m³ (20,000L)**
T_1 = 8°C T_2 = 105°C	T_1 = 12°C T_2 = 105°C
ΔT = 97°C c_p = 4.185kJ/kg · K	ΔT = 93°C c_p = 4.185kJ/kg · K
***Q* = 2,263kWh**	***Q* = 2,170kWh**

***Q*$_{aver.}$ = 2216.5 kWh per day**

Q_{year} **= 809,022kWh/a** (theoretical consumption per year without considering losses in the heating system)

Due to losses of boiler, pipes and reservoirs additional **35% of losses** of energy must be added to the calculated value (**5%** – **10%** are system losses, the rest (**25%** – **30%**) is boiler losses).

Q_{real} **= 1,092,179kWh/a**

Table 25 shows consumption and temperature regimes for heating HW and TCW.

Table 25: Consumption of steam, gas and sanitary water for HW and TCW

	Water consumption		**Flow of water**	**Process operation**		**Temp. regimes**		**Heat demand Theoretical**	
	(m^3/day)	(m^3/a)	(L/h)	Days in year	h/day	*T*vh (°C)	*T*izh (°C)	(kWh/day)	(kWh/a)
SHW	10.00	3,650	418.80	365	24	8 ..12	70	700	255,318
TCW	15.80	5,767	660.00	365	24	8 ..12	105	1,751	639,170
TCW	20.00	7,300	833.00	365	24	8 ..12	105	2,217	809,022

	Heat demand Real		**Gas consumption**		**Energy costs**		**Steam consumption**
	(kWh/day)	(kWh/a)	m^3/a	kWh/a	(m^3/EUR)	(kWh)	(t/a)
SHW	944	344,679	36,27	344,603	**10,810**	**10,683**	417
TCW	2,364	862,880	90,829	862,880	**27,067**	**26,749**	0
TCW	2,992	1,092,180	114,966	1,092,180	**34,260**	**33,858**	0

4.8.5 Available Roof Surface for Mounting Solar Collectors on the Facility of Pomurske mlekarne

The total estimated area of appropriate roof surfaces for mounting solar collectors amounts to 3,100m^2 (**Figure 67**). The theoretical potential of capacities for mounting collectors is **2.17MW of collector power**. Roofs are directed towards southwest with a 20° deviation from the south. The inclination of roofs is approximately 13°.

Figure 67: Red lines on the satellite image mark surfaces for solar energy use (Engis.si)

5 The solar thermal system

5.1 Integration Concept

5.1.1 Design Type of Solar Systems for Industrial Processes Systems

5.1.1.1 Solar Systems without Storage for Industrial Processes

If industrial processes don't have a high heat demand, solar energy storage in this case is not needed. This type of process enables installing an extremely low-cost solar system, when the costs of storage are eliminated. The functionality of such a solar system can in practice be applied, when the industrial process is constant at least 11 hours per working day and the solar gain is not higher than the load gain.

This parameter enables the use of solar systems without storage and feed of solar heat directly to the process or to the heat supply system.

The picture below represents a scheme of solar system without storage.

Between the process and the solar system a heat exchanger is used for separating both circuits, because two different fluids are used. The solar system uses antifreeze and corrosion fluids and the load-process circuit uses water or steam or product fluid (like milk, bear, etc.).

The following figures show 3 types of direct solar energy feeding into the process or the existing heating supply system.

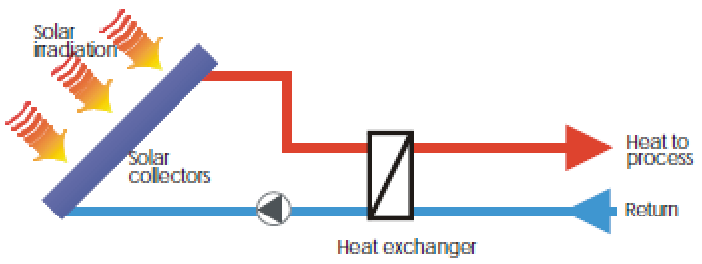


Figure 68: Solar system without storage (Poship 2008)

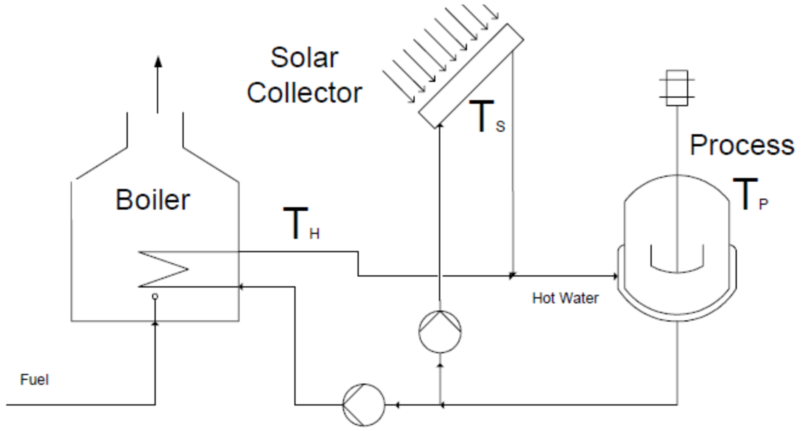


Figure 69: Solar thermal energy feeding into the existing hot water system (IEA-SHIP task 33/IV)

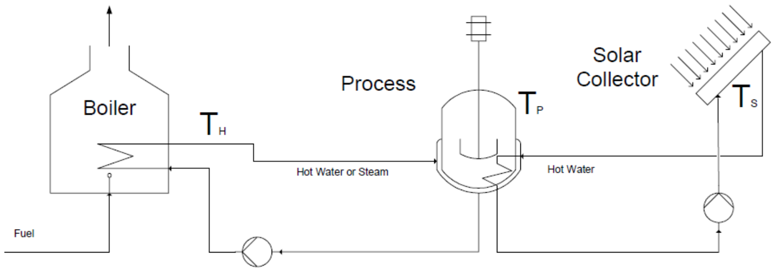


Figure 70: Direct feeding of solar heat to the process equipment (IEA-SHIP task 33/IV)

5.1.1.2 Solar Systems with Heat Storage for Industrial Processes

The industrial process on average operates 5 or 6 days a week and is usually not active on weekends. If we consider the non-active days, the heat storage should be designed so as to accumulate the required energy by weekends and reuse the rest during week. During dimensioning the following facts should be considered: investment price, technical solutions, the production peak loads, break downs, and other facts which guide the production line.

The principle of a solar thermal system with storage is shown in Figure 71.

