Residential Renovation
towards nearly zero energy CITIES

R2CITIES

"**R**enovation of **R**esidential urban spaces: Towards nearly zero energy **CITIES**"

D2.6 Report on the thermal energy demand

WP 2, Task 2.4

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Table of Content

List of Figures

List of Tables

Glossary

Irradiation on to collector surface (active)

Solar energy irradiated onto tilted collector area (active surface area)

Optical collector losses

Reflection and other losses

Thermal collector losses

Heat conduction and other losses

Energy from collector array

Energy output at collector array outlet (i.e. before piping)

Solar energy to storage tank

Energy from collector loop to storage tank (minus piping losses)

Internal piping losses

Internal piping losses

External piping losses

External piping losses

Tank losses

Heat losses via surface area

Circulation losses

Circulation piping losses

Final energy

Final energy supply to system. This can be supplied from natural gas, oil or electricity (not including solar energy) and takes efficiency into account

Supplementary energy to tank

Supplementary energy (e.g. boiler) to tank

Electric element

Energy from electric water heater element

DHW energy from tank

Heat from tank (excluding circulation) for DHW consumption

Executive Summary

Buildings consume 40% of the total energy demand in Europe. In the residential sector, the distribution of energy demand clearly identifies that indoor heating and hot water demand is one of the important energy consuming sectors.

In this report, the thermal energy demand was identified in a broader perspective to create optimal and reliable configurations of indoor heating and domestic hot water (DHW) systems in different climates along with design specifications, planning principles that provide building clusters with domestic hot water (DHW) and indoor heating needs. The specific system design requirement – sizing, architectural and mechanical integration- and system sizing requirement - space heating load, domestic hot water load and existing mechanical system- are identified in detail. Additionally, barriers at the building and district level of solar thermal systems were discussed. In the frame of R2CiTIES, main focus is on three demo sites, Genoa, Valladolid and Kartal and demand calculations are provided for these demo districts.

Within the WP2 Tasks there is interactive information flows. Some information are provided from **Task 2.1** (Identification of architectural and technological aspects for integrating green energy technologies in buildings) and some results of this deliverable will be used for **D2.7** (Report on solar thermal solutions. Location and Power Calculation), **D2.8** (Solar Cooling applied at residential district level), **D2.9** (Solutions for Distributed Thermal Storage) as well as **D2.2** (High Value Energy for Solar Thermal Energy Production).

1 Introduction

The report, D2.6 illustrates the thermal energy demand in the R2Cities Project. It is the final report describing the activities carried out within Subtask 2.4.1: Evaluation of the thermal energy demand which is part of the Task 2.4: Thermal Energy storage and water management in WP2.

Solar hot water (SHW) systems is being analyzed to achieve optimum efficiency under the following categories; Requirements for solar thermal energy production for DHW and indoor heating, calculation methods of thermal energy demand, targeted temperature for each application and boundary conditions at district level. Finally buildings thermal energy demand for domestic hot water is analyzed for each demo sites.

1.1 Purpose and target group

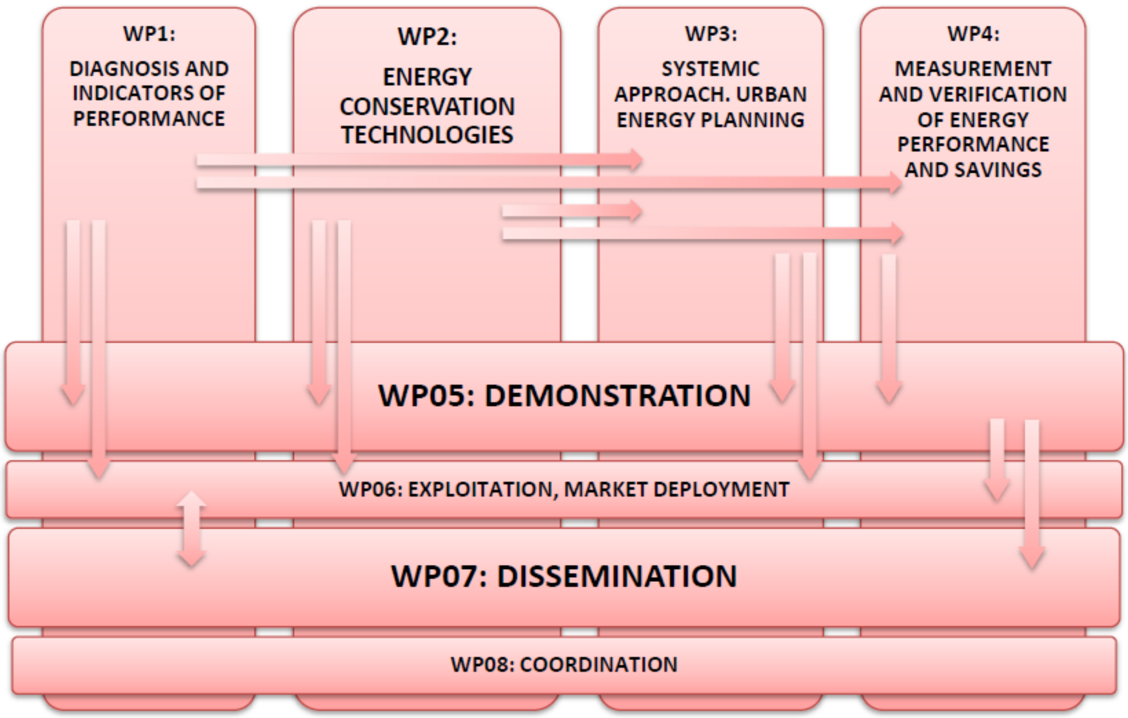

Figure 1: WP2. Interaction with others WPs

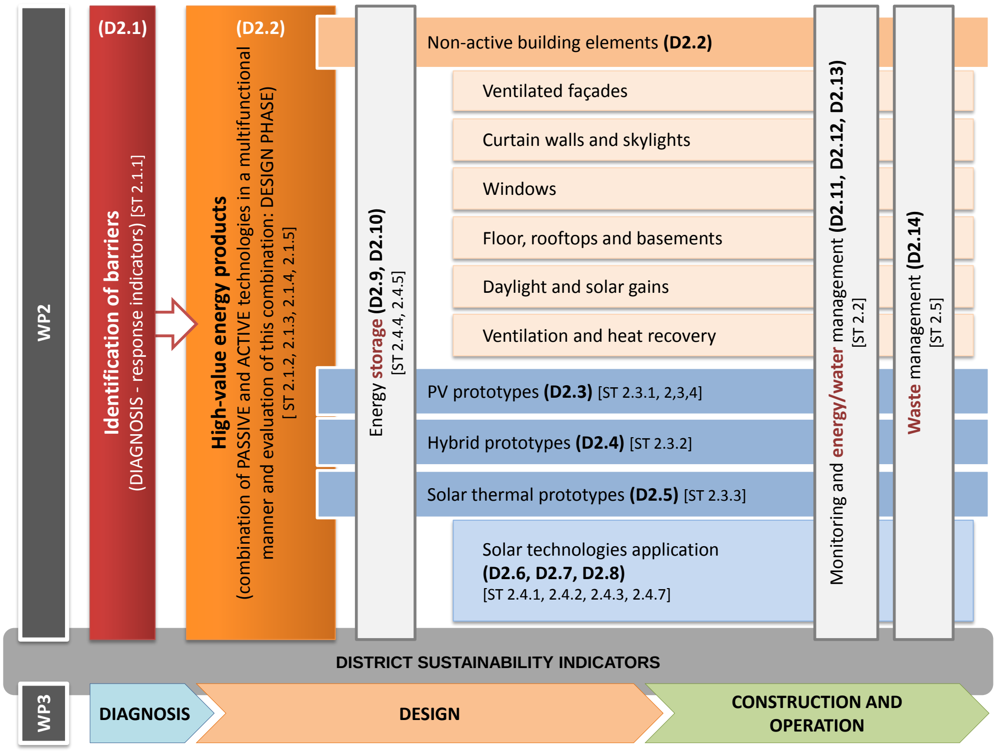

Figure 2: WP2 structure and relationship with WP3

1.2 Contribution of partners

In the following table the main contributions from involved partners in this task are shown.

Participant short name	Contributions
ITU	Overall report coordination and content development. Contribution to sections about requirements, solar thermal applications, calculation methods, analysis of boundary conditions for the demo sites and efficiency and cost analysis.
EZINÇ	Demand profiles calculation for Kartal demo site. Contribution to section about calculation methods.
CAR	Demand profiles calculation for Valladolid demo site. Overall report review and alignment with project objectives and contribution to section about analysis of boundary conditions for Valladolid demo site.
DAPP	Demand profiles calculation for Genoa demo site. Contribution to section about analysis of boundary conditions for Genoa demo site.
ACC	Demand profiles calculation for Valladolid demo site.

1.3 Relation to other activities in the project

The following table shows the main relationships of D2.6 with the other deliverables of the project.

Deliverable	Relationship
D2.2	Report on high-value energy products
D2.7	Report on solar thermal solutions. Location and Power Calculation
D2.8	Solar Cooling applied at residential district level
D2.9	Solutions for Distributed Thermal Storage

2 Requirements for solar thermal energy production

Solar thermal systems directly use the sun`s radiation and convert it to heat on an absorbing surface basically called solar collector. There are various types of solar collector technologies; as flat-plate, unglazed, compound parabolic, evacuated tube, parabolic trough, Fresnel lens, parabolic dish and heliostat field. To evaluate the performance of the collector mainly optical, thermodynamic and thermal analysis must be performed. Typical applications of the solar thermal systems are;

- Solar water heating
- Space heating and cooling
- Refrigeration
- Industrial process heat
- Desalination
- Thermal power systems
- Solar furnaces
- Chemistry application

Therefore, solar energy systems have a wide range of applications. In the frame of R2CITIES, two of these applications are identified; solar space heating and water heating systems.

During the system design process, optimization of the energy production of the solar thermal system depends on several requirements. In this report these requirements are categorized under two groups;

1. Environmental requirements
2. System`s design requirements

2.1 Environmental requirements

The efficiency and performance of solar thermal systems depend on a site's environmental conditions, mainly availability of solar energy source. Solar source is measured by the solar radiation intensity per area. Environmental factors such as **cloud cover** and **latitude** also has major effect on solar radiation intensity thus have to be taken in to account. The amount of solar energy availability varies by geographical location. Environmental conditions that have to be identified for solar thermal system are;

- Climatic conditions; latitude, longitude, total annual global irradiation, diffuse radiation percentage, cloud cover, mean outside temperature, lowest outside temperature and also standard out site temperature.
  - Maximum and average daily, monthly, annually solar radiation intensity on collector surface
- Season of the year, orientation to the path of sun - Sunshine hours
- Air temperature
- Cold water temperature
- Wind speed [1]

- Shading

Each variable has different effect on the system heat losses, energy production, equipment efficiency and building energy consumption. For example, temperature difference between outside and the collector plays major role on the collector efficiency.
Standard outside temperature is the design temperature for space heating energy requirement and must be calculated for every location from local standard values.
Also, air temperature, cold water temperature, solar irradiance values are some of the main parameters which determine the space heating requirements or domestic hot water consumption of the building.

2.2 System`s design requirements

There are three basic system elements of the solar thermal system that must be designed by the consideration of their functionality in the system.

- Collectors convert the sun's irradiated energy into heat
- Piping system transfer the heat to the storage tank
- Buffer tanks store the heat until it is required by the user.

In the process, energy is lost at the collector, in the piping system, and in the storage tank. Minimizing these energy losses is requires a perfect matching of the solar thermal system sizing according to whole building energy demands as well as the system integration (its architectural and mechanical integration) to the rest of the building design scheme. The overall system efficiency directly related to these losses. It is defined as the ratio of **available energy from the solar system** to **the irradiated energy onto the collector area**.

Following categories should be carried out to design a solar thermal system by their specific design requirements;

- System sizing
  - Energy consumption of the building's heating/hot water system
  - Collector performance parameters;
    - Solar system efficiency,
    - Specific solar energy yield,
    - Desired solar fraction
- System integration
  - Architectural Integration
    - Solar collector properties
    - Field size and position of collector systems
    - Shading factor
    - Materials and surface texture
    - Type of jointing
    - Multifunctional elements
  - Mechanical System Integration
    - Storage system efficiency
    - Heat exchanger capacity
    - Control systems

- Piping system insulation and length of distribution system [2]

A solar thermal system does not usually operate as the main heat source, an auxiliary heater is necessary to cover periods of high energy demand or modest solar radiation.

2.2.1 System sizing requirements

The solar thermal system integration into the building requires specific information about the thermal system sizing and the building capacities. Intention of this work is to identify required parameters for system sizing particularly focusing on space heating and domestic hot water heating systems. The parameter must be considered for the system sizing as follows;

- Energy consumption of the building's heating/hot water system
  - Space heating load (Daily/Monthly/Annually)

    The space heating demand is depend on the following factors;

    - Conduction/convection losses through the envelope
    - Ventilation losses to provide good indoor air quality
    - Infiltration due to incomplete tightness of the building
    - Passive solar gains through windows
    - Thermal gains from people inside the building, devices and artificial lightings
    - The thermal mass
    - User behavior

  - Domestic hot water load (Daily/Monthly/Annually)

    A household annual DHW demand depends on the several parameters. To be able to examine the DHW demand and energy consumption in detailed these parameters have to be taken into account. These are;

    - Flow rate,
    - Occupancy rate,
    - Household composition,
    - Installed appliances,
    - Climatic condition

  - Heating system type (radiator, under floor heating etc.)

    Solar space heating systems can be integrated with the following types of systems;

    - *Radiant floor heating*
    - *Forced hot water radiator (baseboard)*
    - *Forced air systems [8]*

    Conventional heating systems operate with feed temperatures of 50-70°C. The collectors cannot reach to this high temperature level except in a very few cases. As a result of this situation, solar fraction of the system reduced. For the increase solar fraction and energy saving, large surface-area heat distribution systems such as underfloor or wall surface heating can be installed. These systems have low feed and return temperature (50°C and 30°C). *With this way the solar fraction and the amount of oil or gas energy saved can quite easily amount to 20-30%. [3]*

- Temperature requirement (DHW and space heating application)

  For the space heating and domestic water heating application, generally water temperature should reach to 50-60°C according to the heating system type [9]. But, solar thermal system outlet temperature (temperature at collector) changes between 30-50°C according to the location and climatic condition [4].For this reason, to be able to reach the desired temperature all year around, auxiliary heating system usually integrated in the system design.

  For domestic hot water heating application, water temperature requirement changes between 40-50°C according to usage such as hand washing, showering, and dishwashing. Maximum water temperature shouldn't exceed 60°C to prevent the scalding problem [3].

- Collector performance parameters
  - Desired solar fraction
  - Solar system efficiency; Auxiliary heating system efficiency
  - Specific solar energy yield,

For accurate calculation of building thermal energy demand and solar system sizing some simulation program can be used; such as T*SOL, Polysun or TRNSYS. [3]

2.2.1.1 Energy consumption of the heating/hot water system

When solar thermal system is designed, most important criteria is the energy consumption of the whole building. Basically, DHW energy requirement depends on the average household water requirement and temperature differences between water inlet temperature and desired water temperature for household. As well, analysis of daily/monthly/annually heating and hot water consumption is very critical. It is also very important to have efficient indoor heating and DHW system to lower building heating loads. There are certain codes for each country to reduce the building energy demand.

The specific space heating energy demand of building was about 200kWh/m^{2}a for central Europe in the mid-1970s. With new building codes in European countries, Space heating demand have reduced specific space heating energy demands below 70kWh/m^{2}a. In the Central Europe, low-energy buildings can be built with a less than 50kWh/m^{2}a space heating demand [4]. *The heating requirement is about same order of magnitude as the energy requirement for hot water heating. A combined system can make a significant contribution as heating support, especially in the transitional months during spring and autumn.* [3]

In Valladolid and Genoa similar requirements are applied. According to climatic zone and building shape energy need of the building cannot be exceed certain limits as shown in Table 1.

Table 1: Limits on primary energy requirements in kwh/m2 on a year for Italy

[MARGINI, A.; “Various approaches to the evaluation of the energy performance of buildings in Italy – some results of calculation procedures application on residential buildings”; CESB10 Prague]

Building Shape Ratio (S/V)	Climate Zone									
	A	B		C		D		E		F
	Till 600 DD	From 601 GG	Till 900 GG	From 901 GG	Till 1400 GG	Frım 1401 GG	Till 2100 GG	From 2101 GG	Till 3000 GG	Over 3000 GG
≤0,2	8.5	8.5	12.8	12.8	21.3	21.3	34	34	46.8	46.8
≥0,9	36	36	48	48	68	68	88	88	116	116

Genoa is located in D climate zone and climate type is warm-marine according to the ASHRAE climatic classification.

Situation for Turkey is represented in Table 2.

Table 2: Limits on primary energy requirements in kwh/m2 on a year for Turkey [TS 825]

Building Shape Ratio (S/V)	Climate Zone			
	1.Region	2.Region	3.Region	4.Region
≤0,2	19.2	38.4	51.7	67.3
≥1,05	56.7	97.9	116.5	137.6

Kartal is located in 2.Region and climate type is warm-marine with 1865 HDD value. [ANSI/ASHRAE/IESNA Standard 90.1-2007 Normative Appendix B – Building Envelope Climate Criteria]

2.2.1.2 Collector performance parameters

Solar Fraction

The percentage of total energy available covered by solar power is termed the solar fraction. Solar fraction*, which is the part of the heating demand (solar hot water and space heating), met by solar energy,* can be change between 10% and 100%. This ratio is *depending on the size of the solar collector, the storage volume, the hot water consumption, the heat load of the building and climate. In some case of extremely insulated houses and low-flow mechanical ventilation, the solar contribution can even reach 100%.* [4]

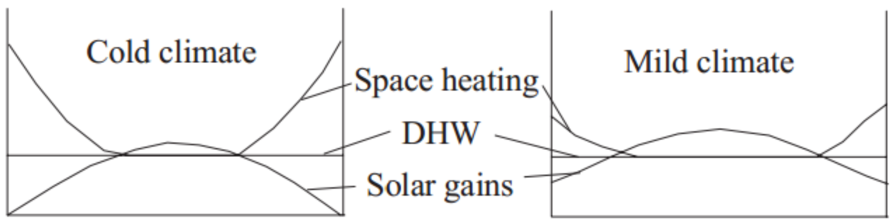

Figure 3: Differences between energy demand and solar gains for mild and cold climates [33]

In summer, solar energy systems reach up to their maximum energy production level and it can be seen overproduction problem. In order to limit the investment cost and avoid overproduction problem, solar fraction should be selected 50-60% in mid-latitude region for the solar DHW (domestic hot water) systems. As a result, collector and other equipment number and the total cost of the system decrease with this system capacity reduction [6]. Lower solar fraction numbers have some drawbacks. One of the main drawbacks occurs in the winter season which space heating is required. With the solar thermal system, only a limited percentage of this demand can be met. In this season, auxiliary heating system can be installed as a supplementary system. An important advantage is that auxiliary heating system can be shut down during the summer. [33]

When space heating and DHW systems examine, it can be seen that there are two type systems which are low solar fraction and high solar fraction for central European region. First type systems can be covered 35% of the full heating requirement of building. The solar thermal system which have high solar fraction can be met more than 70% of the heating energy consumption of building. For these type systems, *another approach is necessary in which the summer sun's energy is stored in long-term of seasonal storage system, from which it is taken in the winter*. [3]

The solar fraction identifies the fractional amount of the building heating energy needed is supplied by the solar thermal system. The solar fraction of solar supported heating networks as:

$Solar\ Fraction = Q_{Solar} / Q_{Boiler} + Q_{Solar}$

where:

Solar Fraction [%]

Q_{Solar} = annual energy produced by collector loop (measured on secondary side) [kWh/a]

Q_{Boiler} =annual heat input of the auxiliary heating system (boiler) [kWh/a]

Solar System Efficiency

The essential parameters must be entered to system in accordance with their definition and their position within the system. When selecting the proper components of a large solar hot water thermal system it is best to use analytical modeling tools such as T*SOL or TRNSYS. These computer programs can estimate parameters such as annual energy collected, storage and heat exchanger effects, system heat losses.

