User Manual
T*SOL Pro®

Version 5.0

Design and Simulation
of Solar Thermal Systems

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Berlin, June 2010

Contents

1   Program Information

1.1   Why T*SOL®?

T*SOL® is a program for the design and simulation of solar thermal systems including hot water preparation, the support of space heating and swimming pool heating.

The program allows the planner to investigate the influence of individual system components on the operating behaviour of a solar thermal system. All system parameters can be quickly changed via the user-friendly interface.

Simulation results can be evaluated in graph or table format, making T*SOL® an excellent tool for planning a solar thermal system.

1.2   What is new in T*SOL 5.0?

The most important features:

- New graphic user interface. One window per vVariant
- New graphic results presentation: Die presentation of system schematics is optimized.
- Data bases: Favorites, tables, sorting and filtering of components
- Data base update: New system types, systems and components regularly.
- Air collector systems
- New tank systems with integrated auxiliary heating
- We have switched from British to U.S. English.
- EnEV-Assistent: annual yield calculation according to EnEV (Energie-Einspar-Verordnung, German act on energy savings)
- New climate data selection

1.3   System Features

1.3.1   Overview

- Simulation of solar thermal systems supporting domestic hot water and space heating over any period of time up to one year

- Design (optimisation of collector array area and storage tank volume) of the system to reach specific targets

- Influence of partial shading by the horizon and other objects (buildings, trees etc)

- Graphic and tabular entry of shade values

- Design Assistant with automatic system optimization

- Comprehensive component database

- Working on a number of system variants at any one time within a project is possible, making it easy to compare systems

- Domestic hot water consumption profiles included in the calculations

- Both radiator and under-floor heating can be included

- Investigation of energy use, pollutant emissions and costs

- Calculation of standard evaluation values for solar thermal systems such as system efficiency, solar fraction etc

- Detailed presentation of results in reports and graphics

- Economic efficiency calculation following simulation over a period of one year

- Online Help facility

1.3.2 System types

You can select a system from the most common system configurations for domestic hot wate and heating support, and you can choose between indoor or outdoor swimming pools to the solar cycle. Additionally, you can select from a number of large-scale solar systems.

The system components (collectors, boiler, storage tank, and also consumption profiles) are taken from the database, respectively.

T*SOL® calculates both shade from the horizon and from objects close to the system. For the objects, you can take account of seasonal variations in shading (e.g. trees with and without leaves).

1.3.3 Simulation and Results

The calculation is based on the investigation of energy flows and provides yield prognoses according to the hourly meteorological data provided.

T*SOL® calculates the energy produced by the solar system in the production of hot water and space heating and the corresponding solar fraction.

The results are saved and can be presented in graph format or in a results overview (Summary Report). The graph maps the course of energy and other values, over any given period, and can be saved as a table in text format, so that the results can be copied into other programs for further evaluation.

By varying individual system parameters, the optimal system configuration can be found.

1.3.4 Economic Efficiency Calculation

After running a simulation over a period of one year, you are able to carry out an economic efficiency calculation for that variant.

Taking into account the system costs and any financial support (e.g. government grant), the economic efficiency parameters, e.g. capital value, annuities and cost of heating, are calculated and detailed in a report.

1.3.5 Comprehensive Database of Components

The program comes with a comprehensive database of the following components:

- Collectors
- Boilers
- Storage tanks

If you want to stay up to date, we would recommend a T*SOL® Service Agreement. You will then be sent regular program updates and revised component database units.

2   Installation

2.1   Hardware and Software Requirements

T*SOL® is a WINDOWS™ application. One of the following operating systems needs to be installed on your computer before you can run the program: Windows ME, Windows NT, Windows 2000 or Windows XP.

T*SOL® requires a minimum of 256 MB RAM. With less memory there is no guarantee that the program will run.

Recommended system configuration:
        500 MHz Pentium PC
        256 MB RAM
        400 MB hard disk drive
        VGA colour monitor
        CD drive

The fully installed program uses approximately 120 MB of hard disk space. Each additional weather data file requires 5 MB. You will require approximately 220 MB of free hard disk space in order to run T*SOL® comfortably, complete with all available weather data. Please ensure that you have enough space free on the hard disk before you install the program.