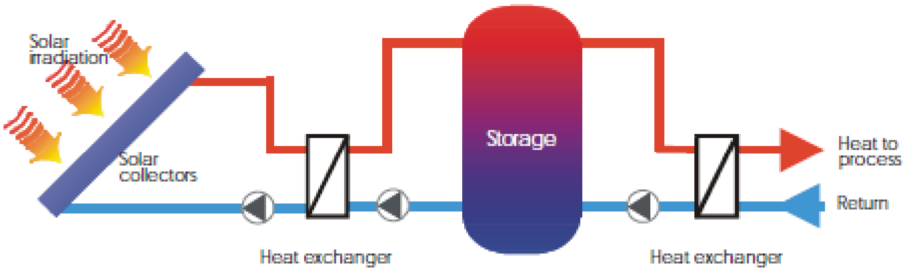


Figure 71: Solar system with heat storage (Poship 2008)

5.1.1.3 Solar System for Hot Water, Washing or Cleaning

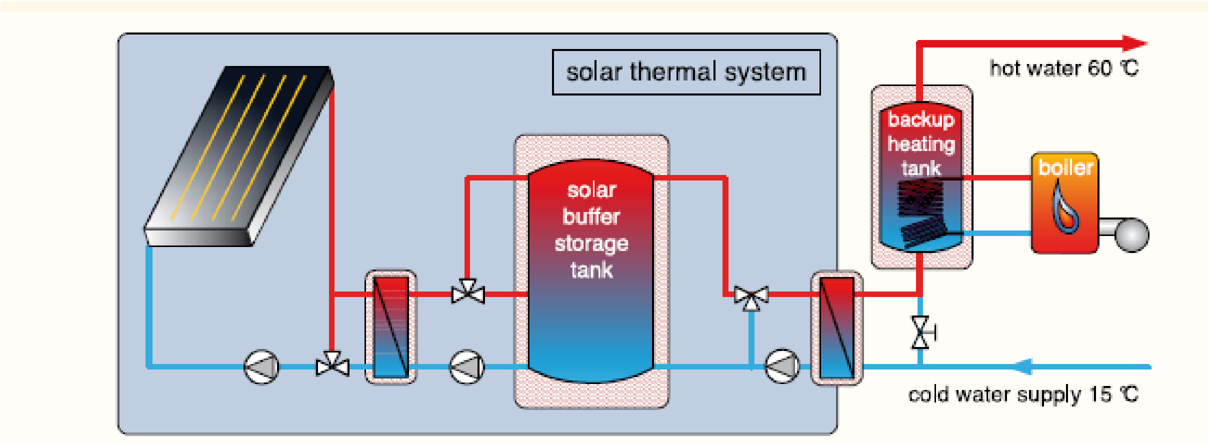


Figure 72: Solar thermal system with heat storage and back up heating system (Poship 2008)

The solar system from picture xx is convenient for hot water preparation. This is a classical solar heating system for cold water with temperature of 10-13°C and with output temperature of 60°C. The backup system is usually directly installed in the heat line or via hot water storage, which is heated with gas boiler, electricity, biomass boiler or heat pump and without any heat recovery system from process. Between the solar tank and the process system the heat exchanger is normally used to achieve the highest exchange performance or a fresh water module is used. The system should be dimensioned so as to have less losses and a constant consumption (constant heat demand). The so-called solar module stagnation temperatures should be avoided or the fact that it will not become higher than the maximum temperature in storage tanks has to be taken into account. Automatically, the losses in the solar system are higher and solar fractions become lower.

5.1.1.4 Heating of Make-up Water for Steam Networks

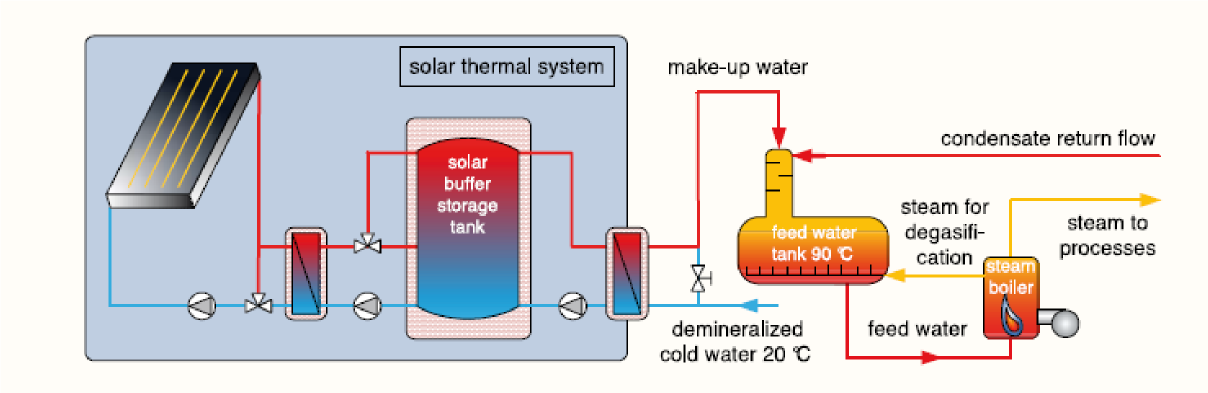


Figure 73: Solar thermal system with steam heat (Poship 2008)

If the process uses the steam heat, the economical use of solar energy is reasonable only if the steam is directly used in processes. The solution for such a solar thermal system is the same as for washing-cleaning system. Because of a higher temperature demand in the steam system, the solar gain is lower in comparison to the washing/cleaning process, where temperature levels are around 60°C.

Few parameters have to be considered: cold water is de-mineralised and is already heated up in the process of de-mineralisation, the feed water in the tank has to be heated up to 90°C, and the steam production varies, depending on the production demand. The solar fraction (efficiency) is lower because of higher output temperature and dynamic daily demand. Integration in the existing steam system can be profitable only when steam costs become higher due to the non-efficiency of the steam boiler, reuse of heat waste and higher oil price.

5.1.2 System Solution for the Support to Heating HW and Boiler Tap Cold Water with the Sun

It's technically possible to integrate the solar system in the existing heating system of Pomurske mlekarne. The available surface is sufficient for installation of the thermal system with the nominal power of 2MW. For the purposes of energy efficient use, it makes sense to combine all consumers on one place, and thus enables the central preparation of hot water. Namely, this would prevent excess line losses, system shifts and redundant heat delays. What is essential in such a solar system is that the hot water preparation system can be connected directly and by bypass connection. In the event of warm weather, when the solar system emits the converted solar energy in the form of useful heat, it is sensible to send the heat directly, without preliminary storage in heat reservoirs. This is enabled by the bypass distributor that knows precisely when there is a demand for hot water in the system and when there is no demand. With this system we can avoid any system, line and phase losses in the utilization of accumulated solar thermal heat. Every conversion and accumulation represents an additional energy loss. The peak of consumption of HW is between 11.00 and 15.00, which tells us that during these hours we will be able to directly use the solar energy for processes.

In order to ensure high preparedness of the water heating system, the primary heating system (with steam from the steam boiler) must still operate 100%, as it supplements deficits in the water heating system. In planning the solar system and in case of integration itself, special attention must be given to proper and appropriate intelligent controllers of the complete system (condensate return, excess compressor heat, steam, etc.).