Solar thermal system overall efficiency depends on the system equipment's efficiencies and design solar fraction. When solar water heating system's performance is compared, it can be seen that the solar fraction of the system can change between 30-100.However, the overall system efficiency is remarkably similar, between 30-40%. [5]

The solar system efficiency describes the ratio between the annual amount of energy supplied to the heat storage unit and the global irradiation that strikes the collector surface:

$$\text{Solar System Efficiency} = Q_{Solar} / G_{active\_solar}$$

where:

solar system efficiency [%]

Q_{Solar} = annual energy produced by collector loop (measured on secondary side) [kWh/a]

G_{active_solar} = annual global irradiation onto active solar collector area [kWh/a].

Specific solar energy yield

The specific solar energy yield describes the annual amount of energy supplied to the heat storage unit from 1 m^2 of collector surface area. Compared to other calculation results, the kind of surface (absorber, aperture or gross collector area) must always be indicated for the specific yield result.

$$\text{Specific annual solar energy yield} = Q_{Solar} / A_{collector\_REF}$$

where:

Specific annual solar energy yield [kWh/m2]

Q_{Solar} = Annual energy produced by collector loop (measured on secondary side) [kWh/a]

$A_{collector\_REF}$ = Collector area on which the solar yield refers to
(gross, aperture or absorber area) [m2]

The specific solar energy yield is often said to be the crucial parameter for measuring the capacity of a solar energy system. For a correct interpretation of this parameter, the size of the system, the solar fraction and the system losses (storage and heat distribution losses) must be considered.

2.2.2 System integration requirements

2.2.2.1 Architectural Integration Requirements

To achieve quality in the architectural integration of STC systems certain requirements need to be fulfilled. The global integration quality depends not just on module shape, size and color but also on all formal characteristics as (Probst and Roecker, 2011):

- Solar collector properties
    - Thermal efficiency
    - Optical efficiency
    - Collector material thermal properties
    - Thermal and chemical properties of fluid
    - Flow rate in collector
    - Total collector absorber area
    - *Color of the absorbers for solar collectors*
    - Shape and size of the modules
- *Field size and position of collector systems*
    - Tilt angle
    - System location
    - Collector orientation
- Shading factor (shading effect of buildings, plants or other collectors)
- *Materials and surface texture*
- *Type of jointing*
- *Multifunctional elements*

For successful integration, above mentioned characteristics must all be coherent with the overall building design logic. [7]

When the system is designed, building location, optimal collector mounting angle and surface of the possible installation must be examined for the maximum solar irradiance. Plants, other collectors and buildings, which are located around the building, should be considered during the design phase, because of their shading effect.

Solar thermal collectors are generally located and orientated where receives most sun radiation to minimize the needed solar collector area. Consequently, this provides increase in energy production and decrease in investment cost. For central European countries, optimum collector tilt angle changes between 30° and 60° and optimum orientation direction is the south to get yearly maximum solar radiation [3]. To get maximum energy in winter days which shorter days and the low level of the solar intensity, collector should be mounted through the south direction [3].

When the solar thermal collectors integrated to the building, aesthetical aspects also should be considered. The collector surface textures, materials and colors interact with the same characteristics of other building envelope elements. Therefore, they should be coherent with the other building skin materials, colors and textures. Also, integrated collectors should be act as an envelope material, while product heat from the sun for the multifunctional aspects. Other parameter is type of jointing. When integrate the collectors to the building, *jointing must be carefully considered when choosing the product, as specific jointing types underline the modular grid of the system in relation to the building in different ways*. [14]

2.2.2.2 Mechanical System Integration Requirements

When the system configuration is designed, all the above mentioned categories, application type, system size as well as existing building system type (for the retrofit application) and household requirement must be considered. System configuration consists of piping, storage, heat exchanger and controller systems.

- Storage system
    - Storage tank configuration
    - Tank material thermal characteristics
    - Storage fluid chemical and thermal properties
- Heat exchanger type and capacity
- Control systems
- Piping system
    - insulation
    - length of distribution system [2]

Storage system

Storage system is one of the important equipment in the solar thermal system. With storage system, hot water demand can be provided, when collectors get low solar irradiation (winter, dusk etc.) or the night time. In system design and sizing phase, following criteria must be considered;

- Energy and water demand of consumer
- Application and system type
- Storage system type and shape
- Storage system location

Storage unit must be insulated to prevent heat loss and create efficient system.

Heat Exchanger Type and Capacity

Heat exchanger is used to transfer the heat which is gained from the sun to the domestic hot water. Heat exchanger type and size is selected according to;

- storage system type,
- system size,
- the flow rate in the collector loop and system [15]

There are two types heat exchanger for the solar thermal system, which are external and internal heat exchanger. Internal heat exchangers are used more suitable for small size system such as thermosyphon systems. External heat exchangers are mostly used in large systems. The heat transfer capacity is higher than the internal heat exchanger. For this reason, external heat exchangers are mostly used in large scale applications [3].

Control System

The Controller of the solar thermal system controls the circulation pump in the system to harvest maximum energy from the sun. This equipment, control the fluid flow in the system according to the temperature differences. The controller is the optional equipment for solar thermal system. According to the system size and type, requirement of this equipment is changed. The controller does not equip in thermosyphon systems. [3]

Piping system

The heat, which generated in the collectors, is transported to the storage system and the user by piping system. The heat must be transport with minimum possible heat losses. To prevent this problem,

- Shortest possible path must be selected
- In the external area, lowest possible length of pipe must be used
- Sufficient insulation must be applied the pipes

Also sufficient space should be provided around pipe for the maintenance process. [3]

2.2.3 System Integration into the existing building

Solar thermal heating system can be divided two groups which are centralized system and decentralized systems. In decentralized system, the storage and collectors supply hot water to individual apartment like ordinary active solar heating systems [16]. This system is more suitable for the existing building application or small scale project.

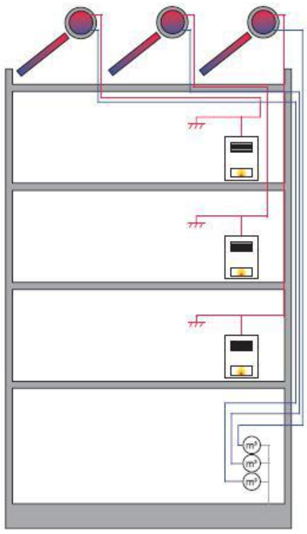

Figure 4: Decentralized system for DHW [19]

For the centralized systems, hot water and heating consumption supply by the central heating system which is supported solar thermal heating system. All collected solar energy is stored in one storage unit and this energy is distributed to the all apartment. For the large scale application, centralized system is more suitable. The major advantage of the system is reduced unit cost with the less piping and auxiliary equipment number. The other important advantage is reduced heat losses from the storage unit [16].

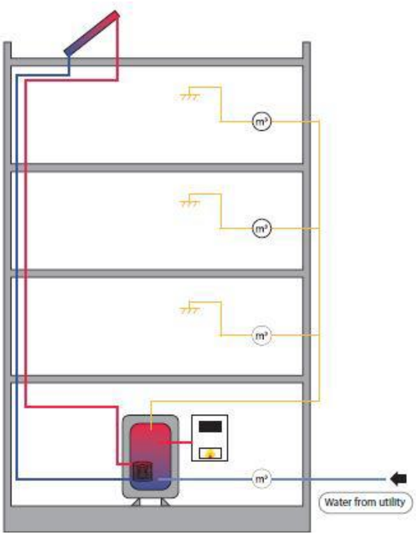

Figure 5: Centralized system for DHW [19]

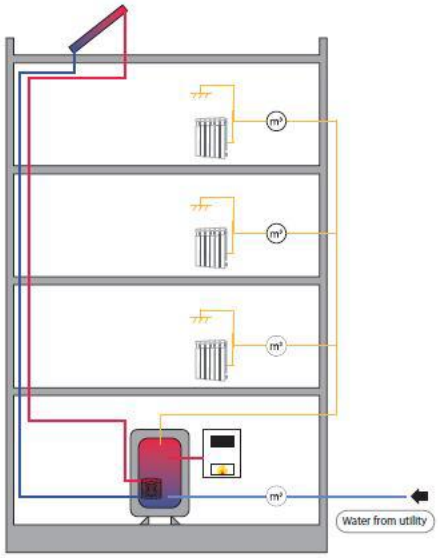

Figure 6: Centralized system for space heating and DHW [19]

2.3 Solar District Heating Systems

Solar district heating system is one of the large applications of the solar thermal energy systems. In solar district heating system, the heat, which is produced by one or many solar thermal collector fields, is fed into the local heating network. Long or short term storage system can be integrated to the system [3]. One of the most important advantages of the long-term storage system is to make possible to store heat in summer for winter use [13].

"The concept of solar-supported district heating systems is considered mainly in connection with the new building developments or large building complexes that have been designed as low-energy building. It is important in such projects that, from the beginning, the best possible technical preconditions are created for the use of solar energy by means of integrated energy planning. These include;

- *A plan of the development with the orientation of the buildings that are favorable for active and passive use of solar energy (south alignment)*
- *Planning of the estate or buildings according to solar architectonic criteria*
- *Increased thermal protection in the buildings (low-energy building method)*
- *Low-temperature heating systems, which permit a low network return temperature and hence a higher solar yield*
- *Central heating plants and storage tanks arranged centrally to minimize distribution losses*
- *Sufficient space for the heat storage tank"*

Total solar fraction is 10-20% for solar district heating with short-term thermal storage. Solar fraction is 40-70% for long-term storage system [3].

2.3.1. Solar Heating System Integration into the District Level

In solar district heating system, various different type network structures can be used for distributing the heat. There are three different type pipe configurations. These are;

- 2+2 conductor network system consist of two conductor lines for the heat supply to the building and additional two conductor lines for the solar circuit.

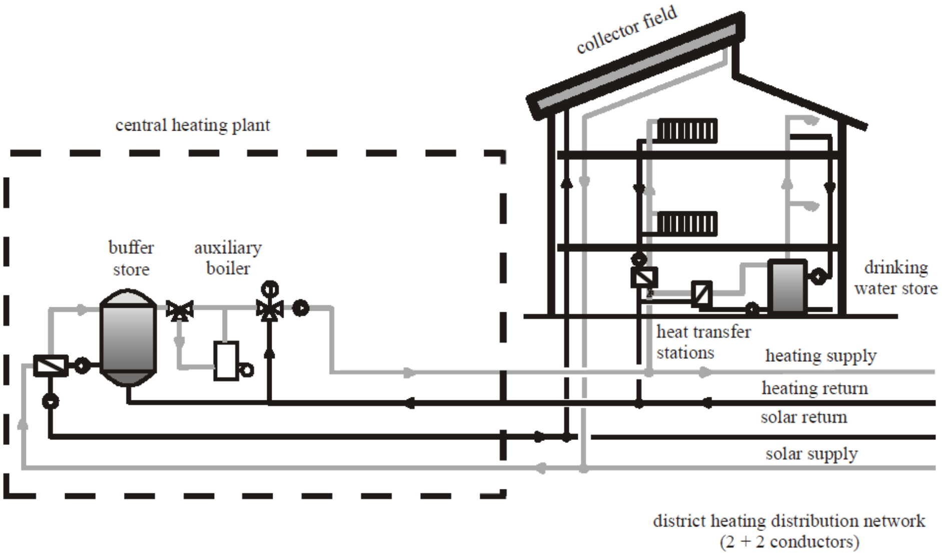

Figure 7: 2+2 conductor network [21]

- 4+2 conductor network system consists of four conductor lines for the heat supply. Two of the lines each are used for supply DHW and space heat. Additional two lines are for the solar circuit. This network system has higher circulation losses.

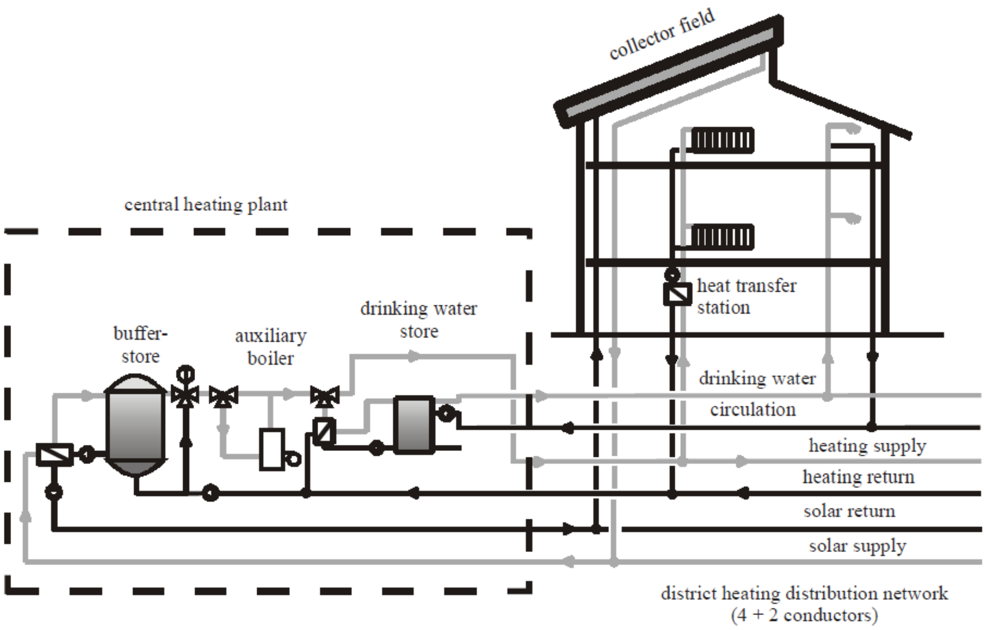

Figure 8: 4+2 conductor network [21]

- 3 conductor line network system is used supply separate DHW and space heat together with a common return [3].

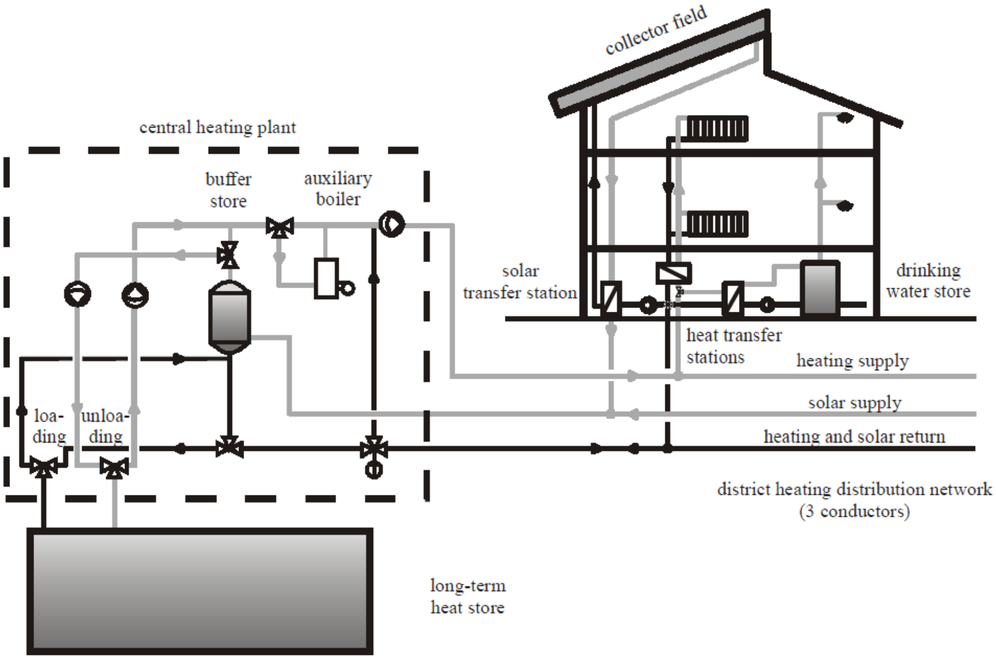

Figure 9: 3 conductor line network [21]

For the district heating system, there are two types connection option to supply heat to the building, direct and indirect integration. In direct connection, heat which comes from the district heating network directly use in the building. This connection has two main advantage and these are cheap and low heat losses. Second option is indirect connection. In this situation, district heating network coupled to the heat exchanger unit in the building. This option is usually preferred by house-owner.