In order to run T*SOL® you must have the full licence rights (full access) to the T*SOL® installation folder.

The formats for currency, numbering, time and date that are defined within the country settings of Windows' system control on your computer are automatically reproduced within T*SOL®. These formats also appear in any T*SOL® documents that you print out. In order to run the program, it is important that the symbols separating thousands and decimals are different.

You should set your monitor display to *Small Fonts* via the Windows system control.

2.2   Program Installation

Please close all programs before commencing the installation procedure.

To install the program put the program CD into your computer's CD drive. The installation program will start automatically and you will be taken through the installation procedure step by step (unless the CD drive autorun function has been deactivated on your computer).

If the autorun function has been deactivated, you will need to start the "Setup.exe" file which is on the CD. To do this you can start File Manager or Explorer and double click on the "Setup.exe" file in the CD drive.

If you install T*SOL onto a computer with WinNT, WIN2000 or WinXP, you will need to have administrator access to the operating system.

To run the program, you will need to have full rights (read and write) to the T*SOL program directory (e.g. C:\Program Files\Valentin EnergieSoftware\TSOL).

2.3   Program Activation

After installing and opening the program, a small window appears asking whether you wish to start the program as a Demo Version or register the Full Program. This dialog appears until you have activated the program successfully.
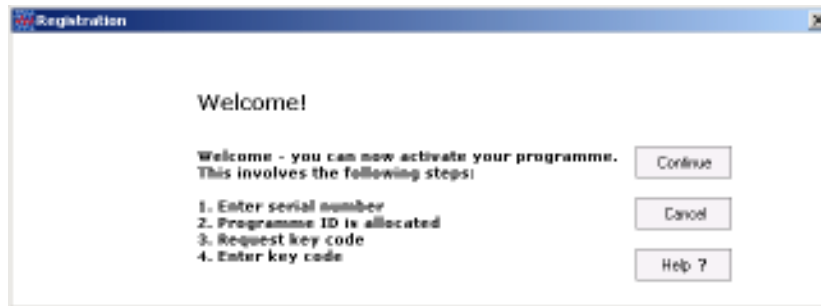
Program **Activation** is carried out by entering a **Key Code**. The Key Code is provided by the program manufacturer on request.

First you will need to make sure that:

- You have a Serial Number

- The program has already been installed

- When you start the program, you click on the "License Full Version" button.

Program Activation is carried out in four steps: *Activation*

- Enter Serial Number

- Notify allocated program ID by e-mail, fax or telephone

- Receive Key Code

- Enter Key Code

2.3.1   Enter the Serial Number

If you purchased the program from us, you will already have a Serial Number. You will find this on the CD case, on the invoice or we have sent it to you by e-mail. The Serial Number has the following format:

30138-012P-250-CHWD-1-EHB8-PH-CEPR-AGU

It needs to be entered exactly as it appears, without any spaces. After the Serial Number has been entered, the program allocates a Program ID, which is based on the Serial Number and a code for your PC.
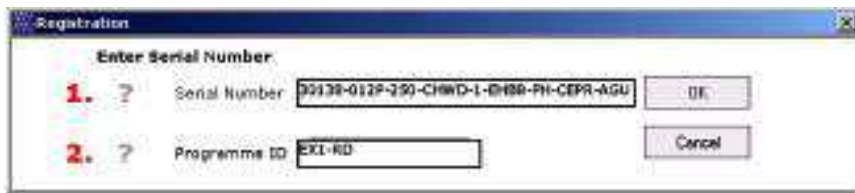
You Still Don't Have a Serial Number?

This could be the case if, for example, you have installed the program from the Demo CD or you have downloaded it from the internet. You will need to purchase a full version of the program before you can receive a Serial Number.

Send us the Order Form which you can print within the program under "**Info/Registration**", or you can purchase the program direct from our website.

You've Purchased the Program and Can't Find Your Serial Number?

No problem. Send us the invoice for the program with your contact details and we will send you the Serial Number again.