For the integration of the solar system the direct buffer heating system seems to be the most rational and sensible option. It must be present in the solar system because of heat surpluses, which appear in the system. Due to greater system efficiency and reduced losses in conversion, it makes sense to integrate the solar system as the primary source of energy and steam boiler as the auxiliary system for additional heating in order to reach the desired temperature (Figure 73). Namely, the current system firstly converts boiler water into steam and then through the heat exchanger converts it into the lower temperature stadium, which takes further losses. If the requirements in the production process enabled solely the use of hot water, the costs of gas consumption would significantly reduce and the efficiency of the entire system would rapidly go up due to smaller transfer and conversion losses.

The most appropriate solar systems, in terms of engineering, for the integration in the energy system of the company Pomurske mlekarne, are described in the previous chapter 5.1.1.3, which is appropriate for the preparation of hot water for washing and rinsing processes; the system solution described in chapter 5.1.1.4 could be used for pre-heating of feed water in the process steam network tank.

5.2 Selection of the Solar Collector Type

5.2.1 How to Choose a Solar Collector Type

To choose the right solar collector, we must know the size of available surface on the roof (inclination), on the façade or the ground, the energy demand and temperature level of processes. All factors influence the proper technical solution and installation, because different types of solar collectors have different efficiencies, surfaces (gross area and aperture area, normally the aperture area is smaller), output temperature levels, stagnation requirements, type of liquid transmitter, storage volume, etc. Two types of collectors most available in the market are the flat-plate and evacuated tube collectors. In general, in recent years, the most frequently installed collector type in the European market is the solar thermal, if compared to other available types in the market.

The **Figure 74** bellow shows a short comparison between the two types.

Flat-plate
- Lower costs
- Better cost / performance ratio
- Able to substitute a conventional roof
- Stagnation: better emptying behaviour and lower stagnation temperatures than evacuated tube collectors with a U-configuration piping (section 6.2)

Evacuated tube
- Higher annual energy gain
- Less collector area needed for the same energy gain
- Higher efficiency at higher collector temperatures and low irradiation (winter)

Figure 74: Comparison of flat-plate and evacuated tube collectors (So-Pro 2010)

If the process temperatures are bellow 50 °C, flat-plate collectors seem to be the most economic solution. To find the right solution in terms of price and efficency, simulation programs help us choose between different available collector types in the market, as they consider all factors (roof area, temperature procesess and demands, storage capacity, etc.). Simulation programs give information about the perfomance system and economic parameters to help us make the right technical and investment decision.

5.2.2 Selection of Solar Collector Producer for the Simulation

For the simulation of the solar system in the milk production line of Pomurske mlekarne I chose the leading Austrian and European producer of solar flat-plate collectors – **Sonnenkraft**. The company was established 1993 and is now present all over the world. The use of solar ennergy in households is alredy the EU standard with regard to the efficient use of energy in low and passive houses. From the very beginng, the company Sonnenkraft has had the leading position in the solar EU market. The success is based on innovative solutions, continuous products and production development, whereby achieving the highest qulity of products and excellent sales results. Today, Sonnekraft products bear the label »frendly use« products, which enables installers and end users to make an easy decision on the use of natural solar energy.

For the simulation the SK500N Flat-plate collector was chosen. The following specifications show technical information. This type is very commonly used for roof mounting solar systems.

5.2.2.1 Advantages of the SK500N Flat-Plate Collector

- Elegant 2.5m^2 units, suitable for all types of assembly, favourable apperance thanks to attractive deep-drawn aluminium collector basin;
- Highly-selective vacuum absorber coating heats water to high temperature in rapid time;
- Hail-resistant solar glass;
- Weather-resistant materials mean long service life;
- Structured absorber entirely of copper with highly-selective coating;
- Elegant, deep-drawn aluminium basin;
- Side wall insulation;
- High-quality rear wall insulation using 50mm thick, non-decaying mineral wool;
- Easy-to-install detachable screw connections;
- Available with four connections for larger installations (SK500N4).

5.2.2.2 Technical Specificaton for SK500N Flat-Plate Collector

Specifications SK500

Name	SK500N	SK500L
Collector type	pre-assembled collector	
Installation type	roof-mounted	
Gross surface area	2.57m²	
Opening surface area	2.3m²	
Absorber surface area	2.2m²	
Height	2079mm	1239mm
Width	1239mm (incl. screw connection: 1257mm)	2079mm incl. screw connection: 2098mm)
Depth	100mm	
Empty weight	44kg	
Collector capacity	1.6l	
Connections	1" screw connections, upper left and upper right hand sides	
Absorber	structure, copper full-surface absorber with highly-selective vacuum coating	
Wiring	harp wiring	
Absorption (α)	0.95	
Emission (ε)	0.05	
Housing	aluminium basin	
Heat insulation	50mm mineral wool insulation, incl. edge insulation	
Collector glazing	3,2mm tempered, low-iron solar safety glass	
No. plates	1	
Conversion factor η_0	0.82	
Angle adjustment factor $K_{50°}$	0.95	
Minimum output	525kWh/(m²a)	
Max. operating pressure	10 bar	
Idle temperature	180° C plus ambient temperature	
Recommended throughput	15 - 40l/h per m²	
Module wiring	max. 6 in series *	
Min. collector angle	15°	
Max. collector angle	75°	

Figure 75: Technical specification for SK500N Flat-Plate Solar Collector (Sonnekraft 2010)

5.2.2.3 Performance Curves of Different Solar Collector Types

The picture bellow shows perfomances of the Sonnenkraft SK500 flat-plate and the evacuated tube collector VK25. The curves show that when the outside temperature ranges 0-55°C, the efficiency ratio is on the side of the flat-plate collector. The flat-plate collectors have a lower price, lower stagnation temperature, and system combinations are more flexible. Due to many great benefits and positive effects, the flat-plate solar collector industry became the leading technology in the market.