2.4. Barriers for Solar Thermal Energy Systems

Most of the barriers related to the market development. According to the international energy agency (IEA) Solar heating and cooling program (SHC) research, SHC member countries' total installed capacity is 234,6GW_{th} and these collectors cover 335,1million m^2. R2CITIES project countries total installed capacity value can be seen in Figure 10. [34]

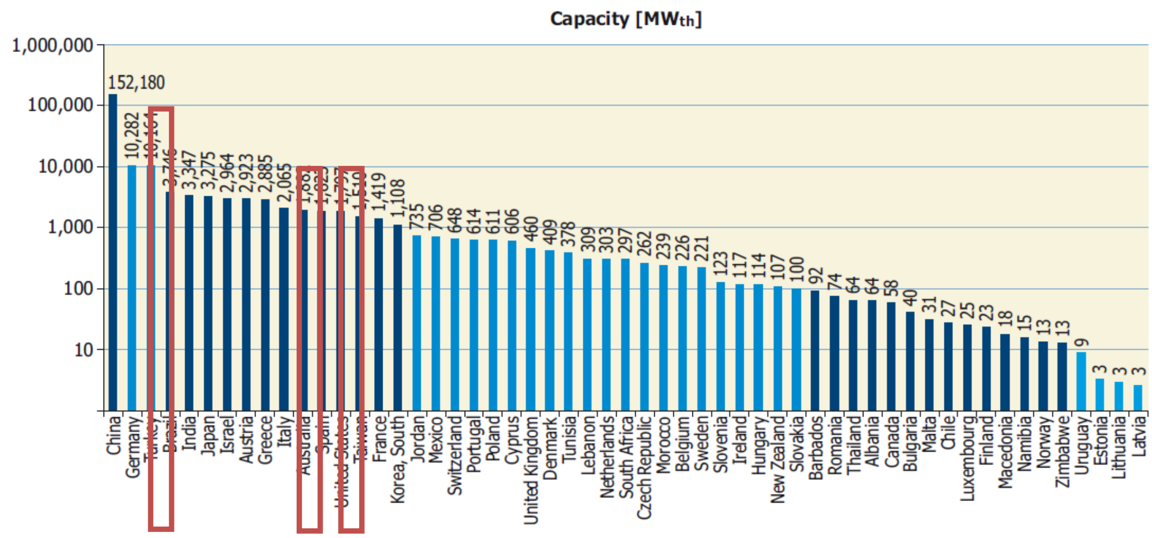

Figure 10: Total capacity of glazed and evacuated tube collectors in operation by the end of 2011 [34]

As seen on the Figure 10, Turkey represents the third country, Italy is 10th and Spain is 12th country according to their total installation capacity of solar thermal. Between 2010 and 2011, total installed capacity increased by 14,3% and its equal to the 48,1GW$_{th}$. In Spain, total installed solar thermal capacity increased by 11% with solar obligation for new building with solar obligation for new building and solid support framework. Also, interest in solar thermal technologies remains very high as can be seen at the major solar and HVAC events in Spain. When Italy is examined, it can be seen that installed capacity increased by 15% between 2010 and 2011. The strong growth in recent years is partly due to the tax break for investments in solar installations. In Turkey, Capacity growth is equal to the 14% [34] [35]. With developed market and technology, Turkey has rapid growth market.

Task 41, which was executed project by International Energy Agency between 2009 and 2012, was conducting an international survey concerning the integration of solar energy systems and architecture in order to identify barriers that architects are facing in incorporating active solar technologies in their design. *The survey investigates the possible barriers of solar thermal and photovoltaic. The web-survey was conducted internationally including 13 countries (Austria, Belgium, Canada, Denmark, France, Italy, South Korea, Norway, Portugal, Spain, Sweden and Switzerland)* [36].

The main barriers for the solar thermal heating systems;

- Economy - Not economically justifiable and lack of governmental incentives, high investment cost for especially large scale solar thermal systems
- Interest - Lack of interest in solar design by architects and clients/developers
- Products – For building integrated solar thermal systems, lack of product suitable for quality building integration and complementary building components
- Knowledge - Lack of sufficient technical knowledge by architect, by client/developer and by consultants
- Process - Lack of tools that support design and dimensioning/sizing of the system

- Technical - Complex structure of the large scale heating system, technical and architectural integration problem of the solar thermal system to the existing building [17] [18].

To overcome these barriers, there are three critical components;

- Public awareness
- Strong market infrastructure
- Incentives and regulatory support

These three components should be supported national, regional and local levels by the government. [18]

When barriers are examined for each demosite in detail, result shows that main barriers are lack of knowledge by client/developer and architecture, lack of interest by client and lack of information of incentives for Italy. For Spain, main barriers are same with the Italy but, it can be seen that lack of suitable product is another important barrier. In fig 10 and 11, survey result can be seen in detail for Italy and Spain [36].

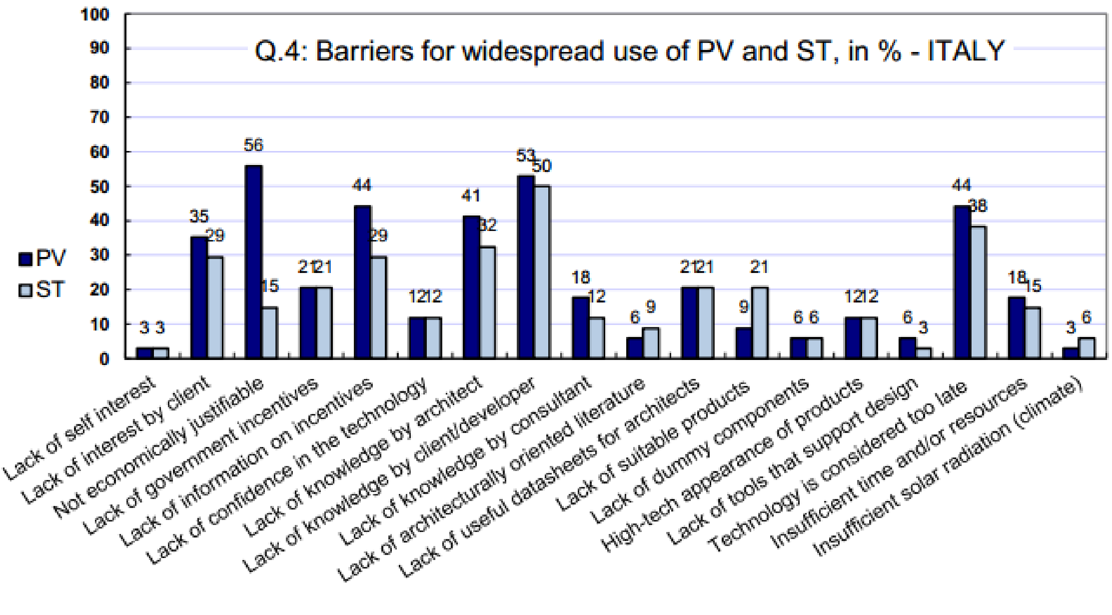

Figure 11: Barriers for photovoltaic and solar thermal for Italy

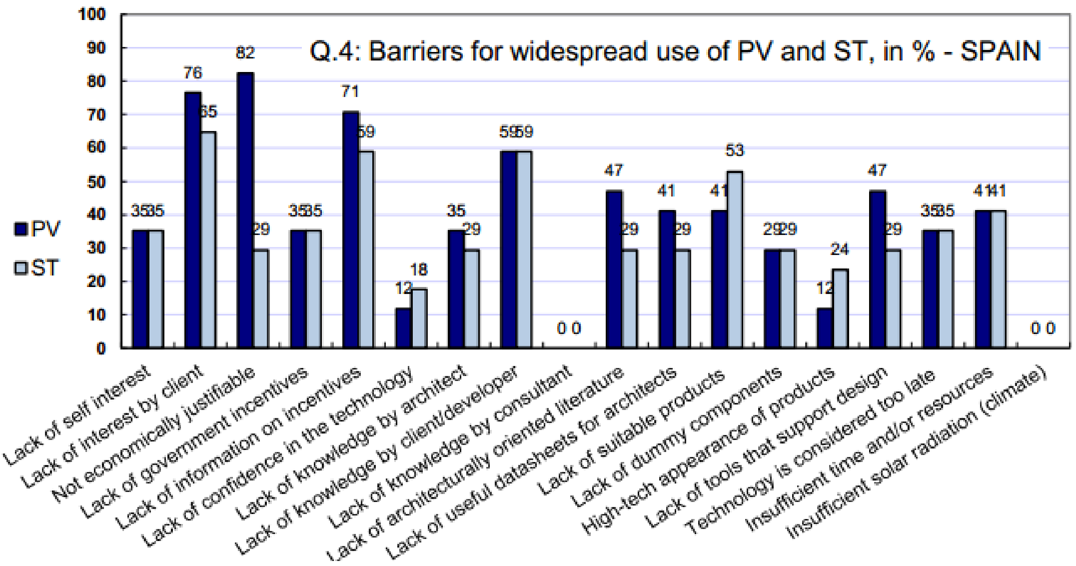

Figure 12: Barriers for photovoltaic and solar thermal for Spain

For the case of Turkey, there is no detailed research related to barriers and their comparisons when it comes to application of solar thermal as given for Spain and Italy. However, there are many researches and experiences that come from widespread application of solar thermal in Turkey, shown that the most important barriers come from financial issues such as lack of government incentives, high system cost that has negative economic impact on overall building construction cost. These follow by other barriers such as lack of knowledge by client and developer, insufficient solar radiation over a year and solar thermal integration in the architectural design process after project design is done [36].

2.4.1. Barriers for Solar District Heating

Barriers for the solar district heating systems are very similar with general solar thermal system barriers. However, there are some barriers which are different from the small scale solar thermal systems. These are;

- Management – For large scale application, management and controlling system create problems.
- Economy – When compared the district heating system and building scale or small scale application, it can be said that investment cost are high because of the expensive seasonal storage system and large collector number.
- Technology – District heating system have complex system (distribution, building system connection and seasonal storage system) [19][20].

3 Design and Development of Solar Thermal Applications

Selecting the right solar thermal system for a specific building depends on three key factors: Climate, budget, and heating usage needs. Solar thermal systems could be economical, especially in large scale buildings where the energy used to heat water or space is significant. There are a number of technologies available to heat water and space efficiently. However, before implementing these technologies, it is important to first reduce hot water and space heating demand by the use of energy saving fixtures and appliances.

Solar thermal heating systems can be used throughout the Europe on any building with a south-facing roof or un-shaded grounds for installation of a collector.

In Southern Europe, generally simple thermosyphon DHW system is used because of the high solar radiation. Usually, collector area is chosen 2-3m2 and storage tank capacity is 150lt for single family house (for four people). Solar fraction changes between 50% and 60%.

In Central and Northern Europe, including Northern Italy, only forced circulation systems are used. Generally, system collector area is chosen 4-6m2 and 300lt storage tank is used for the DHW systems. Solar fraction is about 60% of this type DHW system in these regions.

In Central Europe, especially in Germany, Austria, Switzerland and France, Combi-systems are used for DHW and space heating. Typically, systems consist of 10-15m2 collector and 600-1000lt storage tank. Generally, solar fraction ratio is equal to 25%. [RHC; “Strategic research priorities for solar thermal technology”; 2012]

There are some example application of solar thermal system in Figure 13 andFigure 14.

Figure 13: Application 1

Figure 14: Application 2

3.1 Solar Thermal Equipment

Solar thermal water heating system equipment (Solar collectors, accessories, storage tanks and installation), which are used in this project, are explained detailed in the following section.

Solar thermal heating system equipments are specified in the section “2.2.2.System integration requirements”. In this project solar thermal water heating system integrated into the building. Each system equipment identification are explained in the following section.

3.1.1 Solar collectors

Collectors are one of the main elements of solar thermal systems. Their task is converting light into heat and transferring this heat to the downstream systems. There are many different types and design for different applications, all with different costs and performances. Collectors can be divided in three groups based on their technologies;

- Unglazed collectors
- Glazed collectors
- Evacuated collectors

3.1.1.1 Solar thermal temperatures values according to system applications

Solar thermal systems have different working temperatures for different collector types. For each temperature, there are various applications. These are;

Low temperature application (<30°C)

- Swimming pool heating
- Preheating for domestic hot water heating

Medium temperature applications (30°C-100°C)

- Domestic hot water heating
- Space heating

High temperature applications (>100°C)

- Industrial applications
- Cooling system

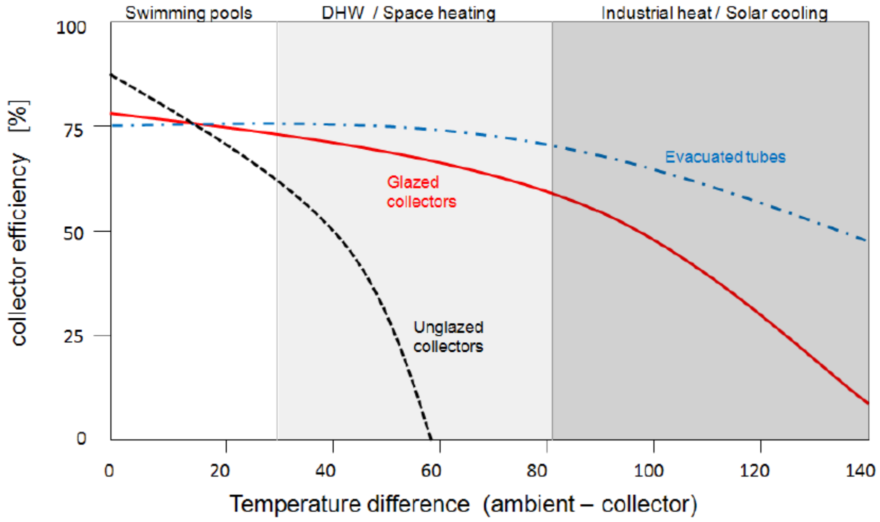

Figure 15: Relationship between temperature difference and collector efficiency

Unglazed collectors can heat fluid up to 50°C. Because of this low temperature, they are generally used for swimming pool heating, DHW pre-heating application which needs low energy consumption. This collector has a lower performance at equal operation temperature than glazed flat-plate collector because of the lacks the glass cover, housing and thermal insulation. Therefore has higher thermal losses and can be used only at very low operating temperatures, but main advantages of these collectors are simple construction and inexpensive. [3]

Evacuated tube collectors can reach higher temperatures than the other types. They can reach up to 120-180°C and tube collectors are especially used for cooling application but are also used for DHW, space heating and industrial applications. *During the manufacturing process, a vacuum is created inside the glass tube. The absence of air creates excellent insulation and minimized heat loss*. As a result, Evacuated tube collectors are able to achieve higher temperatures than other collector types. High working temperature has a disadvantage which is overheating problem for the working fluid. [10]

ICS or batch collectors reduce heat loss by placing the water tank in a thermally insulated box. This is achieved by encasing the water tank in a glass-topped box that allows heat from the sun to reach the water tank. However, the other walls of the box are thermally insulated, reducing convection as well as radiation to the environment. In addition, the box can also have a reflective surface on the inside. This reflects heat lost from the tank back towards the tank. In a simple way one could consider an ICS solar water heater as a water tank that has been enclosed in a type of 'oven' that retains heat from the sun as well as heat of the water in the tank. Using a box does not eliminate heat loss from the tank to the environment, but it largely reduces this loss.

Standard ICS collectors have a characteristic that strongly limits the efficiency of the collector: a small surface-to-volume ratio. Since the amount of heat that a tank can absorb from the sun is largely dependent on the surface of the tank directly exposed to the sun, it follows that a small surface would limit the degree to which the water can be heated by the sun. Cylindrical objects such as the tank in an ICS collector inherently have a small surface-to-volume ratio and most modern collectors attempt to increase this ratio for efficient warming of the water in the tank. There are many variations on this basic design, with some ICS collectors comprising several smaller water containers and even including evacuated glass tube technology, a type of ICS system known as an **Evacuated Tube Batch (ETB) collector**.

Flat plate collectors are an extension of the basic idea to place a collector in an 'oven'-like box with glass in the direction of the Sun. Most flat plate collectors have two horizontal pipes at the top and bottom, called headers, and many smaller vertical pipes connecting them, called risers. The risers are welded (or similarly connected) to thin absorber fins. Heat-transfer fluid (water or water/antifreeze mix) is pumped from the hot water storage tank (direct system) or heat exchanger (indirect system) into the collectors' bottom header, and it travels up the risers, collecting heat from the absorber fins, and then exits the collector out of the top header. Serpentine flat plate collectors differ slightly from this "harp" design, and instead use a single pipe that travels up and down the collector. However, since they cannot be properly drained of water, serpentine flat plate collectors cannot be used in drainback systems.

The type of glass used in flat plate collectors is almost always low-iron, tempered glass. Being tempered, the glass can withstand significant hail without breaking, which is one of the reasons that flat-plate collectors are considered the most durable collector type.

In this project, Superline L USB PU type flat plate solar collector will be used and analyses were done according to these products. Superline L USB PU collectors are manufactured under high quality conditions. Contains sputtered blue high selective copper absorber surface to get the best performance under solar radiation. Superline L USB PU collectors absorber type is high selective coated copper surface with copper tubes and tempered low iron solar glass with high transmittance. Frame is made from electrostatic powder aluminum extrusion profiles. Polyurethane foam and mineral wool layer is used as an insulation material in the collector.

Specifications	Values
Dimensions	1893*1204*99 mm
Gross Area	2,28 m2
Aperture Area	2,16 m2
Absorber Area	2,10 m2
Frame Material	Electrostatic Powder Coated Aluminium Frame
Sealing & Gasket Material	EPDM
Absorber Material	Blue Selective Coated Copper
Absorbtance	97%
Emittance	3%
Welding Type	Ultrasonic Welding
Heat Transfer Fluid Volume	1,49 lt
Header Tubes Material	22 mm
Header Tubes Thickness	1 mm
Number of Header Tubes	2
Riser Tubes Material	Copper
Riser Tubes Diameter	8 mm
Riser Tubes Thickness	0,50 mm
Number of Riser Tubes	10
Cover Material	Solar Tempered Glass
Cover Thickness	4 mm
Transmittance of the Cover	91%
Insulation Material	Polyurethane foam + mineral wool layer
Maximum Operation Pressure	9 Bar
Test Pressure	13,5 Bar
Weight	41,00 Kg (without heat transfer liquid)

Mounting Types : Flat Roof | in Roof | on Roof | on Roof Elevation




3.1.2 Storage tanks

The energy supplied by the solar thermal system cannot meet the full heat requirement. Therefore the generated solar heat must be stored. Generally, storage system type can be divided two main groups. One of it is short-term storage which is generally used in solar thermal water heating application. Second is seasonal storage which is ideal if this heat could be saved from the summer to the winter (seasonal store) that it could be used for space heating [3].

Storage tanks have two main missions which are storage and heat-exchanger. Storage tanks are made from stainless steel, copper or mild steel, with a protective coating inside for avoidance of corrosion. To reduce heat losses, the tanks are insulated with rock-wool insulation pads or polyurethane foam. The tanks’ shape and size change with building water needs.

In this project, Pressurized tanks, which are the most convenient and practical way for the hot water production, is used for the solar thermal systems. This tank supply cold water directly from the main water system without an addition connection. Thus, the system started to work with main water system pressure. When the operation starts, the tank pressure increases with increasing temperature. When compared other tank system, the fluid which is in the pressurized tank, reach high temperatures according to the

Figure 16: Storage tank

3.1.3 Accessories

Control system to regulate the overall operation. The controllers' main task is controlling the circulating pump according to the temperature differences between tank and collectors, to harvest the sun's energy in the optimum way. *Increasingly, controllers are coming onto market that can control different system circuits as one single device, and in addition are equipped with functions such as heat measurement, data logging and error diagnostics* [3].

Figure 17: Solar Controller

3.1.4 Combination equipment

The equipment, which will be used in this project and the connection between this equipment, can be seen in following figure.