2.3.2   Request a Key Code

After entering the Serial Number and automatic allocation of the Program ID, you will need to provide us with this information, so that we can send you your Key Code. You will see the following window on your screen:
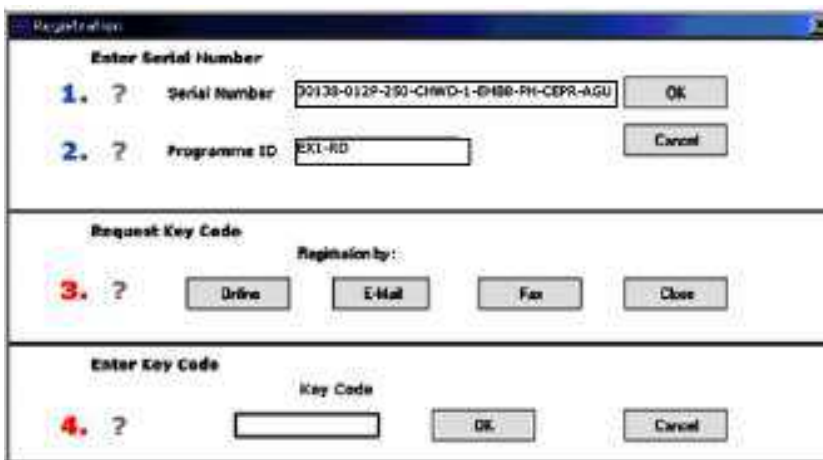
You can request the Key Code in three different ways.

2.3.3   Request a Key Code Online

This method requires that your computer has internet access.

Click on the "Online" button underneath "Program ID" in the Registration window. A form opens in which you enter the data required to obtain a Key Code. The fields marked: * have to be completed to continue.

After completing the form, you can send it straight off – the recipient's address is entered automatically. After sending, you will receive the Key Code by return (allow up to 20 minutes for this). It will be sent to the e-mail address entered on the form.

2.3.4 Request a Key Code by Fax

If you click on the "Fax" button underneath "Program ID" in the Registration window, a form opens for you to complete and print off. Send the completed form by fax to: +49 30 588 439 11.

You will then receive the Key Code by fax within one working day. You can also enter an e-mail address to which the Key Code should be sent.

2.3.5 Request a Key Code by Telephone

If you do not have a fax or an e-mail address, you can request a Key Code by telephone. In this case, you will need to give your Program ID over the phone.

2.3.6 Enter the Key Code

Once you receive the Key Code, you will need to enter it by hand or copy and paste it into the field under "Enter Key Code" in the Registration window and then click on the "OK" button. This completes the program registration and activation procedure.

An information window appears with a message that registration has been completed and the program is now fully functional.
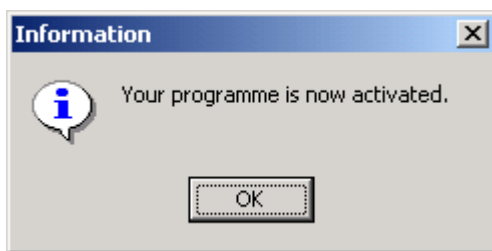
 The logo illustrated here will be used as the program icon. After installation it will appear in the Windows **Start** menu.

The single licence version of T*SOL® can only be installed locally. However, since the database and project files can be saved to any file paths required and these can then be set in the program as the standard file paths, it is therefore possible to move parts of the program to other hard drives.

If you wish to install the whole program onto a network, you will require the network version of T*SOL®.

3   Introduction

3.1   Functional Basics

With the increasing use of thermal insulation in buildings and the resulting reduction in heating energy requirements, the share of energy required for heating water in a building's total energy requirement is growing in significance.

Thermal solar systems can cover a considerable portion of this energy requirement. Current systems for solar water heating function highly reliably and enable annual energy yields of 350 to 500 kilowatt hours per m² of collector area. At the same time, they cut the emission of c. 100-150 kg of the greenhouse gas CO_2. Solar thermal systems directly use the sun's radiation and convert it into heat on an absorbing surface, which is particularly of use in the field of hot water supply.

A thermal solar system must carry out the following tasks:

• Conversion of the sun's irradiated energy into heat with the use of collectors

• Heat transfer to the storage tank via the piping system

• Storage of heat in buffer tanks until required by the user.

In the process, energy is lost at the collector, in the piping system, and in the storage tank. Minimising these energy losses is the job of practical adaptation and planning of the solar system for each specific scenario.