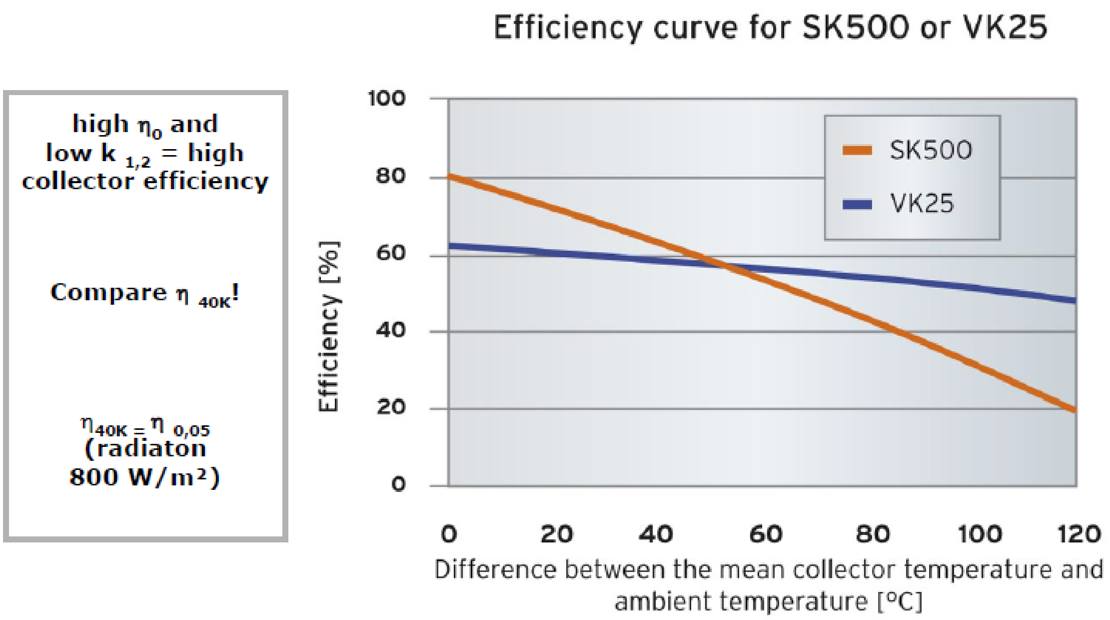


Figure 76: Efficiency curve for SK500N Flat-Plate Sonnenkraft Solar Collector (Sonnenkraft 2010)

5.2.2.4 Dimension of the SK500N Flat-Plate Solar Collector

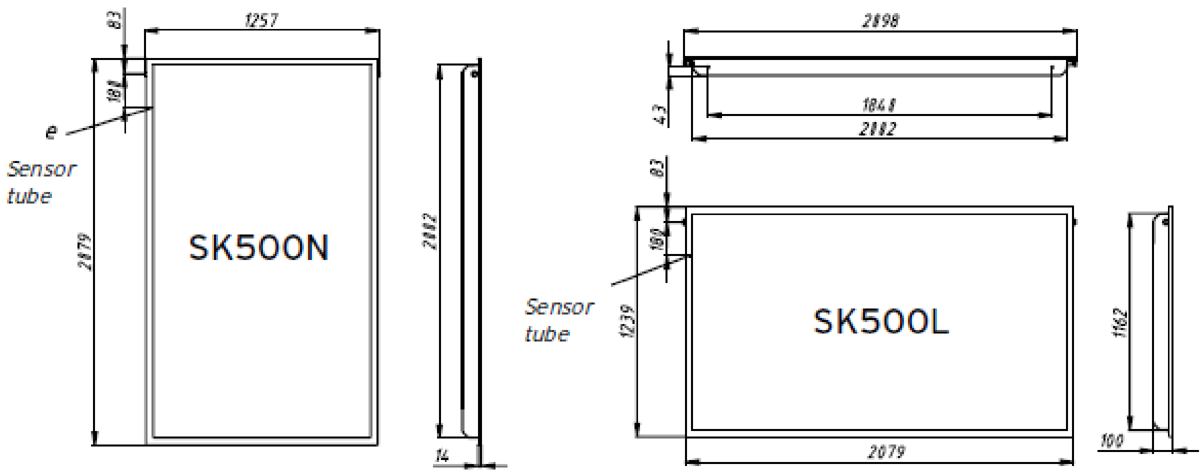


Figure 77: Dimension of the SK500N Flat-Plate Sonnenkraft Solar Collector (Sonnenkraft 2010)

5.2.2.5 Mounting Systems for SK500

Sonnenkraft provides different types of mounting solutions for every roof. In recent years, there has been an increasing interest in roof and façade installations, whereby they developed the perfect technical solution, which provides users with guaranteed waterproof resistance.

Figure 78: On-roof mounting solutions for SK500N Flat-Plate Sonnenkraft Solar Collector (Sonnenkraft 2010)

Figure 79: In-roof mounting solutions for IDMK25 or IDMK12 Flat-Plate Sonnenkraft Solar Collector (Sonnenkraft 2010)

Figure 80: Facade mounting solutions for IFKsolar collector (Sonnenkraft 2010)

5.3 Dimensioning of the Solar Thermal Plant

5.3.1 Designing the Solar System

In planning the solar system, the collector must be mounted on an appropriate sunny position. The building must not be overshadowed by other buildings, forest, hills and the like. Collectors are most frequently mounted on the roof, so the ideal roof orientation for solar installations is due south; other possible orientations are due southeast to southwest (**Figure 81**). When the roof is inappropriate in terms of orientation, this inconvenience may be solved by lifting the collector with a sub-construction to a more favourable position or by moving the collector to another place, but it should not be too far from the thermal reservoir, which should in turn not be too far from the very system consumers. It should also be noted that, next to appropriate orientation, we must also have an appropriate roof inclination, which enables optimum efficiency. In practice we come across inclinations for weather conditions ranging from 30° and 45°. In winter time, a bigger inclination may help us convert more solar energy into useful heat. Because the sun is not a day-long source of energy and cannot guarantee heating energy demands to be fully met, we must connect the solar system with a back-up system or the existing source of heating (gas, biomass, heat pump, heat pipes, etc.).

The existing or a back-up source must have sufficient power in order to ensure: uninterrupted availability of hot water even when there are no solar energy gains, the best ratio between the supply of solar and back-up system. The price of useful kWh mainly depends on two key parameters, i.e. on the price of the surface of the solar energy collectors system per m^2 and on the annual energy output of the installed system.

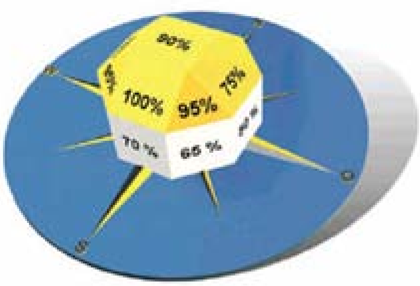


Figure 81: Model orientation and roof inclination (Ape)

5.3.2 Software Used for Designing Solar Systems

In practice all commercial tools for the calculation of characteristics of the solar system use the same basic equation, which defines the current production of solar energy collectors. For the calculation of solar systems, software is divided to:

- Simplified, and
- Precision tools.

Simplified tools use the semi-empirical equation, which considers the data on daily use of energy. They only explain daily energy demands on the basis of monthly average. They are based on simplified physics models, adapted and validated with more detailed models and experiences. Annual simulation includes only 12 calculations for an average day in each month.

Precision tools calculate a more frequent condition of the system from hour to hour and from day to day, and then derive results for a specific period of time. Precision tools provide a clear understanding of the system operation. They are based on precise physics models. It is possible to see the temperature at the outlet from the solar energy collector at the specific date and hour, the highest stagnation temperatures, dimensioning of an appropriate system, etc.

For research purposes we used the professional software T*SOL, which is used to simulate or design a solar system on the basis of daily use and required outlet temperature.

5.3.3 T*SOL Software

T*SOL is a simulation programme for studying changes of the physical state in solar systems. It serves for scientific researches, expert planning, optimization of component parts and systems.

Parameters: User may optionally change parameters and by using the simulation determine the influence of various parameters on target values, such as solar fractions, system efficiency and requested additional heating. In this manner it is possible to optimize individual parameters of the component part for various methods of solar system operations.