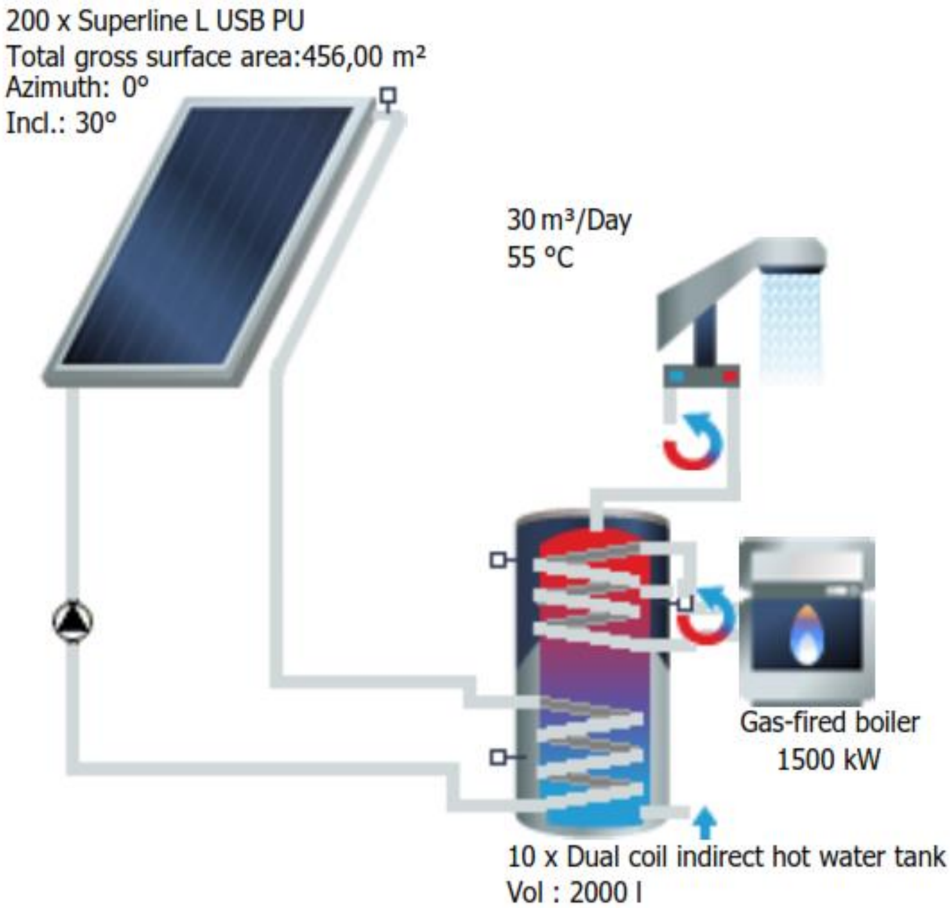

Figure 18: Integrated System

3.1.5 Mounting systems

There are two main types mounting system which are building added solar thermal (BAST) systems and building integrated solar thermal (BIST) systems. Collectors can be mounted on several places on the building. General application places are;

- Roof
- Façade
- Windows
- Balcony rails
- Shading Devices/Canopies

3.1.6 Building added solar thermal system (BAST)

If the collector installation methods are researched, it can be seen that there are two different types which are integration and adding (superimposed) systems. In the adding (superimposed) method, collectors are mounted on the conventional building components (e.g. roof, facade). In other words, collectors add after the building construction [6].

Figure 19: Example for building added solar thermal system (BAST) [11]

3.1.7 Building integrated solar thermal system (BIST)

In the integration (superimposed) method, solar collectors must be replaced the conventional building components. In this way, building components gain energy production ability. For solar thermal systems, this method is called as building integrated solar thermal systems (BIST) [6].

Figure 20: example of building integrated solar thermal systems (BIST) [12]

The main aim of the integrated system is reduce requirement of land and the costs with increased usable area on the building envelope. In addition, an integrated collector gives aesthetics look to building. When BAST and BIST systems are compared, BIST is more cost effective because collector is integrated on the building envelope when constructing the building instead of mounting it later on [7].

There are three locations to integrate these systems into building. These are the roofs, facades and building components like balcony railings and shading devices. [7].

Figure 21: Mounting Systems

3.2 System Definition

A collector, which is often fastened to a roof or a wall facing the sun, heats working fluid in solar thermal systems. This fluid is pumped (active system) or driven by natural convection (passive system) through it [24].

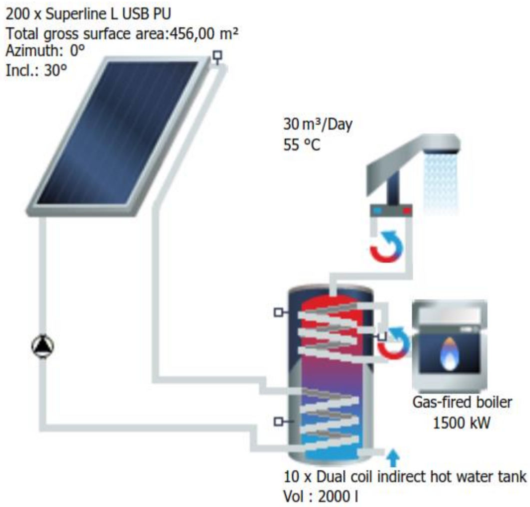

Figure 22: System definition

The collector loop pump is controlled by a solar controller according to the temperature differences between the collector output and the tank reference temperature.

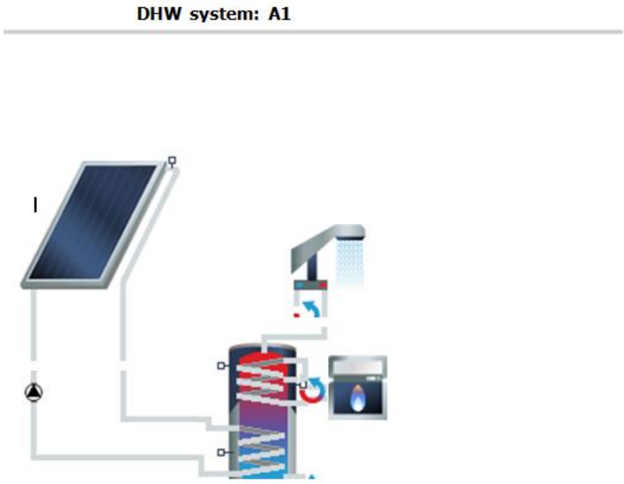

Figure 24: System definition

3.2.1 System Specification

Except in rare case, solar water heating system, which is installing without auxiliary heating, is insufficient to meet full of heat requirement of the building. Many SWH systems have a back-up electric heating element in the integrated tank, the operation of which may be necessary on cloudy days to ensure a reliable supply of hot water [25].

The temperature stability of a system is dependent on the ratio of the volume of warm water used per day as a fraction of the size of the water reservoir/tank that stores the hot water. If a large proportion of hot water in the reservoir is used each day, a large fraction of the water in the reservoir needs to be heated. This brings about significant fluctuations in water temperature every day, with possible risks of overheating or under heating, depending on the design of the system. Since the amount of heating that needs to take place every day is proportional to hot water usage and not to the size of the reservoir, it is desirable to have a fairly large reservoir (i.e. equal to or greater than daily usage,) which will help prevent fluctuations in water temperature [25].

If ample storage is pre-existing or can otherwise be reasonably acquired, a large SWH system is more efficient economically than a small system [26]. This is because the price of a system is not linearly proportional to the size of the collector array, so the price per square meter of collector is cheaper in a larger system. If this is the case, it pays to use a system that covers nearly all of the domestic hot water needs, and not only a small fraction of the needs. This facilitates more rapid cost recovery [25].

Not all installations require new replacement solar hot water stores. Existing stores may be large enough and in suitable condition. Direct systems can be retrofitted to existing stores while indirect systems can be also sometimes being retrofitted using internal and external heat exchangers [25].

The installation of a SWH system needs to be complemented with efficient insulation of all the water pipes connecting the collector and the water storage tank, as well as the storage tank (or "geyser") and the most important warm water outlets. The installation of efficient lagging significantly reduces the heat loss from the hot water system. The installation of lagging on at least two meters of pipe on the cold water inlet of the storage tank reduces heat loss, as does the installation of a "geyser blanket" around the storage tank (if inside a roof). In cold climates the installation of lagging and insulation is often performed even in the absence of a SWH system [25].

3.3 Integration of Existing Equipment to Solar Thermal System

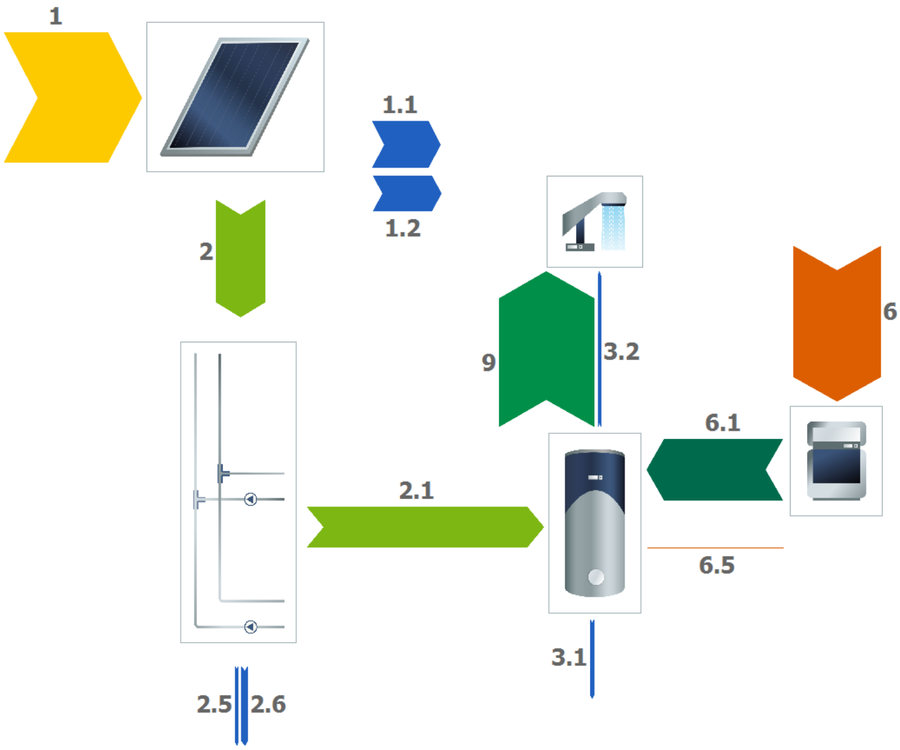

Figure 25: Energy Balance Schematic

Legend

1	Irradiation on to collector surface (active)
1.1	Optical collector losses
1.2	Thermal collector losses
2	Energy from collector array
2.1	Solar energy to storage tank
2.5	Internal piping losses
2.6	External piping losses
3.1	Tank losses
3.2	Circulation losses
6	Final energy
6.1	Supplementary energy to tank
6.5	Electric element
9	DHW energy from tank

4 Calculation Methods for Thermal Energy Demand and System Pre-Dimensioning

Thermal energy demand of the building covers space heating and water heating energy consumption and it is depend on the several parameters which are thermal properties of building envelope materials, passive heat gains, user behavior, occupant number, comfort and climatic conditions. The demand can be calculated with energy simulation software such as eQuest, Design builder. In this project thermal energy demand of each demo-site was performed. E-Quest program has been used for Kartal demo-site, Design Builder has been used for Valladolid demo-site.

Solar thermal system sizing is done, according to the building energy demand. Simulation programs are used to calculate and predict energy production of the system, solar fraction and other system properties –collector outlet temperature, boiler inlet/outlet temperature, total system efficiency etc. –. The simulation performs according to the climatic data and system specifications. In this project, system, which is design according to the building thermal energy demand, simulations were performed with using T*SOL software. T*SOL software also can calculate space heating and water heating energy demand based on certain assumptions..

4.1 Space heating load

For the dimensioning of solar thermal systems, heating load of the space is considered. *This performance variable, and is given in W/m^2 with respect to the living area* [3]. The specific factors of heating demand are identified at section 2.2.1.

Heat losses calculations through the building envelope;

- Exterior surface above grade: $q=UA\Delta T$ ($\Delta T=t_i-t_o$) [W]
- Partitions to unconditioned buffer space: $q=UA\Delta T$ [W] (ΔT=Temp. difference across partition)
- Walls below grade: $q=U_{avg,bw}A\Delta t=UA(t_{indoor}-t_{ground})$ [W]
- Floors on grade: $q=F_P p\Delta t$ [W] (F_p : heat loss coefficient per foot of perimeter)
- Floors below grade: $q=U_{avg,bf}A\Delta t=UA(t_{indoor}-t_{ground})$ [W]
- Ventilation/Infiltration: $q=C_S Q\Delta t$ [W] (C_S : air sensible heat factor, Q : Air volumetric flow rate)
  - Total Sensible load: $q_S=\Sigma q$ [W]

Internal Heat Gains;

From people;

- Sensible heat gain : $q_s=q_{s,per}N$ ($q_{s,per}$: Occupant sensible heat gain, N : Number of occupant)
- Latent heat gain : $q_l=q_{l,per}N$ ($q_{l,per}$: Occupant latent heat gain, N : Number of occupant)
  - Total heat gain from people : $Q= q_s+ q_l$

From lighting equipment;

- $q_{el}=WF_{ul}F_{sa}$ (Ful : lighting use factor, Fsa : lighting special allowance factor, W : Total light wattage)

Solar heat gain;

- Direct beam solar heat gain: $q_b=AE_{t,b}SHGC(\theta)IAC(\theta,\Omega)$ (IAC : indoor solar attenuation coefficient, SHGC : Solar heat gain coefficient)
- Diffuse solar heat gain: $q_d=A(E_{t,b}+E_{t,r})(SHGC)_D IAC_D$
- Conductive heat gain: $q_c=UA(T_{out}-T_{in})$
  - Total fenestration heat gain: $Q= q_b+q_d+q_c$ [22]

The solar thermal system integration into the heating system and operational temperature values are being identified at section 2.2.1.

4.2 Domestic Hot Water Load

The domestic hot water requirements identified at section 2.2.1. DHW demand pattern changes with climate and season, household composition, family income, and cultural background. Factors, which effect the domestic hot water system energy consumption, are;

- The type of fuel used,
- Inflow temperature,
- Set temperature,
- Water heater type,
- Appliance types and efficiency ratings,
- Water or heat losses [9]

DHW system energy consumption;

$Q_w=V_{w,day}c_p\Delta T=V_{w,day}c_p(T_{out}-T_{in})$ (T_{out} : Desired water temperature, T_{in} : water mains system inlet temperature, c_p : specific heat of water, $V_{w,day}$: water volume per day) [23]

4.3 System Simulation: T*SOL Software

T * Sol database covers meteorological data and solar thermal product technical details, which are get from the companies. T*SOL’s Meteorological data such as the solar radiation, sun angle and temperature is provided from Meteonorm software. T*SOL uses the algorithms to make analysis with using product and meteorological data which are defined user. Formulation of this algorithm is not shared by T * Sol the manufacturer.

4.3.1 Simulation

The program calculates the annual energy production and temperatures in the period of one to six minutes. During simulation the temperature of the system components could be displayed in color. System parameters such as efficiency and solar fraction are shown as a simulation result [27].

- The Design Assistant can be also used for a minute-step simulation
- The additional design aid calculates optimal collector area, storage tank volume and boiler performance.

Photo Plan, which is integrated the photo dimensioning program in the T*SOL software, is a visualization tool to create the solar thermal system integration on the roof. Base on a photo view and reference dimensions, the roof and the planned collector arrays can be represented realistically.

4.3.2 Financial Analysis

T*SOL® Pro calculates the economic efficiency of a solar thermal system, including the following:

- Capital value, amortization period and solar production costs (heat price)
- Modified internal rate of return, profit accounting for reinvestment
- Return on equity, return on assets, internal rate of return and return on capital
- Solar fractions for heating and domestic hot water shown separately [27]

4.3.3 Collector Database

T*SOL® Pro provides a database, which is containing over 2,500 flat-plate and evacuated tube collectors. The collector, which is not include in database, can be simulated as required by entering the conversion factor, specific heat capacity, heat transfer coefficient, and incident angle modifier. The program also can be simulated the evacuated tube collectors with or without reflectors [27].

4.3.4 Air collector systems

The building data and ventilation parameters for the planning and yield forecast of air collector systems. With the building model for air collector systems, the connections between building parts and system technology can be recognized, and simulated the building dynamics and ventilation losses. The building capacity is calculated from the data on the building geometry, insulation and construction [27].