The *system efficiency* serves to evaluate these losses. It is defined as the ratio of available energy from the solar system to the irradiated energy onto the collector area. The share of total energy available covered by solar power is termed the *solar fraction*.

3.1.1   Basic Construction of a Solar System

The key component of a solar thermal system is the *collector* or the *absorber*, which converts solar energy into heat and transports it by means of a heat transfer medium via piping systems and heat exchangers to a storage tank. In systems for hot water supply, the storage tank compensates for fluctuations in energy supplies and requirements at varying times of the day. In large solar systems which also greatly contribute to heating energy supplies, an underground seasonal storage tank is usually constructed in a local heating system to compensate for seasonal variations in irradiation and energy demand. These seasonal supply systems are currently at the trial stage and will not be considered further here. Where the solar energy is insufficient, an auxiliary heating system supplies the outstanding amount of energy to cover requirements.

A controller monitors the operational state of the solar system and ensures the most efficient use of the energy irradiated. If there is a temperature difference between the storage tank and the collector, it switches on the circulation pump in the collector loop, ensuring heat transport to the storage tank.

3.1.2   How the Absorber and Collector Work

Black surfaces are particularly good at absorbing shortwave radiation of light and then converting it into heat. This physical property is used in the so-called absorbers. These are made from plastic or metal in the form of panels, mats, or pipes with a black surface which, depending on the quality

of the absorber, is voltaic or otherwise finished. Absorbers are the active part of a solar system. Depending on the scenario and the level of the required temperature, a distinction is made between

• absorber systems and

• collector systems.

Absorber systems are not insulated or covered. The heat transfer medium flows directly through them. These are structurally simple, affordable systems suitable for operating temperatures below 40° C. Their primary areas of application are heating swimming pool water and preheating service water.

Absorber mats, usually made from plastic, can be placed on flat or slightly inclined roofs, also retrospectively, with little construction work.

Collector systems with *flat plate collectors* contain an absorber (typically in metal) in a sealed housing fitted with a transparent cover and heat insulation on the rear side. The transparent covering reduces irradiation from the absorber to the environment, while the thermal insulation reduces heat losses on the rear side, enabling temperatures of over 150° C to be reached. Primary areas of use are in water heating and space heating. Flat plate collectors are available in various sizes from 1 to 10 m². Special designs (e.g. triangular) are also possible. They are integrated within the roof cladding in prefabricated modules or attached to the roof cladding and interconnected.

Evacuated tube collectors contain a metal absorber sealed in evacuated glass tubes. The vacuum ensures that heat losses are kept to a minimum, enabling temperatures of over 200° C to be reached. Areas of use are heating service water, space heating, and generating process heat, as well as solar cooling of buildings.

3.1.3   Task of the Storage Tank

As in all hot water systems, the storage tank's task is to balance peak demand and charging power in supplying hot water and in solar systems additionally compensates for time differences between solar energy supply and hot water requirements. It typically features a heat exchanger at the bottom, in which the transfer medium from the collector (usually a water-antifreeze mixture) transfers the solar energy from the collector to the storage tank's content.

Where required, the upper part of the storage tank is additionally heated by a conventional heating system, so that the hot water taken from the upper part is always at the required target temperature, irrespective of available solar energy. Larger solar systems use several storage tanks connected in series, of which the last one is used for reheating.

3.1.4   How the Controller Works

Solar systems principally use a so-called differential temperature controller. This control principle compares the temperatures at the absorber and in the storage tank. If the absorber temperature is a preset level above that of the storage tank, the circulation pump in the collector loop is switched on. The irradiation energy converted to heat in the absorber system is transported to the storage tank, whose temperature increases. When the temperature of the storage tank is equal to that of the absorber, no more energy can be supplied to the storage tank and the pump is switched off.

3.1.5   Design of a Solar System

Small systems in detached private homes are typically designed such that they largely reach a full supply outside the heating periods, so that the boiler can be shut down in the summer. Around 60 % of annual hot water requirements can be covered by solar energy in this way. Larger solar fractions, i.e. if a large proportion of water must be heated by solar energy in spring, autumn, or in winter, give rise to a surplus in the summer which cannot be used. The solar system is then no longer operating as effectively as possible. In other words, an increasing solar fraction reduces the efficiency of a solar system. For systems in multiple dwellings or social institutions in which the auxiliary heating cannot be switched off because of tenancy laws or other provisions, current solar systems are designed with a solar fraction of up to 30 %.