Energy balance: T*SOL professionally determines all energy currents into the solar system, which can be presented in the tabular format or, for example, in the form of the Sankey diagram. Therefore, it is possible to introduce thermal losses for each individual component of the solar system.

Meteorological data: The programme may produce hourly data required for the simulation of the solar system or an average monthly value of solar radiation and temperature. User may either enter the actual data by himself or the data he acquired by himself. The programme has, in addition to its own database, also the temperature data for approximately 2,000 worldwide locations.

Results: All data, which mark the status of the system and individual calculations, can be presented in minute intervals. With all the results obtained it is possible to dimension individual elements of the solar system in order to optimize the efficiency of the whole system.

5.3.4 Data Used for Designing in the T-SOL software

Table26 shows water consumption and temperature regimes for HW and TCW.

Table 26: Data on water consumption and required temperature levels

	Water consumption		**Water flow**	**Process operation**		**Temperature levels**	
	m^3/day	**m^3/a**	**(L/h)**	**Days in a year**	**h/day**	**Tvh °C**	**Tizh °C**
HW	10.00	3,650	419	365	24	8 – 12	70
TCW	15.80	5,767	660	365	24	8 – 12	105
TCW	20.00	7,300	833	365	24	8 – 12	105

Data Used in the TSOL Simulation Programme for HW and TCW Processes

Climate File

- Location: Murska Sobota
- Climate Data Record: Graz
- Total Annual Global Radiation: 1,126.02kWh.
- Latitude: 47.67°.
- Longitude: – 15.42°.

Domestic Hot Water

- Average Daily Consumption: $10m^3$
- Desired Temperature: 70°C (HW) and 105°C (TCW).
- Cold Water Temperature: February: 8°C / August: 12°C.

System Components

- Manufacturer: Sonnenkraft Gmbh.
- Type: Sonnenkraft SK 500 N.
- Number: 72,120,150 (HW); 80,140,200 (TCW).
- Total Gross Surface Area: 182m^2, 30 m^2 and 385m^2 (HW); 205m^2, 360m^2 and 514m^2 (TCW).
- Total Active Solar Surface Area: m^2.
- Inclination Angle: 45°.
- Azimuth: 0°.

Combination Tank

- Manufacturer: T*SOL Database.
- Type Combination Tank.
- Volume: 10m^3, 15m^3 in 20m^3 (HW); 10m^3, 18m^3 and 25m^3 (TCW).

Auxiliary Heating

- Manufacturer: T*SOL Database.
- Type: District Heating.
- Nominal Output: kW.

Schematic View of the Solar System Used:

For HW preparation

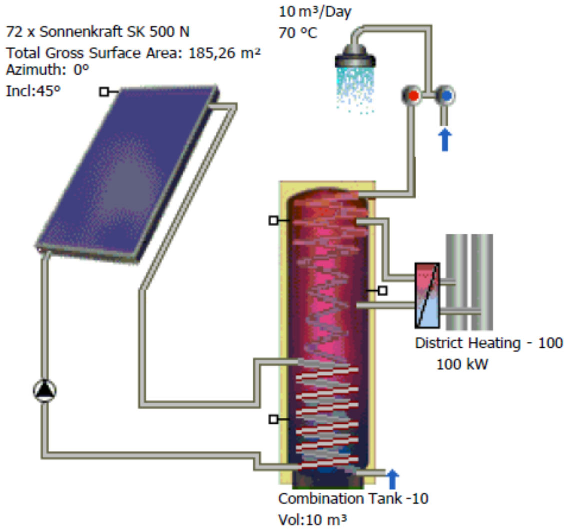


Figure 82: Schematic view of HW solar system in T-SOL

For preheating of TCW

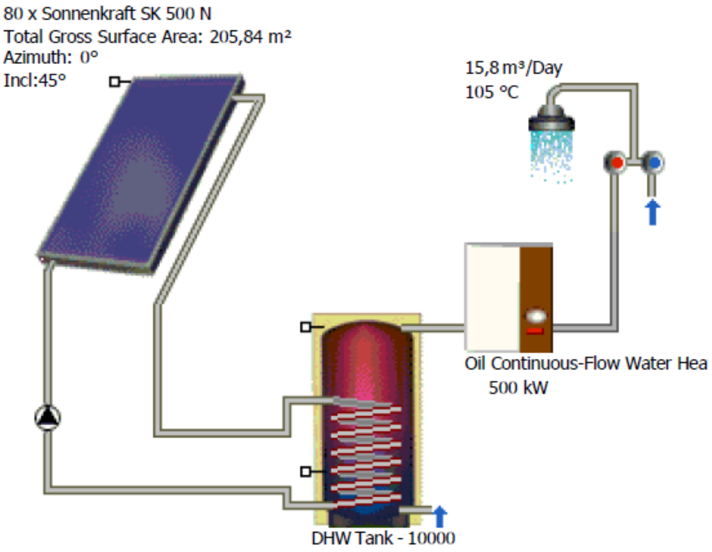


Figure 83: Schematic view of TCW solar system in T-SOL

Table 27 shows simulation results of a different number of solar collectors and for preparation of HW and TCW.

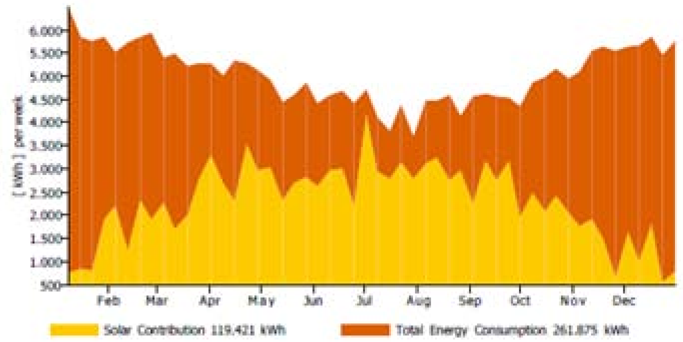
Table 27: Results of the annual simulation for the solar system

Installed Collector Power: (HW and TCW)	129kW – 360kW		
Installed Gross Solar Surface Area:	185,26m² - 514,6m²		
Collector Surface Area Irradiation: (HW and TCW)	200.89 MWh – 558.02 MWh 1,265.92 kWh/m^2		
Energy Produced by Collectors:	87.07 MWh – 253.02 MWh 548.66 kWh/m^2 – 574.00 kWh/m^2		
Heating Energy Supply:	253.71 MWh – 804.75 MWh		
Space Heating Energy Supply:	0 MWh		
Solar Contribution:	138 MWh – 247.3 MWh		
Energy from Auxiliary Heating:	HW: 125 – 174 MWh TCW: 555 – 690 MWh		
Fuel savings for HW:			
Installed Gross Solar Surface Area: (m^2)	182	308	385
Natural gas (m^3/a)	12,378	17,536	20,336
CO_2 Emissions Avoided (t/a)	20	28	33
Total Solar Fraction (%)	33	45	52
Fractional Energy Saving			