4.3.5 Climate Data

The integrated MeteoSyn tool offers:

- Climate data records for approx. 8,000 weather stations worldwide
- New climate data from DWD (German weather service) for Germany for the period 1981-2010
- Creation of new climate data from own monthly average values
- Interpolation of climate data for many more user-defined locations [27]

4.3.6 Results

T*SOL® Pro provided a range of results with tables and diagrams. The project report represents the following results:

- Irradiation, energy balance
- Fuel savings, avoided CO_2 emissions
- System efficiency
- Solar fractions: domestic hot water, heating, total

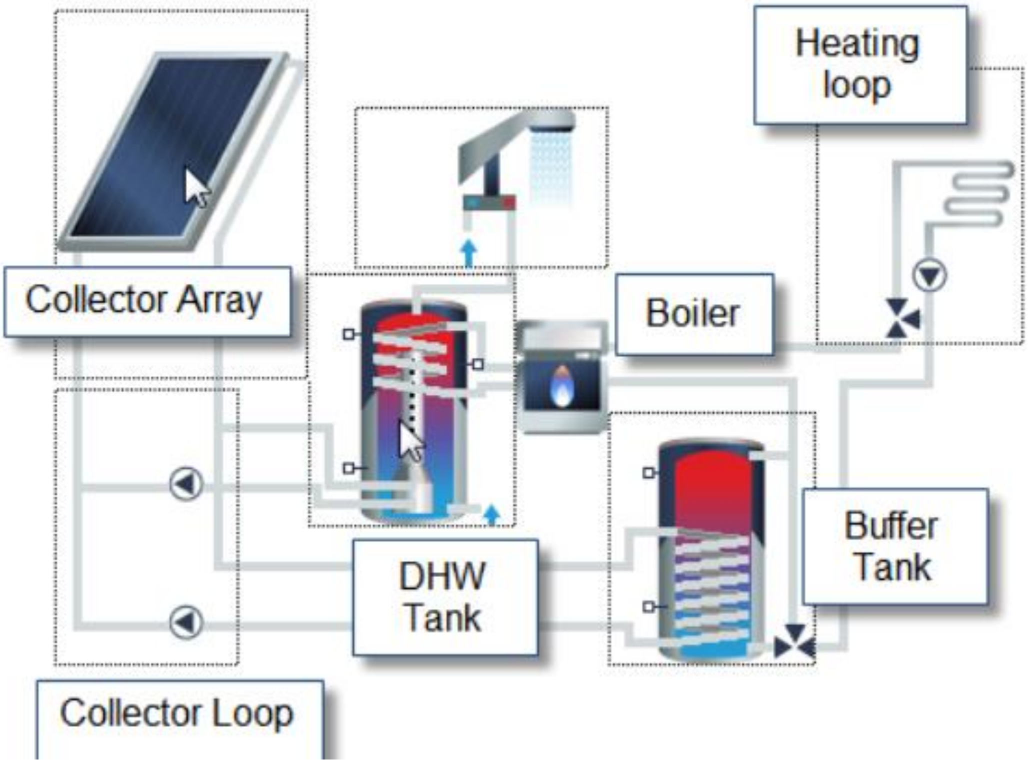

Figure 26: System Layout-component selection boundaries

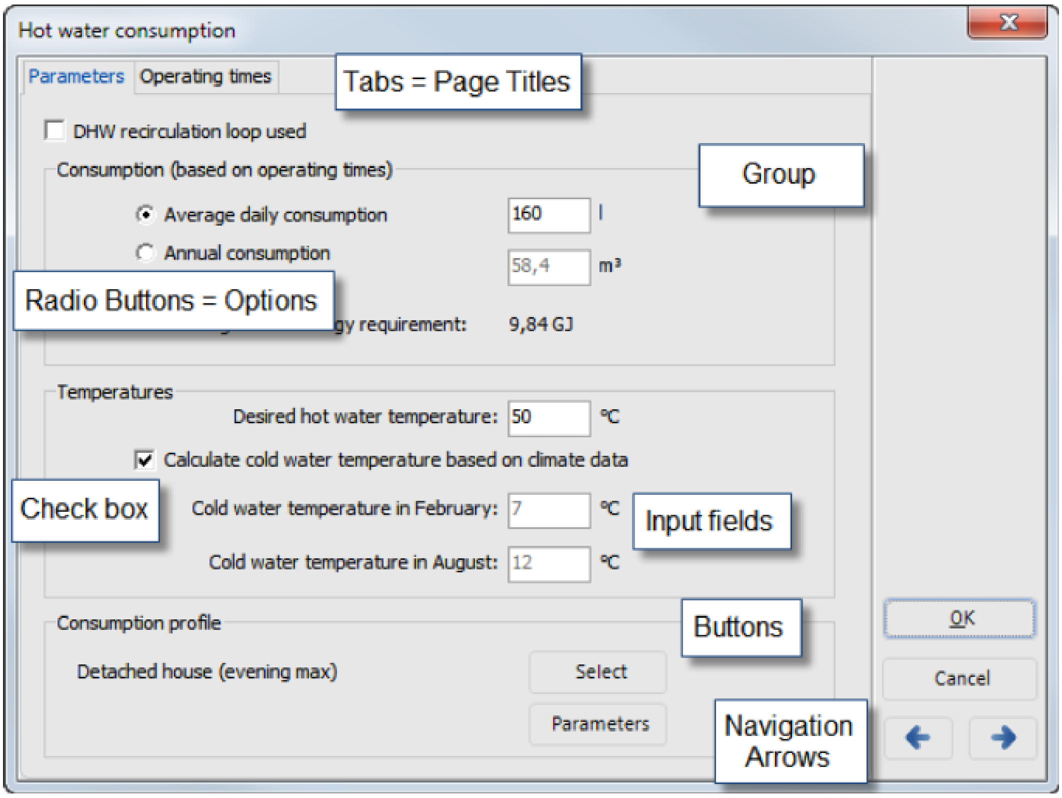

Figure 27: Dialog window-Entry and control elements

5 Analysis of the boundary conditions and district demands

Boundary conditions might be categorized under two groups - environmental requirements and system's requirements. T*SOL program needs inputs about these categories under the following titles. For environmental conditions,

- Total annual global irradiation
- Diffuse radiation percentage
- Mean outside temperature

These also defined the boundary conditions at district level. T*SOL database have also detailed climatic data – solar radiation, sun angle, weather conditions. T*SOL use the METEONORM software to get the weather data for specific locations.

METEONORM version 7.0 contains a database with climatic data from 8,300 stations around the world. The program's algorithms provide to generate hourly values for global radiation, temperature and other meteorological parameters. Users can import their own measurement data or interpolate the meteorological data from the closest known station for any location in the world. These hourly values can be converted for any tilted angle [27].

System requirements specified as;

- Domestic hot water demand
  - Average daily consumption
  - Average number of people living
  - Desired temperature
  - Cold water temperature
- Auxiliary heating system
  - Type
  - Nominal output
- Purpose of the application

Table 3: The boundary conditions for each district

Information For New Project on the T*SOL			
SITE DATA	**For Valladolid**	**For Genoa**	**For Kartal**
Climate			
Location:	Valladolid (Spain)	Italy	Turkey / Istanbul / Kartal
Climate data record:	Valladolid	Genoa	Istanbul / Kartal
Latitude:	41° 37' 58'' N	44° 26' 00'' N	40,89 °
Longitude:	4° 44' 28'' W	8° 48' 00'' E	-29,18 °
Domestic Hot Water			
Average daily consumption [m³]	14,70	40-60	30 m³

Average number of people living	525	270	100 people
Desired temperature [ºC]	60	45	55 °C
Cold water temperature [ºC]	Jan:6 Feb:8 Mar:9 Apr:10 May:12 Jun:15 Jul:18 Aug:18 Sep:16 Oct:12 Nov:9 Dec:7	In between 10-15°	February: 13 °C August: 18 °C
Auxiliary Heating			
Manufacturer	Standard	Standard	Standard
Type	Gas boilers	80% single electric boiler-20% single gas boiler	Gas Fired Boiler
Nominal Output [kW]	13125 kW (525x25 kW)	1000W	1500 KW
Nominal Output [kW]	14000 kW (2x350kW + 1x700kW)	1500W	1500 KW
Purpose			
Purpose	Residential (Private dwellings)	Residential (Private dwellings)	Home (Nursing Home)

For Kartal demosite, there are also two small buildings other than the main building. For these two buildings, package solar water heater system was integrated.

For domestic hot water, water requirement given at the section 2.2.1. For DHW application, design temperatures for each city can be seen on table 1.

Table 4: Design temperatures (target temperatures) of each district

SITE DATA	For Valladolid	For Genoa	For Kartal
Desired temperature [ºC]	60 °C	45 °C	55 °C

5.1 Analysis of the Existing Buildings Thermal Energy Demand For Domestic Hot Water

The criteria for existing building thermal energy demand for domestic hot water for each demo site as they specified at the title 5 are;

- Number of people living in demo sites (Average number of living)
- Location, Latitude and Longitude of demo sites
- Desired Temperatures
- Cold Water Temperatures
- Average daily domestic hot water consumption
- Existing systems and their outputs
- The program used for analysis is T*SOL.

The minimum requirements of the system are typically determined by the amount or temperature of hot water required during winter, when a system's output and incoming water temperature are typically at their lowest. The maximum output temperature of the system must be limited to prevent scalding risk.

Data for analyzing the existing buildings thermal energy demand for domestic hot water for each demo site are given at 5.1.1. for Valladolid, 5.1.2. for Genoa and 5.1.3. for Kartal.

5.1.1 Analysis of the Existing Buildings Thermal Energy Demand for Domestic Hot Water Based On Demo Valladolid Pilot

For Valladolid, Requirements of demand analysis are given. The analysis results of the data will also be provided D2.7.

For Valladolid, two options are given for the auxiliary heater. The first of these, The Project A, Gas condensing boiler (525x25 kW) has nominal output is 13,13 MW. The other, The Project B, Gas condensing boiler (3kW) has nominal output is 1400 kW. On the other hand, other variables such as average daily consumption are the same for Project A and Project B.

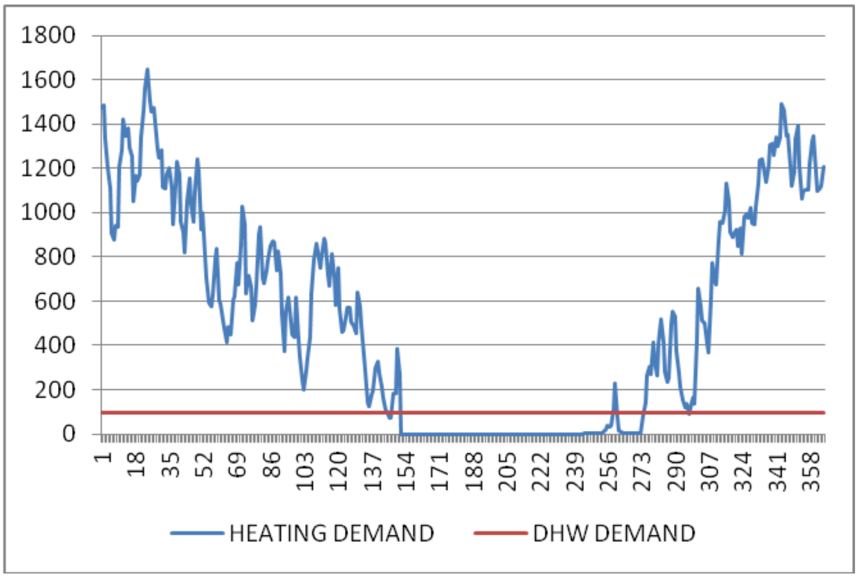

Figure 28: Daily DHW and space heating demand values for Valladolid

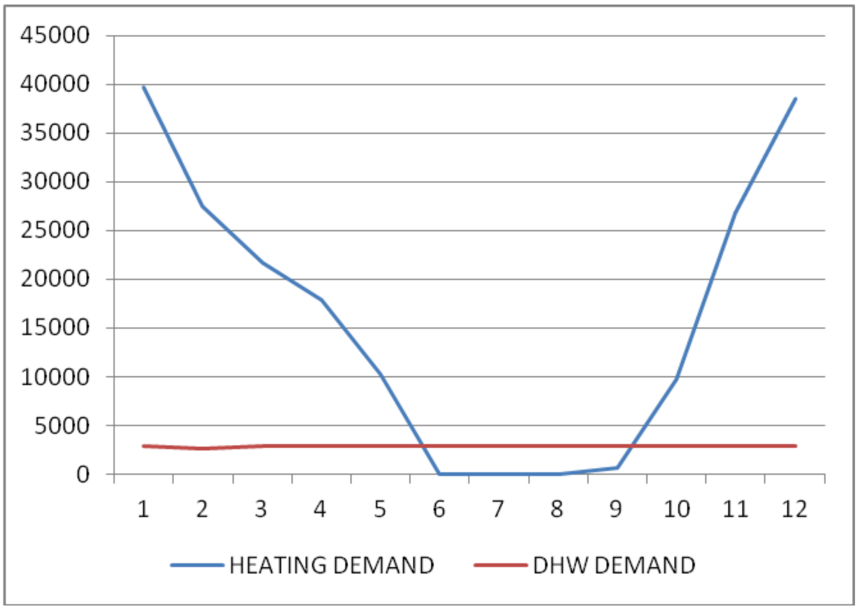

Figure 29: Monthly DHW and space heating demand values for Valladolid

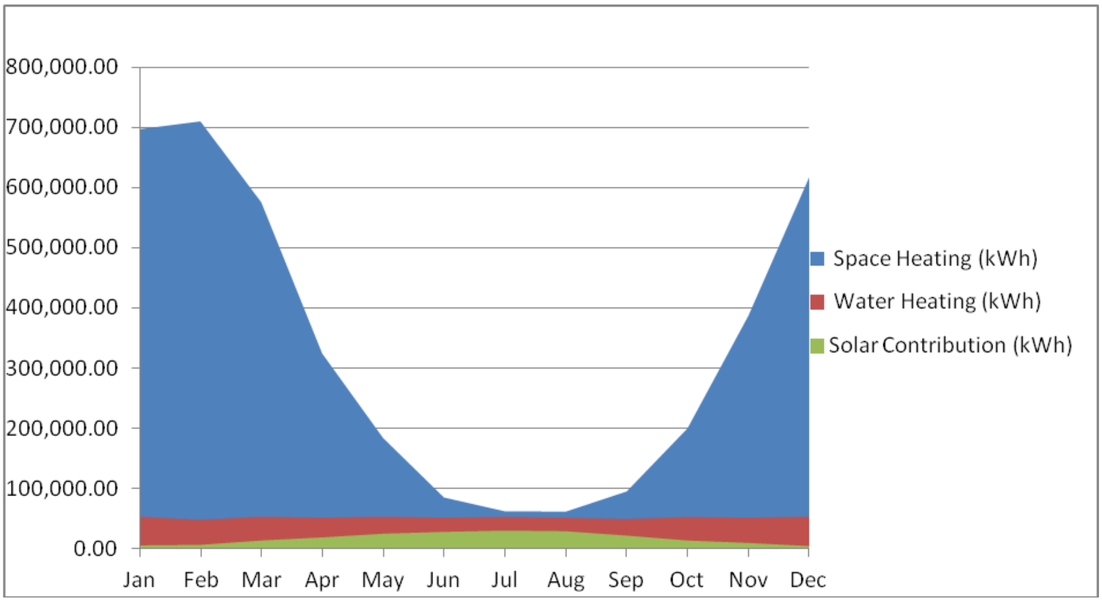

Figure 30: Monthly heating demand and solar contribution values for Valladolid demosite

Valladolid demosite annual energy requirement is analysed, it can be seen that annual space heating energy requirement is equal to 192.480,91 kWh which comes to 192,2kWh/m^2 and water heating energy demand is 34.339,20 kWh which comes to 34,3kWh/m^2 for one unit where is selected as a case study building.

SITE DATA	

Climate file	
Location:	Valladolid (Spain)
Climate data record:	Valladolid (Spain)
Total annual global irradiation:	1642,701 kWh/m²
Latitude:	41,38 °
Longitude:	4,44 °

Domestic hot water		
Average daily consumption:	14,7 m³	
Desired temperature:	60 °C	
Consumption profile:	Multi-family dwelling	
Cold water temperature:	February: 7 °C	August: 18 °C
Circulation:	Yes	

Option 1

System Definition

System	
Collector loop	
Manufacturer:	Ezinc
Type:	Superline L USB PU
Number:	114
Total gross surface area:	259,92 m²
Total active solar surface area:	246,24 m²
Tilt angle:	40 °
Collector Orientation:	180 °
Azimuth:	0 °
Dual coil indirect hot water tank	
Manufacturer:	Standard
Type:	5 x Dual coil indirect hot water tank
Volume:	5 x 3000 l
Auxiliary heating	
Manufacturer:	Standard
Type:	Gas condensing boiler(525x25 kW)
Nominal output:	13,13 MW
Legend	
With test report	
Solar Keymark	

Climate	

Data record:	Valladolid (Spain)
Location:	Valladolid (Spain)
Latitude:	41,38 °
Longitude:	4,44 °
Total annual global irradiation:	1642,701 kWh/m²
Diffuse radiation percentage:	43,38%
Mean outside temperature:	12,52 °C
Hot water consumption	
DHW consumption:	
Average daily consumption:	14,7 m³
Annual consumption:	5365,5 m³
Max daily consumption:	17,56 m³

Hot water consumption	
DHW consumption:	
Desired temperature:	60 °C
Cold water temperature:	7 °C / 18 °C
Annual energy requirement:	295,92 MWh
Days in operation:	365 Days
Not operating:	-No limitation-
Circulation:	
One-way length of piping system:	100 m
Temperature difference - supply/return:	3 K
Specific losses:	0,3 W/(m·K)
Annual losses (estimated):	13,49 MWh
Daily operating times:	6 : 00 - 22 : 00
Consumption profile	
Profile:	Multi-family dwelling

Option 2

Auxiliary heating

System Definition

System	
Collector loop	
Manufacturer:	Ezinc
Type:	Superline L USB PU
Number:	114
Total gross surface area:	259,92 m²
Total active solar surface area:	246,24 m²

Tilt angle:	40 °
Collector Orientation:	180 °
Azimuth:	0 °
Dual coil indirect hot water tank	
Manufacturer:	Standard
Type:	5 x Dual coil indirect hot water tank
Volume:	5 x 3000 l
Auxiliary heating	
Manufacturer:	Standard
Type:	**Gas condensing boiler(2x350 kW +1x700 kW)**
Nominal output:	1400 kW
Legend	
With test report	
Solar Keymark	