There are no simple methods to calculate the yield of a solar system precisely. The number of parameters which determine the performance of a system is too large, and includes not only the changeable, non-linear characteristic of the weather but also the dynamic processes in the system itself.

In larger systems, computer simulation is the only way to investigate the influences of ambient conditions, user behaviour, and of various components on the operational state of the solar system.

Solar systems can also be used for heating wherever heat is required in the summer or where solar energy can be used for cooling in summer. A further use of solar systems for auxiliary heating is in the field of low-energy houses. There, the fraction of heating energy occupies the same order of magnitude as the hot water supply.

In buildings with current thermal insulation standards, designing solar systems with the option of seasonal storage for heating purposes, also in winter, is inadvisable. This results in very large collector areas and, at the time, high surplus energy in the summer, i.e. in systems with very poor efficiency and consequently very high solar heat prices.

3.1.6   Economics of Solar Systems

Current solar systems are always bivalent, as they can never be solely responsible, at least not year-round, for supplying heating energy. They are therefore connected upstream with conventional systems and function as "fuel savers" by transporting more or less preheated water to the downstream heating system.

To consider the economics of a solar thermal system, the investment costs are applied to the lifetime of the system, taking into account simple interest and an amount for maintenance and operating costs. In relation to the annual heating amounts supplied, this gives the heating price in cents/kWh. The heating price for a kilowatt hour generated by solar energy is of the same order as the generation of hot water from electrical current, now considerably lower for larger systems.

This development will also enable and intensify the use of solar thermal systems in medium-rise housebuilds in the coming years. The money saved from the oncosts of burning fossil fuels is not included here. However, the slightly higher heating energy bills are becoming accepted by many tenants today as a result of an improved social image and a considerable improvement to residential surroundings with the visibly ecological "advertisement".

3.2   Calculation Basics

3.2.1   General Design Notes

There are no simple methods to calculate the yield of a solar system precisely. The number of parameters which determine the performance of a system is too large, and includes not only the changeable, non-linear characteristic of the weather but also the dynamic processes in the system itself.

Although there are rules of thumb, such as around 1-2 m² of collector area per person and 50 l storage content per m² collector area, these apply at best for small systems in detached or semi-detached houses. In larger systems, computer simulation is the only way to investigate the influences of ambient conditions, user behaviour, and various components on the operational state of the solar system.

Solar systems can primarily be used for heating purposes where heating is also required in the summer. These systems can then also make an appreciable contribution to building heating in the spring and autumn. In buildings with current thermal insulation standards, designing solar systems with the option of seasonal storage for heating purposes, also in winter, is inadvisable. This results in very large collector areas and, at the time, high surplus energy in the summer, i.e. in systems with very poor efficiency and consequently very high solar heat prices.

To design or optimize a solar system with T*SOL®, the following steps must be followed:

3.2.2   Energy Balance

A thermal energy balance is generated to calculate status and temperature changes during a simulation period. Mathematically, this means the numerical solution of a differential equation.

$$\text{Change in temperature} = \frac{\text{Total of all input and output energy}}{\text{Total of all heat capacity}}$$

Balancing means that the total of all input energy, output energy, and storage of energy via the heat capacity of the system components must be equal to zero. This balancing is not carried out wholesale for the entire system but for the individual system components.

- Collector
- Collector loop
- Heat exchanger
- Unlimited layers in storage tanks with stratification

For each of these components, the change in temperature is calculated with the above formula on the basis of energy input and output and the heat capacity of the respective component.

Energy input can be (depending on the component):

- Irradiation,
- Heat supply to the heat exchanger,
- Heat transfer by mass flow due to consumption or circulation,
- Intermixture of storage tank layers.

Energy output can be:

- Heat losses by radiation from the collector (quadratic transmission coefficient),

- Heat losses at the insulation of the collector, the piping (collector loop or circulation), the valves, or the storage tanks,
- Heat transfer to the heat exchanger,
- Heat transfer by mass flow due to consumption or circulation,
- Intermixture of storage tank layers.