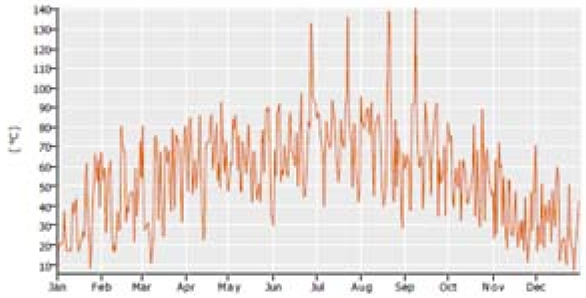
System Efficiency: (%)	42	35.7	33.1
Savings in heating of TCW:			
Installed Gross Solar Surface Area: (m^2)	205 – 514		
Natural gas (m^3/a)	17,242 – 36,400		
CO2 Emissions Avoided (t/a)	46 – 96		
Total Solar Fraction (%)	16 – 35		
Fractional Energy Saving			
System Efficiency: (%)	40.7 – 54.3		

The simulation results obtained may deviate from the actual values due to oscillations in temperature (climate) and other unpredictable factors. The simulation also provides us with a graphical presentation of energy demand and uses different colours to present energy demand and share of solar energy. In our examples we can see that the share of met demands for the preparation of TCW from the sun is the highest in summer time; or, in other words, when the demand for additional heating from the existing heating system is the smallest.

For the TCW process, where water consumption is higher, the percentage of met demand from the sun is smaller, but there is no risk of system overheating occurring in a year's time, because heat rejection is constant throughout the year. **Figures 84, 85** and **86** show the difference between the system for the preparation of HW and TCW. They thoroughly present the percentage of obtained solar energy for HW and TCW. Considering that the major contribution of solar energy for HW in July represents 100% fulfilment of the demand, it may happen that the temperatures on solar collector exceed 130°C (stagnation temperature of flat-plate collectors occurs at 180°C). However, in heating TCW with the solar system, the picture is completely different. A share of solar energy is significantly smaller, but even temperatures on collectors don't exceed 90°C. This means that outputs of conversion are good and that there are no surpluses of waste heat on collectors. The efficiency of the solar system in simulations is the smallest at 33.1% and the biggest at 54.3%. In majority of cases, solar systems have problems particularly in warm periods, because heat rejections are smaller, but that's not the case of the company Pomurske mlekarne d.d., because the observed processes are active 365 days a year, 24 hours a day.

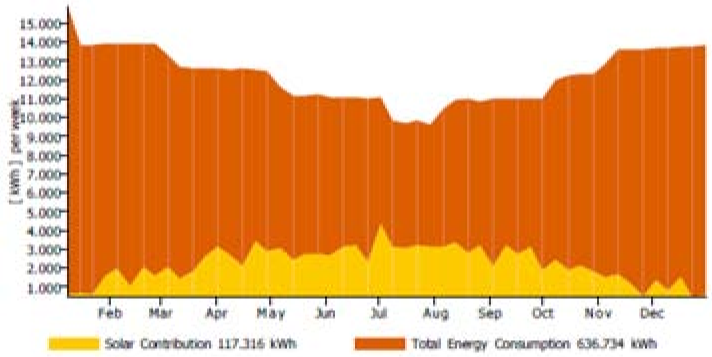


Solar Contribution in yellow and Total Energy Consumption in orange

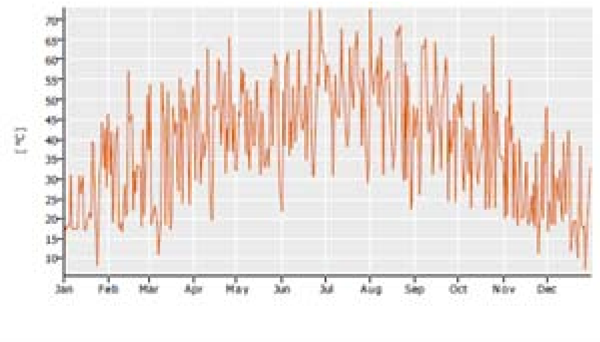


Daily Maximum Collector Temperature

Figure 84: Consumption of HW is 10m^3, 120 collectors, 15m^3 buffer

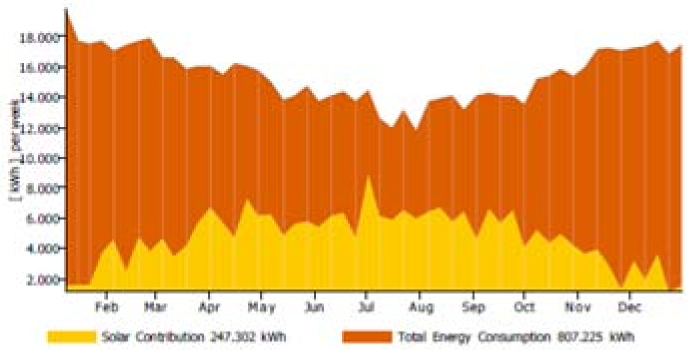


Solar Contribution in yellow and Total Energy Consumption in orange

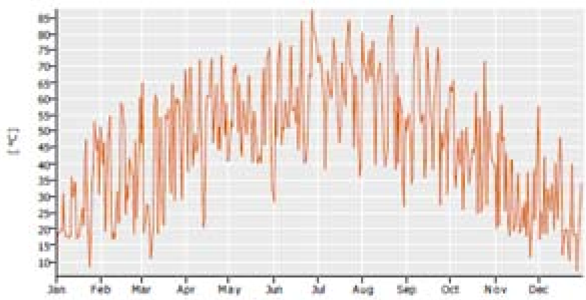


Daily Maximum Collector Temperature

Figure 85: Consumption of TCW is 15.8m^3; 80 collectors, 10m^3 buffer



Solar Contribution in yellow and Total Energy Consumption in orange



Daily Maximum Collector Temperature

Figure 86: Consumption of TCW is 20m^3, 200 collectors, 25m^3 buffer

Energy Balance

The T-Sol software provides a schematic presentation of energy balances of the solar system for observed production processes. **Figure 87** shows a schematic presentation of mass balances for the solar system.