5.1.1.1 System Configuration Based on the Calculated System Demand

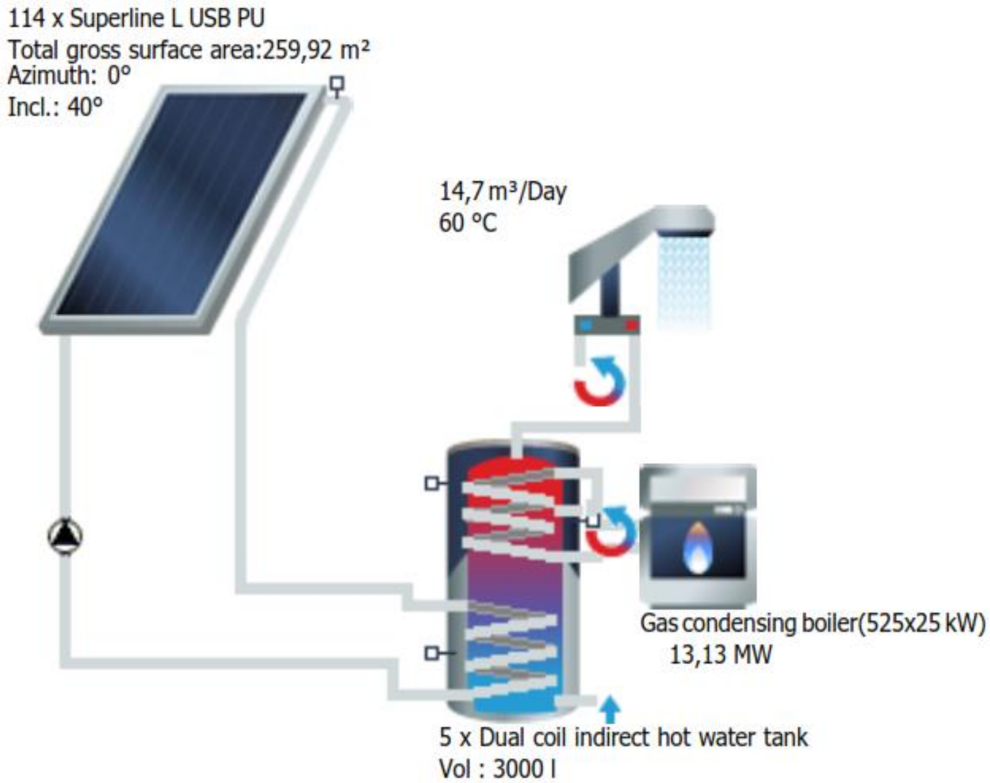

Figure 31: System configuration for Valladolid

5.1.2 Analysis of the Existing Buildings Thermal Energy Demand for Domestic Hot Water Based On Genoa Pilot

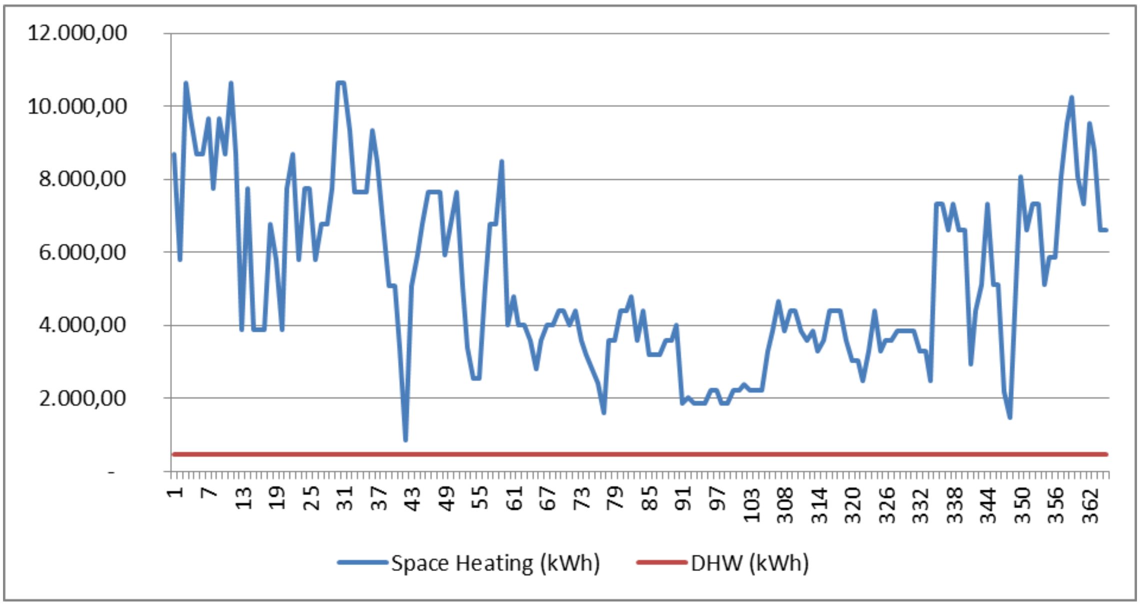

Figure 32: Daily DHW and space heating demand for Genoa

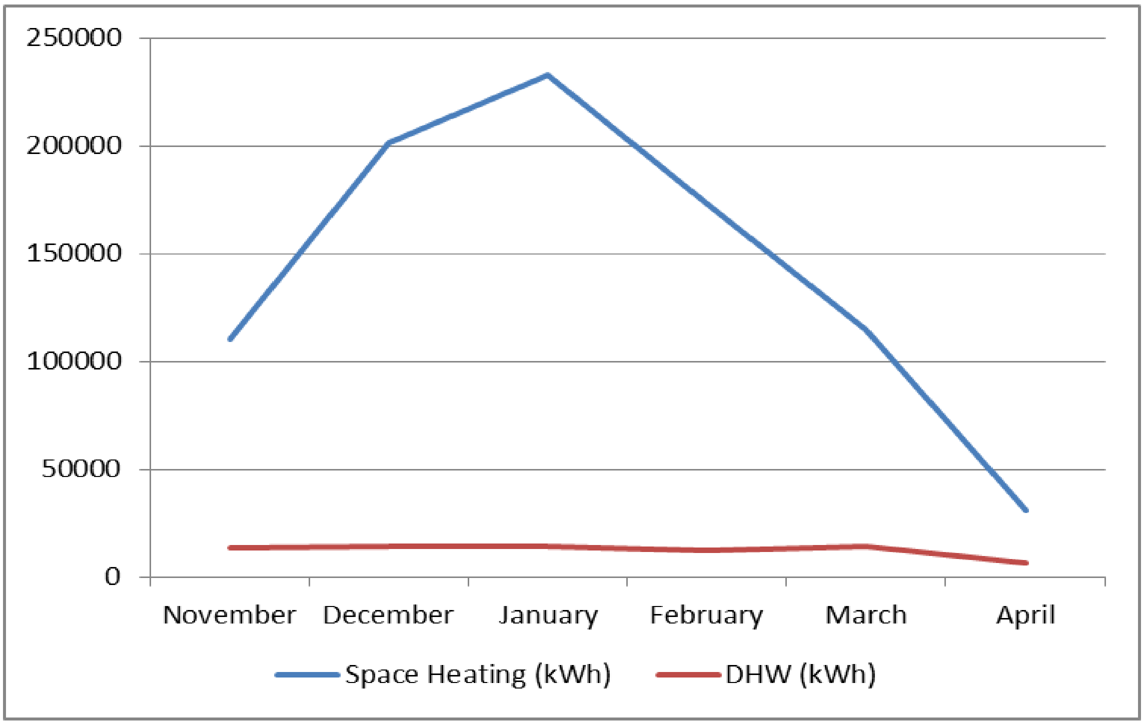

Figure 33: Monthly DHW and space heating demand for Genoa

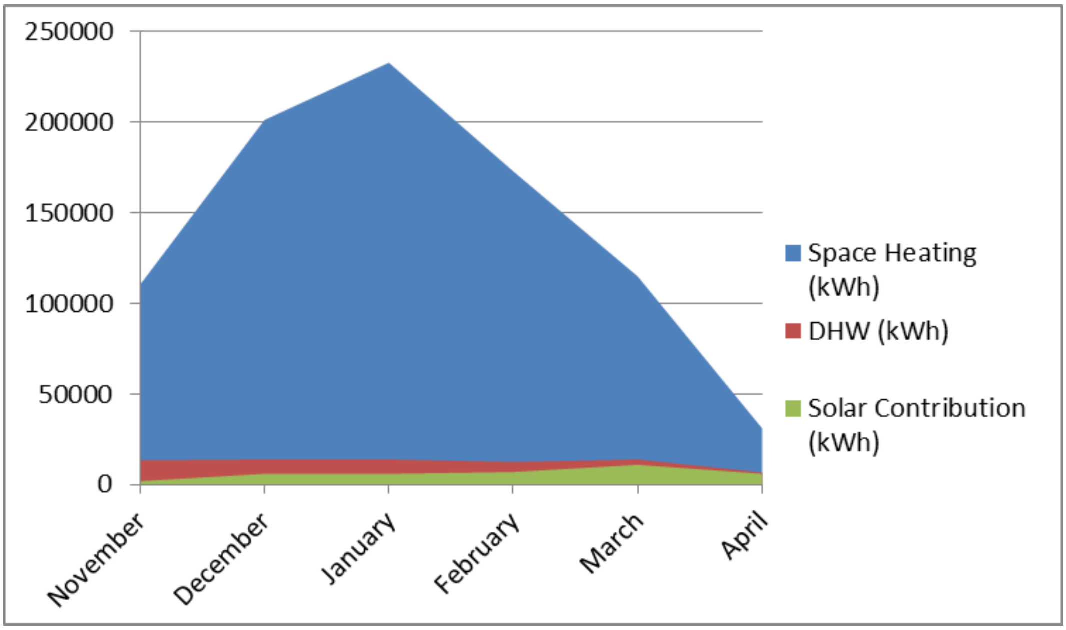

Figure 34: Monthly heating demand and solar contribution values for Genoa demosite

Genoa demosite was provided monitored monthly energy demand for 6 months (January February, March, April, November and December) between 2013 and 2014. Information about summer months are not provided and accordingly not included in graphics. The results can be seen in Figure 34 and when total energy demand is examined, it can be seen that space heating energy requirement is equal to 863662kWh which comes to 103,4kWh/m^{2}and water heating energy demand is 74867kWh which comes to 8,9kWh/m^2 for two buildings.

SITE DATA	
Climate file	
Location:	Genoa (UNI 10349)
Climate data record:	Genoa (UNI 10349)
Total annual global irradiation:	398,996 kWh/m²
Latitude:	44,42 °
Longitude:	-8,88 °

Domestic hot water		
Average daily consumption:	16,2 m³	
Desired temperature:	45 °C	
Consumption profile:	Multi-family dwelling	
Cold water temperature:	February: 13 °C	August: 18 °C
Circulation:	Yes	

5.1.2.1 System Definition

System	
Collector loop	
Manufacturer:	Ezinc
Type:	Superline L USB PU
Number:	123
Total gross surface area:	280,44 m²
Total active solar surface area:	265,68 m²
Tilt angle:	40 °
Collector Orientation:	180 °
Azimuth:	0 °
Dual coil indirect hot water tank	
Manufacturer:	Standard
Type:	5 x Dual coil indirect hot water tank
Volume:	5 x 3000 l
Auxiliary heating	
Manufacturer:	Standard
Type:	Continuous-flow water heater
Nominal output:	540 kW
Legend	
With test report	
Solar Keymark	

Climate	
Data record:	Genoa (UNI 10349)
Location:	Genoa (UNI 10349)
Latitude:	44,41 °
Longitude:	-8,88 °
Total annual global irradiation:	1398,996 kWh/m²
Diffuse radiation percentage:	46,94 %
Mean outside temperature:	15,81 °C
Hot water consumption	
DHW consumption:	
Average daily consumption:	16,2 m³
Annual consumption:	5913 m³
Max daily consumption:	19,35 m³

Hot water consumption	
DHW consumption:	
Desired temperature:	45 °C
Cold water temperature:	13 °C / 18 °C
Annual energy requirement:	202,54 MWh
Days in operation:	365 Days
Not operating:	-No limitation-
Circulation:	
One-way length of piping system:	100 m
Temperature difference - supply/return:	3 K
Specific losses:	0,3 W/(m·K)
Annual losses (estimated):	8,23 MWh
Daily operating times:	6 : 00 - 22 : 00
Consumption profile	
Profile:	Multi-family dwelling

5.1.3 Analysis of the Existing Buildings Thermal Energy Demand for Domestic Hot Water Based On Demo Kartal Pilot

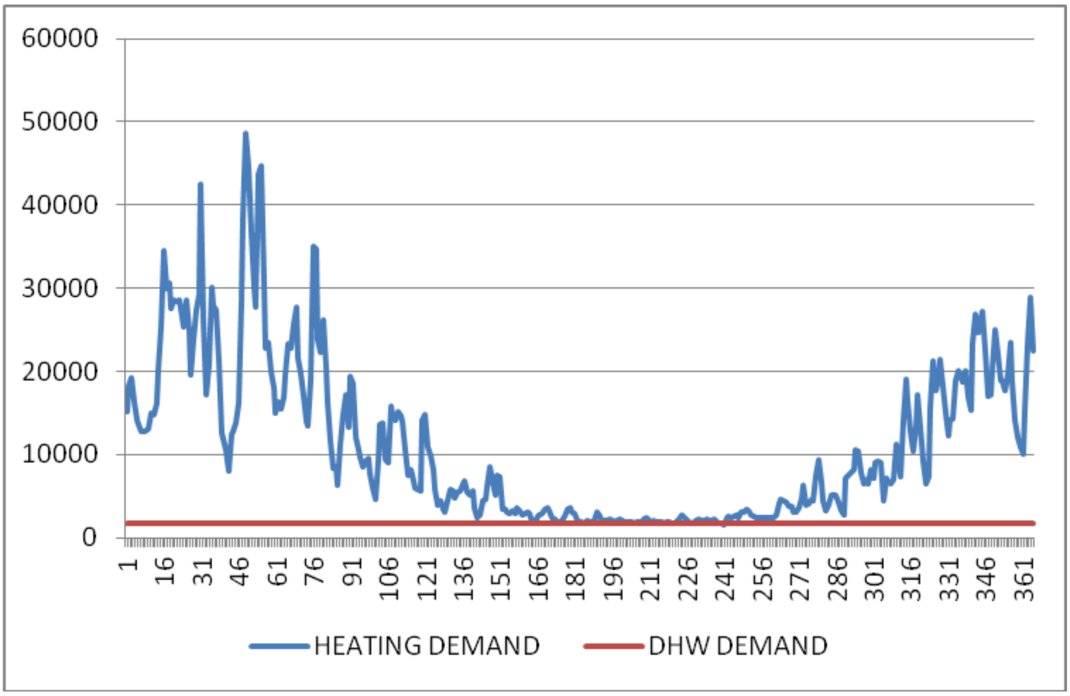

Figure 35: Daily DHW and space heating demand for Kartal

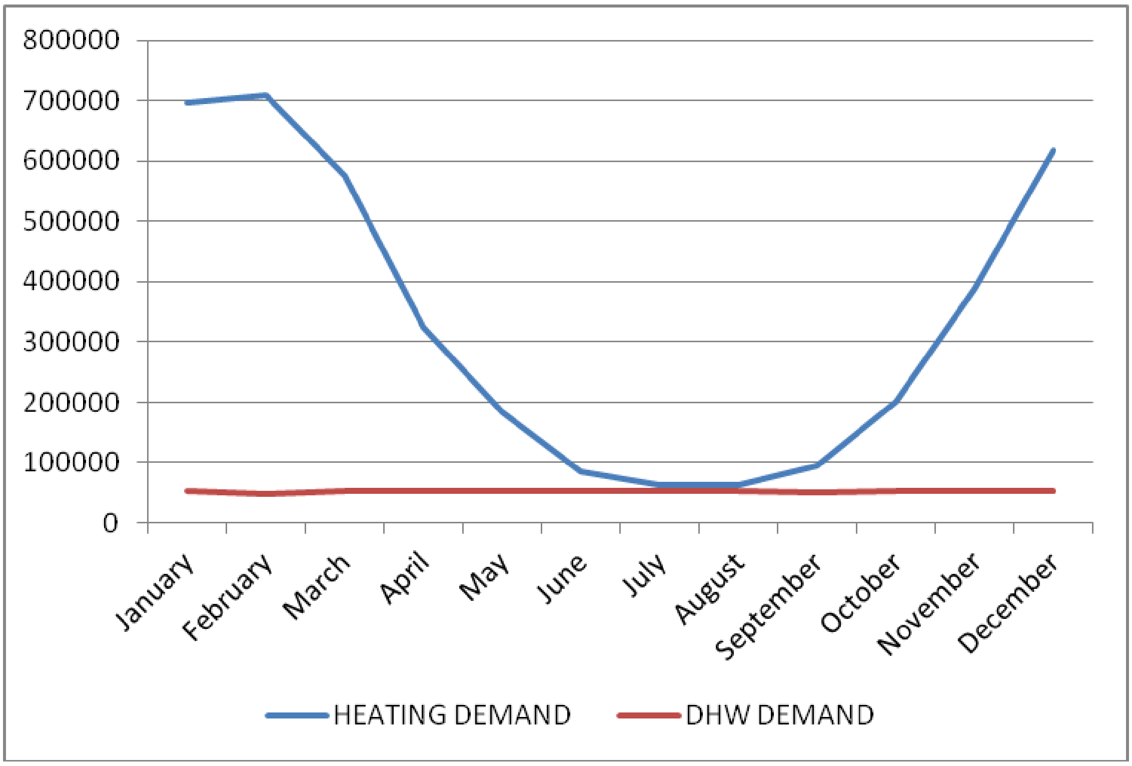

Figure 36: Monthly DHW and space heating demand for Kartal

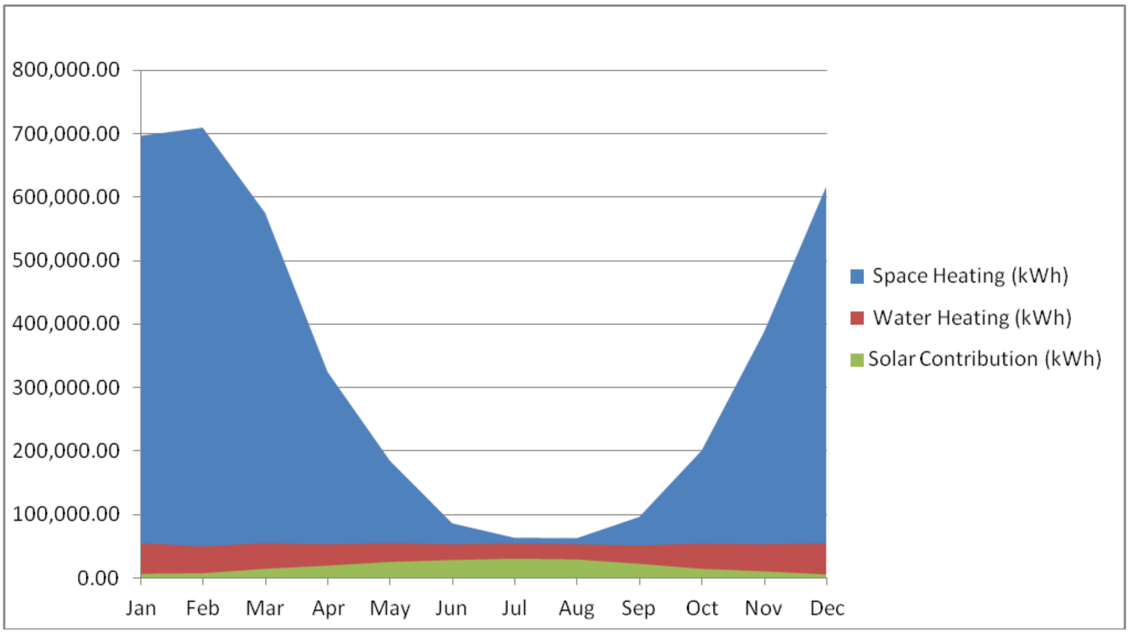

Figure 37: Monthly heating demand and solar contribution values for Kartal demosite

Kartal demosite monthly energy requirement can be seen in Figure 37 and when annual energy demand is examined, it can be seen that space heating energy requirement is equal to 4.002.040,59 kWh which comes to 221kWh/m^2 and water heating energy demand is

631.175,64 kWh which comes to 34,9kWh/m^2 for the elderly building which has 18108m^2 total area.

Analysis of the data has been entered for the nursing home.