The *heat capacities* of the following components are taken into account:

- Collector
- Piping of the collector loop
- Storage tank content

3.2.3   Irradiation Processor

In the supplied climate files, irradiation to the horizontal plane is given in watts per square metre of active solar surface. The program converts this to the tilted surface during the simulation and multiplies it by the total active solar surface.

Here, the radiation must be split into diffuse and direct radiation. The splitting is carried out according to Reindl's radiation model with reduced correlation. [Reindl, D.T.; Beckmann, W. A.; Duffie, J.A. : Diffuse fraction correlations; Solar Energy; Vol. 45; No. 1, S.1.7; Pergamon Press; 1990]

These are then converted into irradiation on the tilted surface, using the anisotropic sky model by Hay and Davis. [Duffie,J.A.; Beckmann, W.A.: Solar engineering of thermal process; John Wiley & Sons, USA; second editions; 1991]

This model takes into account the anisotropy factor for circumsolar radiation and the ground reflection factor (= 0.2).

Irradiation on the collector area (active solar surface) is calculated from the radiation strength (W/m²) on the horizontal plane:

the height of the sun and the solar azimuth is determined on the basis of the date, time, and latitude.

On the basis of the height of the sun, the solar azimuth angle, the collector tilt angle, and the collector azimuth angle, the position of the sun relative to the collector surface is calculated. This allows conversion of the direct share of solar radiation on the horizontal plane into the direct share of solar radiation to the collector, taking into account the active solar surface. The position of the sun relative to the collector surface is also required when calculating the reflected irradiation (see incident angle modifiers in the collector equation).

3.2.4   Consumption of Primary Energy

Consumption values, efficiencies, solar fractions, and other parameters can be calculated from the temperatures and the energy flows of the system.

The use of fuels by energy type (natural gas, oil, wood pellets, district heating) is calculated from the energy transferred to the auxiliary heating at the heat exchanger via the heat equivalent and the efficiency of the auxiliary heating. The efficiency of the auxiliary heating is determined depending on the return flow temperature, enabling simulation of the various efficiency levels at different capacity utilisation of the heating system.

3.2.5   Calculation of CO_2 Emissions

The CO_2 emissions saved by the solar system are calculated in the results summary. For this, it is necessary to know which type of primary energy is saved by the solar system. Emissions factors by fuel type are used to calculate the CO_2 emissions of a heating system. The following emissions factors are used in T*SOL®:

Fuel	Heating value	Emissions g CO2 /kJ
Oil	36722 kJ/l	7,32748
Gas	41100 kJ/m³	5,14355
District heating		5,14355
Wood pellet	15490 kJ/kg	CO_2-neutral

Table 3.1   Heating values and emissions factors

3.2.6   Efficiency and Solar Fraction

The collector loop efficiency is defined as follows:

$$\text{Collector loop efficiency} = \frac{\text{Energy output from the collector loop via the heat exchanger}}{\text{Energy irradiated onto the collector area (active solar surface)}}$$

The system efficiency is defined as follows:

$$\text{System efficiency} = \frac{\text{Energy output from the solar system}}{\text{Energy irradiation onto the collector area (active solar surface)}}$$

The **energy output by the solar system** consists of the energy transferred from the solar storage tank (as a result of consumption and, where applicable, a recirculation system controlled in the solar storage tank) to the standby tank. As there is no difference between the solar and standby tanks in some systems (single storage tank model, e.g. bivalent storage tank or reheated buffer tank), the system efficiency of these cannot be calculated. The storage losses are therefore at the expense of reheating.

The **solar fraction** is defined as follows:

$$\text{Solar fraction} = \frac{\text{Energy supplied to the standby tank from the solar system}}{\text{Total energy supplied to the standby tank (Solar system + auxiliary heating)}}$$