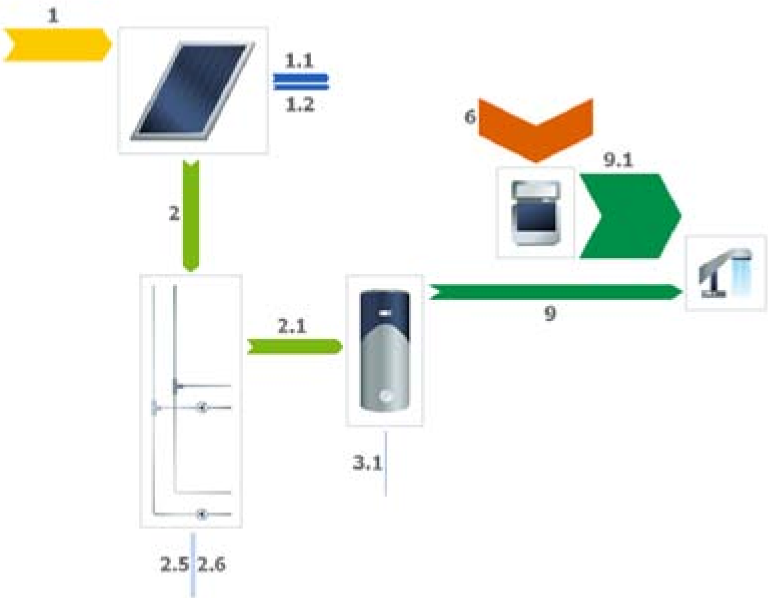


Figure 87: Energy balance schematic view in TSOL

Imprint

1 Collector Surface Area Irradiation	261 MWh
1.1 Optical Collector Losses	61 MWh
1.2 Thermal Collector Losses	43 MWh
2 Energy from Collector Array	119 MWh
2.1 Solar Energy to Storage Tank	117 MWh
2.5 External Piping Losses	1,255 kWh
2.6 Internal Piping Losses	293 kWh
3.1 Tank Losses	80 kWh
6 Final Energy	694 MWh
9 Energy from Tank	117 MWh
9.1 Energy via Continuous-Flow Water Heater	519 MWh

6 Economical assessment

6.1 Results of the Simulation and Economical Analysis of Investment

For the HW and TCW (**tap cold water**) processes was prepared a simulation in the T-SOL software for various water consumptions (10m^3, 15.8m^3 and 20m^3). In each case was simulated three different solar systems (with a different number of collectors and buffer size). Simulation results were only briefly mentioned in the previous chapter, while the simulation imprint also contains the data obtained. If we summarize the findings from the previous item, the solar system for the observed process of HW preparation can fulfil about 33% to 52% of energy demand, and about 16% to 35% for TCW (depending on the power of the solar system).

It should also be noted that the utilization of the system is very high, above 40%, which means that all processed heat from the sun will effectively be used in the observed system. The predicted highest temperatures for the preparation of HW will not exceed T = 130°C, and in case of TCW temperature will be T = 90°C. Summer overheating produces the greatest losses for the quickest possible reimbursement of investment.

Table 28 provides theoretical calculations of energy demands and simulation data, which serve as the basis for the calculation of economic justification of investment. In the calculation for gas consumption savings we had to observe system efficiency of the existing system and the utilization rate of the gas boiler from 1985. With regard to measurements and system requirements, the losses are approximately 40% and are taken into consideration in calculating gas savings.

With regard to the current prices of energy, the economic justification of investment is between 16 and 23 years, without considering any costs of loans and all other economic parameters (**Table 29**). We prepared an analysis in the event of the increase in prices of energy products by 30%, 50% and 70%, as well as a comparison with the price of gas, which is at present being paid by average Slovenian households, that amounts to 0.83EUR/m^3 (**Table 30).**

When indicators of the price of energy products change, the payback period is on a steep decrease (**Table 31**). In the event the industry price of gas increases on the today's level of household consumers in Slovenia, the payback periods will be from 5 to 8 years. Namely, the company Pomurske mlekarne d.d. are paying 184% cheaper gas than household customers. We should neither neglect the savings of CO_2 emissions, which range from 20t/a to 96t/a in the event of the utilization of solar energy. In the future, with the implementation of energy ID cards, our country and EU will put a higher tax on major environment pollutants and reward those, who will decrease CO_2 emissions, or decrease the environmental tax.

Table 28: Presentation of simulation and a simple economic analysis

Processes	Water consumption (m³/dan)	$Q_{teor.}$ (kWh/a)	Q_{realna} (kWh/a)	Heat costs (EUR/a)	No. of solar collectors (piece)	Surface (m²)	Installed collector power (kW)
HW	10.00	255,318	344,679	10,810	72	182.26	129.68
HW	10.00	255,318	344,679	10,810	120	308.76	216.13
HW	10.00	255,318	344,679	10,810	150	385.95	270.16
TCW	15.80	639,170	862,880	27,067	80	205.8	144.09
TCW	15.80	639,170	862,880	27,067	140	360.2	252.15
TCW	15.80	639,170	862,880	27,067	200	514.6	360.22
TCW	20.00	809,022	1,092,180	34,260	80	205.8	144.09
TCW	20.00	809,022	1,092,180	34,260	140	360.2	252.15
TCW	20.00	809,022	1,092,180	34,260	200	514.6	360.22

Table 29: Savings and payback time of solar systems

Solar tank (m³)	Solar fraction (%)	Solar Contribution (kWh)	CO_2 emissions reduction (t/a)	Natural gas savings (m³)	Natural gas savings (EUR)	Solar system cost (EUR)*	Payback time (a)
10	33	84,000	20.5	12,379	3,689	68,849	18.66
15	45	119,000	28.9	17,537	5,226	112,102	21.45
20	52	138,000	33.5	20,337	6,060	139,230	22.97
10	19	117,000	46.0	17,242	5,138	73,090	14.23
18	28	180,000	70.0	26,526	7,905	126,146	15.96
25	35	227,000	88.0	33,453	9,969	176,668	17.72
10	16	121,000	47.0	17,832	5,314	73,090	13.75
18	24	193,000	75.0	28,442	8,476	128,858	15.20
25	31	247,000	96.0	36,400	10,847	176,668	16.29

*The offer is obtained for the solar system of the Austrian producer of solar collectors Sonnekrat Gmbh. The price excludes VAT, installation is included - 15% without preliminary inspection and material inventory. Discounts for such a system were observed.

Table 30: Savings in the event of change in price of natural gas

			Natural gas price increase			Natural gas price for domestic use today cost cca. 0.83EUR/m^3
			30%	50%	70%	
Processes	**Water consumption** (m^3/day)	**Natural gas savings** (m^3)	**Natural gas savings** (EUR/a)	(EUR/a)	(EUR/a)	**Natural gas savings** (EUR/a)
HW	10.00	12,379	4,692	5,533	6,271	10,275
HW	10.00	17,537	6,647	7,839	8,884	14,556
HW	10.00	20,337	7,708	9,091	10,303	16,880
TCW	15.80	17,242	6,535	7,707	8,735	14,311
TCW	15.80	26,526	10,054	11,857	13,438	22,017
TCW	15.80	33,453	12,679	14,953	16,947	27,766
TCW	20.00	17,832	6,758	7,971	9,034	14,800
TCW	20.00	28,442	10,780	12,714	14,409	23,607
TCW	20.00	36,400	13,796	16,271	18,440	30,212

Table 31: Payback time in the event of the change in price of natural gas

	Natural gas price increase			Natural gas price for domestic use today cost cca. 0.83EUR/m^3
	30%	**50%**	**70%**	
Solar system cost (EUR)	**Payback time (a)**	**(a)**	**(a)**	**Payback time (a)**
68,849	14.7	12.4	10.9	6.7
112,102	16.9	14.3	12.6	7.7
139,230	18.1	15.3	13.5	8.2
73,090	11.2	9.5	8.4	5.1
126,146	12.6	10.6	9.4	5.7
176,668	13.9	11.8	10.4	6.4
73,090	10.8	9.2	8.1	4.9
128,858	11.9	10.1	8.9	5.5
176,668	12.8	10.9	9.6	5.9
Average payback time	**13.7**	**11.6**	**10.2**	**6.2**

6.2 Support Mechanisms for Investments in Solar Process Heat Systems

The EU strategy according to different challenges and regulations to achieve the common goal is to reduce greenhouse gas emissions. One of the biggest polluter is the industrial sectors which consume more than 30% of all primary energy.