SITE DATA	
Climate file	
Location:	Würzburg Climate
data record:	Istanbul / Kartal Total
annual global irradiation:	1447,686 kWh/m^2
Latitude:	40,89 °
Longitude:	-29,18 °

Domestic Hot Water	
Average daily consumption:	30 m^3
Desired temperature:	55 °C
Consumption profile:	Constant load
Cold water temperature:	February: 13 °C August: 18 °C
Circulation:	Yes

5.1.3.1 System Definition

System	
Collector loop	
Manufacturer:	Ezinc
Type:	Superline L USB PU
Number:	200
Total gross surface area:	456 m^2
Total active solar surface area:	432 m^2
Tilt angle:	30 °
Collector Orientation:	180 °
Azimuth:	0 °
Dual coil indirect hot water tank	
Manufacturer:	Standard
Type:	10 x Dual coil indirect hot water tank
Volume:	10 x 2000 l
Auxiliary heating	
Manufacturer:	Standard
Type:	Gas fired boiler
Nominal output:	1500 kW
Legend	
With test report	

Solar Keymark	

Climate	
Data record:	İstanbul / Kartal
Location:	İstanbul / Kartal
Latitude:	40,89 °
Longitude:	-29,18°
Total annual global irradiation:	1447,686 kWh/m²
Diffuse radiation percentage:	47,45%
Mean outside temperature:	15,37 °C
Hot water consumption	
DHW consumption:	
Average daily consumption:	30 m³
Annual consumption:	10950 m³
Max daily consumption:	30 m³

Hot water consumption	
DHW consumption:	
Desired temperature:	55 °C
Cold water temperature:	13 °C / 18 °C
Annual energy requirement:	502,21 MWh
Days in operation:	365 Days
Not operating:	-No limitation-
Circulation:	
One-way length of piping system:	100 m
Temperature difference - supply/return:	3 K
Specific losses:	0,3 W/(m·K)
Annual losses (estimated):	11,74 MWh
Daily operating times:	6 : 00 - 22 : 00
Consumption profile	
Profile:	Constant Load

5.1.3.2 The solar thermal system for the two apartment buildings in Kartal

The solar thermal system can provide hot water for four seasons and all day with electrical support heater. Ezinc thermosyphon system has two different types. These are;

Open-loop system (direct system without heat exchanger)

This system is developed for warm countries where do not have freezing risk or corrosion risk. Cold water moves to open loop tank directly, and then moves into solar collector to be heated. Heated water moves back to tank for storing.

Closed-loop system (indirect system with heat exchanger)

There is an external heat exchanger surrounding the DHW tank. Heated fluid inside the solar collector rises and moves into the heat exchanger and fluid gives heat to the DHW tank and cooled fluid returns back to the solar collector. Then cold water, which is used by households, is heated by the heat exchanger in the tank. Ezinc thermosyphon systems are consisting of;

- Ezinc solar collectors in suitable type and size
- Ezinc enamelled hot water storage tank
- Suitable support base for every type of roof
- All necessary fittings and accessories

6 Efficiency and Cost Analysis

In sunny, warm locations, where freeze protection is not necessary, an ICS (batch type) solar water heater can be extremely cost effective [28]. In higher latitudes, there are often additional design requirements for cold weather, which add to system complexity. This has the effect of increasing the initial cost (but not the life-cycle cost) of a solar water heating system, to a level much higher than a comparable water heater of the conventional type. The biggest single consideration is therefore the large initial financial outlay of solar water heating systems [29]. Offsetting this expense can take several years and the payback period is longer in temperate environments where the insolation is less intense [30] [31]. When calculating the total cost to own and operate, a proper analysis will consider that solar energy is free, thus greatly reducing the operating costs, whereas other energy sources, such as gas and electricity, can be quite expensive over time. Thus, when the initial costs of a solar system are properly financed and compared with energy costs, then in many cases the total monthly cost of solar heat can be less than other more conventional types of water heaters (also in conjunction with an existing water heater). At higher latitudes, solar heaters may be less effective due to lower solar energy, possibly requiring larger and/or dual-heating systems [31].

The calculation of long term cost and payback period for a household SWH system depends on a number of factors. Some of these are:

- Price of purchasing solar water heater (more complex systems are more expensive)
- Efficiency of SWH system purchased
- Installation cost
- Price of electricity use for mains pumping (if this is used)
- Price of water heating fuel (e.g. gas or electricity) saved per kW.h
- Amount of water heating fuel used per month by a household
- Upfront state or government subsidy for installation of a solar water heater
- Recurrent or annual tax rebates or subsidy for operating renewable energy
- Annual maintenance cost of SWH system (e.g. antifreeze or pump replacements)
- Savings in annual maintenance of conventional (electric/gas/oil) water heating system [25]

The calculation is based on the balance of energy flows and supplies yield prognoses with the help of meteorological data input hourly. T*SOL calculates the energy produced by the solar system for hot water production and heating as well as the corresponding solar fractions. The results are saved and can be presented as detailed documentation or as a clearly-arranged presentation. Additionally, graphs can show the course of energy and other values, over any given period. They can be saved as a table in text format and copied from the clipboard into other programs.

After running a simulation for a period of one year, an economic efficiency calculation can be run for the current variant. Taking into account the system costs and subsidies, the economic efficiency parameters, e.g. capital value, annuities and cost of heating are calculated and presented in a report.

The simulations of the systems are made based on assumptions. Therefore, to calculate the exact cost, real application of solar thermal system must be finished in demo-sites. The results will be updated at this stage. The system efficiency and other related results of the demosite will also be provided at D2.7.

7 Conclusions and Recommendations

The report aims to give a clear profile of thermal energy demand of residential buildings based on the indoor heating and DHW applications. Specific attention is given to system design requirements to match the building indoor heating and DHW needs and solar thermal system capacity. Calculation method, targeted temperature and boundary condition at the building and district level as well as barriers of system applications are identified for the three demo sites of R2CITIES project: Valladolid, Genoa and Kartal.

Based on many researches that are referred in this work most of the barriers in solar thermal applications are basically related to market barriers not related to unmatched building demand or solar thermal system production.

The solar thermal energy demand calculation for three demo sites is prepared by T*SOL software to get the energy produced by the solar system for the building indoor heating and DHW as well as the corresponding solar fractions.

According to the analyses carried out, common results for three demo sites are compared in below.

Specific results are for,

- Cuatro de Marzo district:

For Valladolid district, annual water heating energy demand is 34,3kWh/m^2 and space heating energy requirement is 192,2kWh/m^2. Hot water contribution from solar thermal system is 44, 2% of total hot water energy requirement. When it comes to the barriers, specific barriers are lack of interest by client/developer and architect, solar thermal integration in the architectural design process after project design is done and lack of suitable product. According to the section 2.4 and Figure 10, total installed capacities of each demosite are examined and it can be seen that Spain is 12th country in the world with 1823MW capacity. When three demosites are compared, total installed capacity of Spain is 13% lower from Italy and 18% lower than Turkey.

- Pegli 3 district:

For Genoa district, 6 months (November, December, January, February, March, April and May) water heating energy demand is 8,9kWh/m^2 and space heating energy requirement is 103,4kWh/m^2. Hot water contribution from solar thermal system is 55,4 % of total hot water requirement. When it comes to the barriers, specific barriers are lack of interest by clients/developers and architects, lack of information on incentives and lack of suitable product. In section 2.4 at Figure 10, total installed capacities of each demosite are examined and it can be seen that Italy is 10th country with 2065MW capacity in the world. When three demosites are compared according to the installed capacity, total installed capacity of Italy is 13% higher from Spain and 20% lower than Turkey.

- Kartal Yakacik district:

For Kartal district, annual water heating energy demand is 34,9kWh/m^2 and space heating energy requirement is 221kWh/m^2. Hot water contribution from solar thermal system is 39,6% of total hot water requirement. The amount of application of solar thermal compare to other renewable technology in Turkey as well other countries are much higher. As it mentioned in section 2.4 at Figure 10, total installed capacity is 6 times higher from Spain and is 5 times higher from Italy. When it comes to the barriers for Turkey, the biggest barrier is lack of government incentives, lack of knowledge by client/developer and solar thermal integration in the architectural design process after project design is done.

After running a simulation for a period of one year, an economic efficiency calculation can be run for the current modification. Taking into account the system costs and subsidies, the economic efficiency parameters, capital value, annuities and cost of heating will be calculated and presented in D2.7.

The exact location, the size and the estimated costs of the solar thermal system will be provided only during the finalization of the design stage. Many assumptions are taken to due to the early stage of project development. Therefore, results that presented in this report can be subjected to modifications according to further updated analyses and decisions.

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9 Appendix

9.1 DHW and Space heating demand for Valladolid

Table 5: Monthly DHW and space heating demand values for Valladolid

	HEATING DEMAND	DHW DEMAND
January	39.667,84	2.916,48
February	27.464,05	2.634,24
March	21.696,66	2.916,48
April	17.808,15	2.822,40
May	10.255,06	2.916,48
June	-	2.822,40
July	-	2.916,48
August	-	2.916,48
September	630,93	2.822,40
October	9.718,04	2.916,48
November	26.752,94	2.822,40
December	38.487,24	2.916,48

Table 6: Daily DHW and space heating demand values for Valladolid

Month	Day	HEATING DEMAND	DHW DEMAND
January	**1**	1.475,07	94,08
January	**2**	1.486,42	94,08
	3	1.334,77	94,08
	4	1.198,82	94,08
	5	1.110,54	94,08
	6	908,07	94,08
	7	877,85	94,08
	8	941,41	94,08
	9	936,59	94,08
	10	1.209,58	94,08
	11	1.282,43	94,08
	12	1.424,29	94,08
	13	1.347,87	94,08
	14	1.378,54	94,08
	15	1.292,62	94,08
	16	1.253,56	94,08
	17	1.050,63	94,08
	18	1.166,94	94,08
	19	1.146,47	94,08
	20	1.172,92	94,08

	21	1.342,45	94,08
	22	1.464,74	94,08
	23	1.561,64	94,08
	24	1.645,05	94,08
	25	1.504,54	94,08
	26	1.458,85	94,08
	27	1.473,55	94,08
	28	1.408,81	94,08
	29	1.281,79	94,08
	30	1.249,21	94,08
	31	1.281,80	94,08
	32	1.113,41	94,08
February	**33**	1.110,67	94,08
	34	1.174,53	94,08
	35	1.202,99	94,08
	36	1.113,92	94,08
	37	946,65	94,08
	38	1.124,65	94,08
	39	1.227,92	94,08
	40	1.172,63	94,08
	41	959,45	94,08
	42	910,34	94,08
	43	821,18	94,08
	44	1.052,39	94,08
	45	1.155,61	94,08
	46	1.038,51	94,08
	47	960,63	94,08
	48	1.091,85	94,08
	49	1.240,22	94,08
	50	1.190,72	94,08
	51	921,06	94,08
	52	997,85	94,08
	53	804,81	94,08
	54	702,25	94,08
	55	594,23	94,08
	56	576,05	94,08
	57	630,46	94,08
	58	789,98	94,08
	59	839,12	94,08
	60	604,91	94,08
March	**61**	585,97	94,08
	62	515,38	94,08

	63	480,06	94,08
	64	414,36	94,08
	65	483,00	94,08
	66	447,83	94,08
	67	604,32	94,08
	68	624,18	94,08
	69	775,48	94,08
	70	673,27	94,08
	71	851,73	94,08
	72	1.027,23	94,08
	73	946,51	94,08
	74	635,46	94,08
	75	713,14	94,08
	76	662,91	94,08
	77	511,82	94,08
	78	580,26	94,08
	79	668,56	94,08
	80	898,97	94,08
	81	936,57	94,08
	82	702,07	94,08
	83	680,87	94,08
	84	738,05	94,08
	85	782,07	94,08
	86	851,32	94,08
	87	873,92	94,08
	88	863,61	94,08
	89	738,94	94,08
	90	823,89	94,08
	91	724,21	94,08
April	**92**	542,08	94,08
	93	376,72	94,08
	94	552,49	94,08
	95	619,76	94,08
	96	564,56	94,08
	97	447,73	94,08
	98	438,95	94,08
	99	614,56	94,08
	100	426,60	94,08
	101	346,99	94,08
	102	239,12	94,08
	103	198,70	94,08
	104	287,45	94,08

	105	347,02	94,08
	106	434,97	94,08
	107	634,97	94,08
	108	790,07	94,08
	109	859,64	94,08
	110	828,25	94,08
	111	747,36	94,08
	112	802,10	94,08
	113	882,05	94,08
	114	857,31	94,08
	115	715,15	94,08
	116	671,12	94,08
	117	815,26	94,08
	118	707,14	94,08
	119	584,68	94,08
	120	751,14	94,08
	121	565,79	94,08
May	**122**	460,09	94,08
	123	464,39	94,08
	124	530,53	94,08
	125	573,04	94,08
	126	570,45	94,08
	127	507,81	94,08
	128	488,71	94,08
	129	456,29	94,08
	130	639,09	94,08
	131	575,29	94,08
	132	490,81	94,08
	133	353,76	94,08
	134	285,62	94,08
	135	144,15	94,08
	136	125,84	94,08
	137	176,00	94,08
	138	192,77	94,08
	139	296,21	94,08
	140	327,57	94,08
	141	277,15	94,08
	142	209,92	94,08
	143	165,27	94,08
	144	105,77	94,08
	145	103,63	94,08
	146	75,70	94,08

	147	75,69	94,08
	148	180,05	94,08
	149	180,63	94,08
	150	385,54	94,08
	151	271,52	94,08
	152	-	94,08
June	**153**	-	94,08
	154	-	94,08
	155	-	94,08
	156	-	94,08
	157	-	94,08
	158	-	94,08
	159	-	94,08
	160	-	94,08
	161	-	94,08
	162	-	94,08
	163	-	94,08
	164	-	94,08
	165	-	94,08
	166	-	94,08
	167	-	94,08
	168	-	94,08
	169	-	94,08
	170	-	94,08
	171	-	94,08
	172	-	94,08
	173	-	94,08
	174	-	94,08
	175	-	94,08
	176	-	94,08
	177	-	94,08
	178	-	94,08
	179	-	94,08
	180	-	94,08
	181	-	94,08
	182	-	94,08
July	**183**	-	94,08
	184	-	94,08
	185	-	94,08
	186	-	94,08
	187	-	94,08
	188	-	94,08

	189	-	94,08
	190	-	94,08
	191	-	94,08
	192	-	94,08
	193	-	94,08
	194	-	94,08
	195	-	94,08
	196	-	94,08
	197	-	94,08
	198	-	94,08
	199	-	94,08
	200	-	94,08
	201	-	94,08
	202	-	94,08
	203	-	94,08
	204	-	94,08
	205	-	94,08
	206	-	94,08
	207	-	94,08
	208	-	94,08
	209	-	94,08
	210	-	94,08
	211	-	94,08
	212	-	94,08
	213	-	94,08
August	**214**	-	94,08
	215	-	94,08
	216	-	94,08
	217	-	94,08
	218	-	94,08
	219	-	94,08
	220	-	94,08
	221	-	94,08
	222	-	94,08
	223	-	94,08
	224	-	94,08
	225	-	94,08
	226	-	94,08
	227	-	94,08
	228	-	94,08
	229	-	94,08
	230	-	94,08

	231	-	94,08
	232	-	94,08
	233	-	94,08
	234	-	94,08
	235	-	94,08
	236	-	94,08
	237	-	94,08
	238	-	94,08
	239	-	94,08
	240	-	94,08
	241	-	94,08
	242	-	94,08
	243	-	94,08
	244	5,88	94,08
September	**245**	5,07	94,08
	246	5,22	94,08
	247	2,69	94,08
	248	1,66	94,08
	249	1,97	94,08
	250	1,11	94,08
	251	1,46	94,08
	252	1,11	94,08
	253	2,37	94,08
	254	9,57	94,08
	255	20,47	94,08
	256	38,79	94,08
	257	30,93	94,08
	258	36,69	94,08
	259	113,25	94,08
	260	230,61	94,08
	261	71,89	94,08
	262	16,19	94,08
	263	7,37	94,08
	264	3,28	94,08
	265	1,89	94,08
	266	0,55	94,08
	267	0,73	94,08
	268	1,24	94,08
	269	5,85	94,08
	270	3,60	94,08
	271	5,76	94,08
	272	1,53	94,08

	273	2,20	94,08
	274	83,81	94,08
October	**275**	144,89	94,08
	276	264,33	94,08
	277	304,20	94,08
	278	268,08	94,08
	279	416,58	94,08
	280	327,63	94,08
	281	264,04	94,08
	282	409,91	94,08
	283	520,04	94,08
	284	413,73	94,08
	285	283,20	94,08
	286	232,20	94,08
	287	253,88	94,08
	288	493,99	94,08
	289	552,89	94,08
	290	531,27	94,08
	291	374,11	94,08
	292	276,34	94,08
	293	210,50	94,08
	294	155,82	94,08
	295	121,43	94,08
	296	138,97	94,08
	297	89,16	94,08
	298	119,21	94,08
	299	167,18	94,08
	300	133,68	94,08
	301	420,53	94,08
	302	657,33	94,08
	303	574,28	94,08
	304	514,85	94,08
	305	502,71	94,08
November	**306**	410,47	94,08
	307	369,10	94,08
	308	611,92	94,08
	309	773,87	94,08
	310	690,26	94,08
	311	677,28	94,08
	312	875,25	94,08
	313	960,31	94,08
	314	954,89	94,08

	315	1.008,53	94,08
	316	1.129,58	94,08
	317	1.051,17	94,08
	318	912,09	94,08
	319	887,78	94,08
	320	907,86	94,08
	321	924,10	94,08
	322	847,49	94,08
	323	931,79	94,08
	324	812,09	94,08
	325	980,30	94,08
	326	994,17	94,08
	327	978,39	94,08
	328	1.022,23	94,08
	329	954,34	94,08
	330	949,76	94,08
	331	1.028,48	94,08
	332	1.133,09	94,08
	333	1.233,77	94,08
	334	1.239,89	94,08
	335	1.208,72	94,08
December	**336**	1.140,14	94,08
	337	1.204,94	94,08
	338	1.306,18	94,08
	339	1.312,61	94,08
	340	1.257,67	94,08
	341	1.339,20	94,08
	342	1.300,39	94,08
	343	1.340,40	94,08
	344	1.489,12	94,08
	345	1.459,70	94,08
	346	1.345,16	94,08
	347	1.353,23	94,08
	348	1.207,49	94,08
	349	1.120,75	94,08
	350	1.185,50	94,08
	351	1.335,58	94,08
	352	1.395,17	94,08
	353	1.215,49	94,08
	354	1.062,85	94,08
	355	1.097,85	94,08
	356	1.102,14	94,08

	357	1.105,10	94,08
	358	1.216,17	94,08
	359	1.323,64	94,08
	360	1.347,30	94,08
	361	1.180,31	94,08
	362	1.095,72	94,08
	363	1.106,89	94,08
	364	1.122,21	94,08
	365	1.209,64	94,08

9.2 DHW and Space heating demand for Kartal

Table 7: Monthly DHW and space heating demand values for Kartal

	HEATING DEMAND [kWh]	DHW DEMAND [kWh]
January	696.874,20	53.966,69
February	709.779,28	48.980,64
March	575.449,15	53.966,69
April	324.680,02	52.206,91
May	184.483,95	53.966,69
June	85.642,79	52.206,91
July	62.765,61	53.673,39
August	62.179,01	52.206,91
September	95.614,89	50.447,12
October	200.322,00	53.380,09
November	387.152,33	52.206,91
December	617.097,36	53.966,69

Table 8: Daily DHW and space heating demand values for Kartal

Month	Day	HEATING DEMAND [kW]	DHW DEMAND [kW]
	1	15.077,64	1.743,61
January	**2**	18.187,56	1.743,61
	3	19.149,69	1.743,61
	4	16.254,87	1.743,61
	5	14.082,62	1.743,61
	6	13.654,51	1.743,61