The following applies to a solar system with bivalent storage tank (internal heat exchanger) for water heating and auxiliary heating:
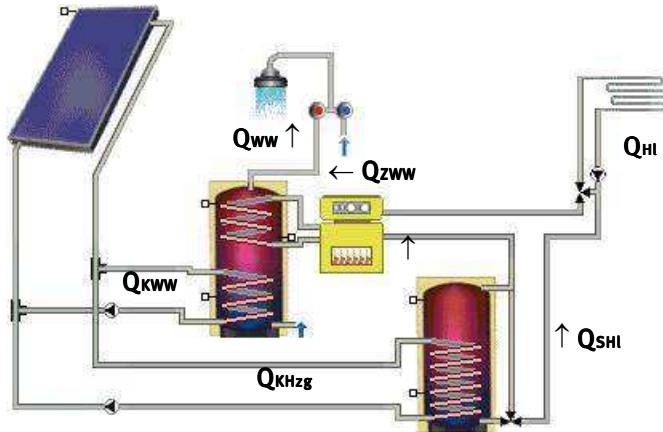
$$\text{solar fraction, total} = \frac{Q_{KWW} + Q_{SHzg}}{Q_{KWW} + Q_{SHzg} + Q_{ZWW} + Q_{ZHzg}}$$

$$\text{Solar fraction, hot water} = \frac{Q_{KWW}}{Q_{KWW} + Q_{ZWW}}$$

$$\text{Solar fraction, heating} = \frac{Q_{SHzg}}{Q_{SHzg} + Q_{ZHzg}}$$

The calculation for a solar system with a combined storage tank is as follows:
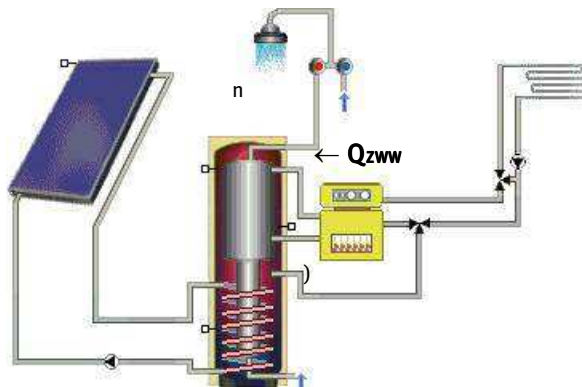
$$\text{Solar fraction, total} = \frac{Q_K}{Q_K + Q_{ZWW} + Q_{ZHzg}}$$

$$\text{Solar fraction, hot water} = \frac{Q_K - Q_{SHzg}}{Q_K - Q_{SHzg} + Q_{ZWW}}$$

$$\text{Solar fraction, heating} = \frac{Q_{SHzg}}{Q_{SHzg} + Q_{ZHzg}}$$

Legend:

C	Collector loop
A	Auxiliary heating
S	Solar yield as per the storage tank (net)
HL	Heating loop
DHW	Domestic hot water (including

The **energy supply for heating drinking water** is the energy required to heat the cold water to the temperature of hot tap water. Losses from the storage tank or the circulation are not included here.

The **fuel used** is the amount of fuel required to reheat the standby tank / the standby part of the storage tank to the target temperature. Heat losses from the storage tank and the boiler efficiency are included here.

3.2.7   Storage Tank Model and Operation

The **stratified storage tank model** uses storage layers of varying thickness, i.e. also of varying volume, whose number can vary depending on the operational state. The number of layers is not set, rather new layers are formed and the layer thickness is changed during the course of the simulation. This takes place via the feed-in and feed-out of volumes of water and the intermixture of temperature layers if the temperature stratification is reversed. The minimum layer thickness is defined by two system definitions: a layer cannot contain less than 1 % of the overall storage volume, and a temperature difference must be present between the layers.

3.2.8   Feed-In and Feed-Out

The cold water intake is always in the lowest storage tank layer, hot water is generally drawn from the highest layer. The inlets and outlets of the internal heat exchanger are set by the selected storage tank and are correctly represented in the storage tank view in the T*SOL® interface, as are the levels of the temperature sensor to control the collector loop and auxiliary heating.