An important factor of investment in the solar process heat system is the investment plan and calculation analysis. Usually, the companies try to find support from governments to receive subsidies and consequently receive some % of investment amount or find loans with low interest rates, etc. There are also other solutions in terms of reduction of emissions that give companies the possibility to receive TAX reduction with environmental TAXes and other supporting schemes.

The funding and financing structure is quite wide:

Public Funding:

- **EU community funding programmes** (programme guide the common EU interests in energy, environmental and services systems)
- Past examples:
- **- The fifth framework programme** (innovation & sustainability programmes offered 35% refunding expenses).
  - **Altener and save projects** (oriented in policies topics, the program offered 50% refunding expenses)
- **National funding programmes** (these refer to special subsidies funds (20%, etc.) and tax regulations for private and public sectors investing in sustainable and efficient use of energy)
- **Regional funding programs:** (oriented by the regions to support local environment efforts and investments)

Financing models:

- **Bank supports** loans and leasing agreements (also the so-called green-RES loans with low and fixed interest rates, with long term payments, normally governments give special guarantee schemes to support green investments.. in crisis times the moratorium loans are welcome to pay investments in a save way)
- **Eco loans** from government departments (in Slovenia the EKOSKLAD found is the subsidy and eco loans divider)
- **Private & public partnership investment models**
- **Contracting long term agreements** is divide into two segments:
  - Energy supply-delivery contracting (used for investments in new, substitutive and supplemental devices for energy supply)
  - Energy performance contracting (includes investment in sustainable and efficient use of energy in all sectors: heating, lightning, insulations, etc.)

7 Conclusions

After the analysis of all processes in the company Pomurske mlekarne d.d., the most appropriate processes for the exploitation of solar energy are the preparation of HW and TCW in the boiler room. The curves relating to the average daily consumption show that the disposal of HW is the highest during 9:00 and 15:00. In terms of year-long disposal, the most intense solar radiation on average occurs within these hours, which means that when solar radiation is most intense, the disposal from the process will be constant and overheating of the solar system will be prevented, which represents an additional loss in the system.

After the examination of available roof surfaces of the company, we determined that there are a great number of possibilities for mounting solar collectors, because nearly all roof surfaces have great dimensions and are also properly oriented. A smaller technical drawback appears in relation to the inclinations, but this can be solved in practise by additional sub-constructions for achieving optimum inclination of collectors, which in practice amounts to approximately 45°. The current hot water heating system is relatively scattered and is not centrally organized. In the reconstruction it will be necessary to prepare and design the unique central system with hydraulic control for the utilization of all possible heat sources, which are present in the company (waste heat, condensate, solar energy, geothermal energy, etc.), because such control will certainly offer the greatest system efficiency.

For best exploitation of solar energy direct use is the best option. In other words, everything generated from the sun is directly disposed into the process. In such a way we achieve the minimum conversion losses and at the same reduce demands for storage capacities for hot water. It should also be noted, that current system losses of the heating system by calculations range from 35% to 40%, which is not negligible information. There are many tightly interconnected factors influencing the final savings of the company. The today's situation with regard to the price of an energy product paid by the company shows, that such an investment does not suggest an attractive output or savings for the implementation.

If we look at the prepared simulation in the previous points for cases of various increases in prices of energy products, we can count that in a 4 to 6 years' time the price of gas will go up 70%. In this case the payback time will be 10 years. If we look and compare the price of gas that is today paid by household customers, it is by 184% higher, which would mean that in the future we can expect such growth of the energy product that will reimburse such an investment within 6 to 8 years.

In order to increase the attraction of investments in the industry utilization of solar energy, other parameters will have an impact, such as:

- Price of fossil energy on worldwide markets
- Tax reliefs (smaller CO_2 emission, green coupons)
- Energy ID cards
- Grants from various funds (Slovenian and foreign)
- Ecological and social orientation of companies
- Energy independence of companies from fossil fuels
- Favourable financial loans

8 References

Literature:

Aristotelis Aidonis(CRES); Vassilki Drosou(CRES); Thomas Muller (AEE Intec); Lars Staudacher (ZAE Bayern); Silvio Spencer (ADENE); ProceSol II; (2005); InfoSol - Germany

Claudia Vannoni; Riccardo Battisti; Serena Drigo; Potential for Solar Heat in Industrial Processes; (2008); Department of Mechanics and Aeronautics University of Rome „La Sapienza“ Italy

Dr. Janez Petek, Valentin Odar; Aleš Šimenko; Borut Hergula; Dalibor Šoštarič; Vlado Šiško; Andreja Goršek; Boštjan Baboc; Detailed Energy Review in Pomurske mlekarne d.d. (2010), STENG d.o.o. - Slovenia

European Commission; Solar Heat For Industrial Processes ; (2001), Aiguasol Enginyeria – Spain

European Solar Thermal Industry Federation-ESTIF; Solar Industrial Process Heat; (20)

Werner Weiss; Irene Bergman; Roman Stelzer; Solar Heat Worldwide; (2010); AEE – INTEC Austria

Werner Weiss; Dagmar Jaehnig; Design Guidelines – Soalr Space Heating of Factory Buildings – With Underfloor Heating Systems; (2007); AEE – INTEC Austria

Werner Weiss (AEE – INTEC); Matthias Rommel (Fraunhofer ISE); Process Heat Collectors; (2008); AEE – INTEC Austria & Fraunhofer ISE-Germany

Soteris Kalogirou; The Potential Of Solar Energy In Food Industry Process Heat Applications (2001); Higher Technical Institute - Cyprus

Soteris Kalogirou; The Potential of Low-Temperature Solar Industrial Process Heat Applications in Cyprus; Applications (2004); Higher Technical Institute - Cyprus

Werner Weiss; Solar Thermal Systems And Components, (2010); TUV-NewEnergy-MSc RES program

Werner Weiss; Overview on technology and market potential for industrial process heat and other medium temperature applications; (2005); Freiburg-Germany

Webpages:

www.aee-intec.at: AEE – INTEC (Institute for Sustainable Technologies)

www.engis.si; Geographical information system EnGIS of Slovenia

www.iea-shc.org; The Solar Heating and Cooling Programme

www.iea-shc.org/task33/; Solar Heat for Industrial Processes

www.steng-nccp.si; STENG - national cleaner production centre Ltd.

www.solar-process-heat.eu; SO-PRO Solar Process Heat EU project

www.sonnenkraft.si; Sonnenkrat Slovenia

www.valentin.de; T-SOL