	7	12.780,34	1.743,61
	8	12.829,71	1.743,61
	9	12.921,29	1.743,61
	10	13.180,03	1.743,61
	11	14.962,51	1.743,61
	12	14.846,15	1.743,61
	13	16.164,82	1.743,61
	14	20.066,90	1.743,61
	15	25.290,32	1.743,61
	16	34.576,06	1.743,61
	17	29.906,91	1.743,61
	18	30.588,26	1.743,61
	19	27.508,29	1.743,61
	20	28.544,11	1.743,61
	21	28.349,91	1.743,61
	22	28.651,66	1.743,61
	23	27.565,07	1.743,61
	24	25.313,65	1.743,61
	25	28.570,89	1.743,61
	26	24.827,94	1.743,61
	27	19.516,95	1.743,61
	28	23.806,89	1.743,61
	29	27.391,98	1.743,61
	30	29.333,61	1.743,61
	31	42.563,39	1.743,61
	32	26.343,25	1.743,61
February	**33**	17.242,65	1.743,61
	34	20.811,00	1.743,61
	35	30.071,09	1.743,61
	36	27.934,92	1.743,61
	37	27.411,97	1.743,61
	38	21.312,87	1.743,61
	39	12.592,81	1.743,61
	40	11.934,54	1.743,61
	41	10.540,63	1.743,61
	42	7.959,89	1.743,61
	43	12.467,13	1.743,61
	44	12.678,19	1.743,61
	45	13.744,93	1.743,61
	46	16.101,51	1.743,61
	47	28.485,00	1.743,61
	48	38.474,14	1.743,61

	49	48.611,62	1.743,61
	50	44.603,92	1.743,61
	51	36.723,80	1.743,61
	52	29.971,66	1.743,61
	53	27.798,14	1.743,61
	54	43.656,52	1.743,61
	55	44.739,26	1.743,61
	56	30.703,45	1.743,61
	57	22.841,05	1.743,61
	58	23.399,40	1.743,61
	59	19.966,21	1.743,61
	60	18.036,83	1.743,61
March	**61**	14.985,89	1.743,61
	62	16.338,33	1.743,61
	63	15.557,58	1.743,61
	64	16.768,66	1.743,61
	65	19.485,44	1.743,61
	66	23.331,28	1.743,61
	67	22.731,54	1.743,61
	68	25.665,57	1.743,61
	69	27.753,29	1.743,61
	70	21.526,67	1.743,61
	71	19.705,60	1.743,61
	72	17.003,41	1.743,61
	73	14.022,23	1.743,61
	74	13.461,28	1.743,61
	75	18.949,21	1.743,61
	76	35.015,92	1.743,61
	77	34.656,78	1.743,61
	78	23.756,49	1.743,61
	79	22.216,43	1.743,61
	80	26.211,53	1.743,61
	81	20.424,23	1.743,61
	82	16.382,55	1.743,61
	83	11.534,18	1.743,61
	84	8.302,68	1.743,61
	85	8.491,27	1.743,61
	86	6.365,32	1.743,61
	87	11.160,99	1.743,61
	88	14.735,69	1.743,61
	89	17.108,59	1.743,61
	90	13.299,95	1.743,61

	91	19.346,30	1.743,61
April	**92**	18.602,66	1.743,61
	93	12.015,74	1.743,61
	94	10.609,40	1.743,61
	95	9.757,93	1.743,61
	96	8.541,63	1.743,61
	97	9.215,63	1.743,61
	98	9.520,48	1.743,61
	99	7.701,82	1.743,61
	100	6.030,20	1.743,61
	101	4.642,84	1.743,61
	102	9.391,89	1.743,61
	103	13.689,37	1.743,61
	104	13.763,41	1.743,61
	105	9.430,97	1.743,61
	106	8.986,82	1.743,61
	107	15.751,61	1.743,61
	108	14.588,53	1.743,61
	109	14.078,62	1.743,61
	110	15.066,95	1.743,61
	111	14.633,14	1.743,61
	112	13.891,13	1.743,61
	113	10.474,56	1.743,61
	114	7.484,10	1.743,61
	115	8.099,85	1.743,61
	116	7.476,45	1.743,61
	117	5.962,20	1.743,61
	118	5.854,66	1.743,61
	119	5.671,55	1.743,61
	120	14.190,30	1.743,61
	121	14.799,11	1.743,61
May	**122**	10.834,24	1.743,61
	123	9.907,65	1.743,61
	124	8.192,67	1.743,61
	125	5.833,55	1.743,61
	126	3.936,44	1.743,61
	127	4.376,46	1.743,61
	128	3.460,57	1.743,61
	129	3.142,81	1.743,61
	130	4.432,55	1.743,61
	131	5.751,71	1.743,61
	132	5.611,57	1.743,61

	133	4.717,91	1.743,61
	134	5.372,24	1.743,61
	135	5.559,84	1.743,61
	136	6.437,11	1.743,61
	137	6.806,80	1.743,61
	138	5.430,47	1.743,61
	139	5.154,53	1.743,61
	140	5.644,69	1.743,61
	141	3.543,16	1.743,61
	142	2.452,31	1.743,61
	143	2.683,05	1.743,61
	144	4.466,95	1.743,61
	145	4.643,20	1.743,61
	146	6.109,64	1.743,61
	147	8.501,57	1.743,61
	148	6.590,61	1.743,61
	149	5.099,48	1.743,61
	150	7.481,15	1.743,61
	151	7.263,56	1.743,61
	152	3.362,09	1.743,61
June	**153**	3.473,73	1.743,61
	154	3.139,45	1.743,61
	155	2.921,56	1.743,61
	156	3.203,88	1.743,61
	157	2.965,90	1.743,61
	158	3.653,69	1.743,61
	159	3.197,83	1.743,61
	160	2.656,46	1.743,61
	161	2.942,70	1.743,61
	162	3.151,63	1.743,61
	163	2.912,16	1.743,61
	164	1.963,35	1.743,61
	165	1.922,98	1.743,61
	166	2.518,52	1.743,61
	167	2.705,30	1.743,61
	168	2.946,69	1.743,61
	169	3.434,43	1.743,61
	170	3.599,22	1.743,61
	171	3.224,54	1.743,61
	172	2.411,87	1.743,61
	173	2.186,26	1.743,61
	174	1.890,25	1.743,61

	175	1.748,99	1.743,61
	176	2.003,47	1.743,61
	177	2.482,34	1.743,61
	178	3.359,80	1.743,61
	179	3.570,58	1.743,61
	180	3.151,52	1.743,61
	181	2.875,61	1.743,61
	182	2.046,78	1.743,61
	183	1.936,83	1.743,61
	184	1.839,78	1.743,61
	185	1.726,02	1.743,61
	186	1.989,21	1.743,61
	187	1.860,38	1.743,61
	188	1.916,20	1.743,61
	189	2.026,67	1.743,61
	190	2.997,48	1.743,61
	191	2.578,75	1.743,61
	192	2.099,57	1.743,61
	193	1.999,70	1.743,61
	194	1.991,07	1.743,61
	195	2.143,03	1.743,61
	196	2.026,88	1.743,61
	197	1.946,08	1.743,61
July	**198**	2.090,45	1.743,61
	199	2.146,00	1.743,61
	200	1.969,85	1.743,61
	201	1.855,49	1.743,61
	202	1.915,35	1.743,61
	203	1.855,04	1.743,61
	204	1.826,28	1.743,61
	205	1.786,04	1.743,61
	206	1.829,18	1.743,61
	207	1.848,47	1.743,61
	208	1.908,66	1.743,61
	209	2.281,89	1.743,61
	210	2.311,08	1.743,61
	211	2.051,04	1.743,61
	212	1.952,52	1.743,61
	213	2.018,57	1.743,61
	214	1.926,89	1.743,61
August	**215**	1.884,55	1.743,61
	216	1.832,73	1.743,61

	217	1.776,28	1.743,61
	218	1.828,01	1.743,61
	219	1.822,57	1.743,61
	220	1.719,62	1.743,61
	221	1.706,17	1.743,61
	222	1.846,28	1.743,61
	223	2.204,58	1.743,61
	224	2.758,91	1.743,61
	225	2.337,95	1.743,61
	226	2.207,77	1.743,61
	227	1.871,52	1.743,61
	228	1.770,01	1.743,61
	229	1.909,72	1.743,61
	230	2.017,85	1.743,61
	231	2.177,99	1.743,61
	232	1.995,42	1.743,61
	233	2.056,62	1.743,61
	234	2.241,76	1.743,61
	235	2.064,53	1.743,61
	236	2.071,74	1.743,61
	237	2.228,79	1.743,61
	238	1.824,95	1.743,61
	239	1.736,38	1.743,61
	240	1.762,21	1.743,61
	241	1.606,76	1.743,61
	242	2.453,46	1.743,61
	243	2.577,29	1.743,61
	244	2.419,78	1.743,61
September	**245**	2.626,33	1.743,61
	246	2.678,72	1.743,61
	247	2.440,78	1.743,61
	248	3.049,94	1.743,61
	249	3.117,74	1.743,61
	250	3.367,94	1.743,61
	251	3.057,97	1.743,61
	252	2.646,01	1.743,61
	253	2.550,81	1.743,61
	254	2.428,53	1.743,61
	255	2.374,25	1.743,61
	256	2.369,21	1.743,61
	257	2.436,20	1.743,61
	258	2.474,37	1.743,61

	259	2.438,63	1.743,61
	260	2.404,95	1.743,61
	261	2.376,84	1.743,61
	262	2.673,16	1.743,61
	263	4.028,95	1.743,61
	264	4.604,63	1.743,61
	265	4.393,05	1.743,61
	266	4.224,62	1.743,61
	267	3.781,62	1.743,61
	268	3.752,88	1.743,61
	269	3.078,54	1.743,61
	270	3.124,80	1.743,61
	271	3.533,85	1.743,61
	272	4.824,03	1.743,61
	273	6.313,41	1.743,61
	274	3.928,76	1.743,61
October	**275**	4.136,99	1.743,61
	276	4.555,94	1.743,61
	277	4.421,06	1.743,61
	278	7.494,54	1.743,61
	279	9.398,78	1.743,61
	280	6.649,12	1.743,61
	281	4.395,46	1.743,61
	282	3.315,41	1.743,61
	283	3.936,74	1.743,61
	284	5.031,71	1.743,61
	285	5.120,63	1.743,61
	286	5.157,08	1.743,61
	287	4.296,57	1.743,61
	288	3.241,30	1.743,61
	289	2.735,96	1.743,61
	290	7.151,92	1.743,61
	291	7.543,82	1.743,61
	292	7.836,37	1.743,61
	293	8.136,40	1.743,61
	294	10.526,10	1.743,61
	295	10.461,90	1.743,61
	296	7.802,80	1.743,61
	297	6.532,01	1.743,61
	298	7.006,49	1.743,61
	299	6.478,28	1.743,61
	300	8.207,99	1.743,61

	301	7.186,95	1.743,61
	302	9.087,78	1.743,61
	303	9.231,59	1.743,61
	304	9.075,12	1.743,61
	305	4.408,85	1.743,61
November	**306**	7.187,55	1.743,61
	307	6.780,78	1.743,61
	308	6.539,59	1.743,61
	309	6.944,68	1.743,61
	310	11.150,79	1.743,61
	311	9.624,80	1.743,61
	312	7.287,52	1.743,61
	313	14.091,27	1.743,61
	314	19.116,20	1.743,61
	315	16.323,67	1.743,61
	316	12.679,66	1.743,61
	317	10.336,38	1.743,61
	318	13.381,32	1.743,61
	319	17.164,05	1.743,61
	320	13.269,85	1.743,61
	321	9.126,20	1.743,61
	322	6.474,74	1.743,61
	323	7.349,24	1.743,61
	324	15.490,67	1.743,61
	325	21.330,63	1.743,61
	326	17.647,15	1.743,61
	327	19.189,16	1.743,61
	328	21.467,19	1.743,61
	329	18.238,59	1.743,61
	330	14.896,51	1.743,61
	331	12.274,72	1.743,61
	332	14.048,97	1.743,61
	333	14.338,65	1.743,61
	334	18.816,18	1.743,61
	335	20.035,93	1.743,61
December	**336**	19.809,99	1.743,61
	337	18.650,96	1.743,61
	338	20.135,74	1.743,61
	339	16.859,07	1.743,61
	340	15.303,53	1.743,61
	341	23.261,83	1.743,61
	342	26.886,75	1.743,61

	343	24.611,26	1.743,61
	344	26.419,72	1.743,61
	345	27.198,48	1.743,61
	346	22.378,18	1.743,61
	347	17.070,70	1.743,61
	348	17.148,12	1.743,61
	349	20.229,13	1.743,61
	350	25.041,10	1.743,61
	351	22.081,13	1.743,61
	352	18.882,09	1.743,61
	353	18.882,09	1.743,61
	354	17.608,85	1.743,61
	355	19.622,40	1.743,61
	356	23.549,20	1.743,61
	357	18.818,33	1.743,61
	358	14.202,00	1.743,61
	359	12.073,76	1.743,61
	360	10.938,44	1.743,61
	361	10.005,14	1.743,61
	362	15.136,93	1.743,61
	363	23.184,95	1.743,61
	364	28.971,32	1.743,61
	365	22.495,84	1.743,61

9.3 DHW and Space heating demand for Genoa

Table 9: Monthly DHW and space heating demand values for Genoa

	HEATING DEMAND [kWh]	DHW DEMAND [kWh]
January	233006	164617,92
February	172987	164617,92
March	114937	164617,92
April	31029	164617,92
November	110358	164617,92
December	201346	164617,92

Table 10: Daily DHW and space heating demand values for Genoa

Month	Day	Space Heating (kWh)	DHW (kWh)
January	1	8.701,48	451,008
	2	5.800,99	451,008
	3	10.635,15	451,008
	4	9.668,31	451,008
	5	8.701,48	451,008
	6	8.701,48	451,008
	7	9.668,31	451,008
	8	7.734,65	451,008
	9	9.668,31	451,008
	10	8.701,48	451,008
	11	10.635,15	451,008
	12	8.701,48	451,008
	13	3.867,33	451,008
	14	7.734,65	451,008
	15	3.867,33	451,008
	16	3.867,33	451,008
	17	3.867,33	451,008
	18	6.767,82	451,008
	19	5.800,99	451,008
	20	3.867,33	451,008
	21	7.734,65	451,008
	22	8.701,48	451,008
	23	5.800,99	451,008
	24	7.734,65	451,008
	25	7.734,65	451,008
	26	5.800,99	451,008
	27	6.767,82	451,008
	28	6.767,82	451,008
	29	7.734,65	451,008
	30	10.635,15	451,008
	31	10.635,15	451,008
February	1	9.327,73	451,008
	2	7.631,78	451,008
	3	7.631,78	451,008
	4	7.631,78	451,008
	5	9.327,73	451,008
	6	8.479,75	451,008
	7	6.783,80	451,008

	8	5.087,85	451,008
	9	5.087,85	451,008
	10	3.391,90	451,008
	11	847,98	451,008
	12	5.087,85	451,008
	13	5.935,83	451,008
	14	6.783,80	451,008
	15	7.631,78	451,008
	16	7.631,78	451,008
	17	7.631,78	451,008
	18	5.935,83	451,008
	19	6.783,80	451,008
	20	7.631,78	451,008
	21	5.087,85	451,008
	22	3.391,90	451,008
	23	2.543,93	451,008
	24	2.543,93	451,008
	25	5.087,85	451,008
	26	6.783,80	451,008
	27	6.783,80	451,008
	28	8.479,75	451,008
March	1	3.990,85	451,008
	2	4.789,02	451,008
	3	3.990,85	451,008
	4	3.990,85	451,008
	5	3.591,77	451,008
	6	2.793,60	451,008
	7	3.591,77	451,008
	8	3.990,85	451,008
	9	3.990,85	451,008
	10	4.389,94	451,008
	11	4.389,94	451,008
	12	3.990,85	451,008
	13	4.389,94	451,008
	14	3.591,77	451,008
	15	3.192,68	451,008
	16	2.793,60	451,008
	17	2.394,51	451,008
	18	1.596,34	451,008
	19	3.591,77	451,008
	20	3.591,77	451,008

	21	4.389,94	451,008
	22	4.389,94	451,008
	23	4.789,02	451,008
	24	3.591,77	451,008
	25	4.389,94	451,008
	26	3.192,68	451,008
	27	3.192,68	451,008
	28	3.192,68	451,008
	29	3.591,77	451,008
	30	3.591,77	451,008
	31	3.990,85	451,008
April	1	1.865,11	451,008
	2	2.034,66	451,008
	3	1.865,11	451,008
	4	1.865,11	451,008
	5	1.865,11	451,008
	6	2.204,22	451,008
	7	2.204,22	451,008
	8	1.865,11	451,008
	9	1.865,11	451,008
	10	2.204,22	451,008
	11	2.204,22	451,008
	12	2.373,78	451,008
	13	2.204,22	451,008
	14	2.204,22	451,008
	15	2.204,22	451,008
November	1	3.294,26	451,008
	2	3.843,30	451,008
	3	4.666,86	451,008
	4	3.843,30	451,008
	5	4.392,34	451,008
	6	4.392,34	451,008
	7	3.843,30	451,008
	8	3.568,78	451,008
	9	3.843,30	451,008
	10	3.294,26	451,008
	11	3.568,78	451,008
	12	4.392,34	451,008
	13	4.392,34	451,008
	14	4.392,34	451,008
	15	3.568,78	451,008

	16	3.019,73	451,008
	17	3.019,73	451,008
	18	2.470,69	451,008
	19	3.294,26	451,008
	20	4.392,34	451,008
	21	3.294,26	451,008
	22	3.568,78	451,008
	23	3.568,78	451,008
	24	3.843,30	451,008
	25	3.843,30	451,008
	26	3.843,30	451,008
	27	3.843,30	451,008
	28	3.294,26	451,008
	29	3.294,26	451,008
	30	2.470,69	451,008
December	1	7.321,66	451,008
	2	7.321,66	451,008
	3	6.589,50	451,008
	4	7.321,66	451,008
	5	6.589,50	451,008
	6	6.589,50	451,008
	7	2.928,67	451,008
	8	4.393,00	451,008
	9	5.125,17	451,008
	10	7.321,66	451,008
	11	5.125,17	451,008
	12	5.125,17	451,008
	13	2.196,50	451,008
	14	1.464,33	451,008
	15	5.125,17	451,008
	16	8.053,83	451,008
	17	6.589,50	451,008
	18	7.321,66	451,008
	19	7.321,66	451,008
	20	5.125,17	451,008
	21	5.857,33	451,008
	22	5.857,33	451,008
	23	8.053,83	451,008
	24	9.518,16	451,008
	25	10.250,33	451,008
	26	8.053,83	451,008

	27	7.321,66	451,008
	28	9.518,16	451,008
	29	8.786,00	451,008
	30	6.589,50	451,008
	31	6.589,50	451,008