3.3   Economics Calculation

The economics calculation in T*SOL®, according to the pay-off method, is based on the following formulae:

$$\text{Capital expenditure} = \text{system costs} - \text{subsidies}$$
$$\text{Annual operating costs} = \text{pump capacity} * \text{lifetime} * \text{electricity costs}$$

The cash value (CV) of a price-dynamic payment sequence Z, Z*r, Z*r² ... over T years (lifetime) as per VDI 2067 is:

Cash value CV = Z * b(T,q,r)

$$\text{Cash value factor } b(T,q,r) = \begin{cases} \dfrac{1-(r/q)^T}{q-r} & \text{für } r <> q \\ T/q & \text{für } r = q \end{cases}$$

q: Simple interest factor (e.g. 1.08 at 8 % simple interest)
r: Price change factor (e.g. 1.1 at 10 % price change)

The following applies for the capital value of the total investment:

Capital value of the total investment

$= \sum [\text{CV of price - dynamic payment sequences over the lifetime}]$

$-$ Investments

$+$ Subsidies

The pay-back time is the period the system must operate for the investment to yield a cash value of zero. Pay-back times of over 40 years are not supported.

To calculating the heating price, the cash value of the costs is determined:

$\text{CV of costs} = \text{investment} + \text{CV of operating and maintenance costs}$

If the CV of the costs is converted into a constant sequence of payment (r = 1), then the following applies to this sequence Z:

$Z = CV of \cos ts / b(T,q,r)$

For r = 1, $1/b(T,q,r)$ to the annuity factor $a(q,T) = q^T * (q-1)/(q^T-1)$ (again as per VDI 2067).

The heating price is then:

$Heating price = Annual \cos ts \; Z / Annual energy yield$

3.4   Swimming Pool Calculation

The swimming pool is calculated as a 1-layer storage tank, including the following gains and losses:

- Evaporation losses at the surface
- Convection losses at the surface
- Transmission losses at the pool wall
- Irradiation gains at the surface
- Reflection losses at the surface
- Heat radiation at the surface
- Fresh water intake as a result of evaporation, pool discharge, and filter cleaning

The swimming pool heating requirement - to the extent that auxiliary heating is available - is defined as the total energy transferred from the solar system and the auxiliary heating to the swimming pool. Using the swimming pool heating requirement, the solar fraction of the swimming pool is derived.

There is the possibility that the target temperature cannot be reached in pools without auxiliary heating. As a result, the swimming pool heating requirement cannot be determined from the simulation. In this case, the swimming pool fraction is defined as the percentage of time in which the swimming temperature is above the target temperature to the total operating time.

A fraction of 100 % means that the pool temperature was reached or exceeded over the entire operating time. As the pool can also heat from irradiation and warm ambient temperature without the solar system or auxiliary heating, this also results in a positive solar fraction.

The swimming pool and - where auxiliary heating is available - swimming pool heating requirement fraction are shown in the project report.

4   Brief Instructions

The aim of this section is to introduce the user to the scope of the T*SOL® program, drawing on the most important and most frequent questions raised by users. The planning and design of a solar thermal system using T*SOL® will be illustrated using the menus and following the various steps that need to be carried out, in their recommended order. The corresponding speed button symbols for direct access to the dialogs will be shown.

4.1   General Information on Design

There is no simple method of calculation which can be used to exactly determine the yields for a solar system. The number of parameters required to determine the operating behaviour of a system is too large. This is not only affected by the changeable, non-linear behaviour of the weather, but also by the dynamic nature of the system itself.

Of course there are rules of thumb such as 1-2 m² collector surface per person and 50 litre storage tank capacity per m² of collector surface, but these are only valid, if at all, for small systems serving one or two households. Only calculation-based simulation makes it possible to investigate larger systems in respect of the influence of the surrounding conditions, consumption variations and different components on the operating conditions of the solar system.

Solar systems can be used for heating purposes, above all, in areas where heating is also required in summer. These systems will then, even during the transitional period, make a considerable contribution to heating the building. However, something that should be avoided at all costs is the design of a solar system for heating without the possibility of seasonal storage, even in winter. This would lead to extremely large collector surfaces and at the same time excess energy in summer, i.e. to systems with very poor efficiency and therefore very high heating costs!

In order to design and optimize a solar system with T*SOL®, the following steps should be followed:

4.2   Enter Site Data

Site Data are characteristics of the project, which don't change with the variant, i.e. data on climate, building, hot water consumption, heating demand, process heating, or such. Therefore, they menu Site Data is to be found in the main menu bar.
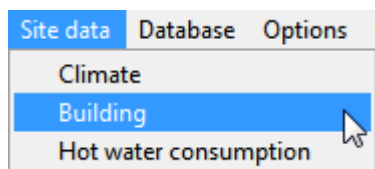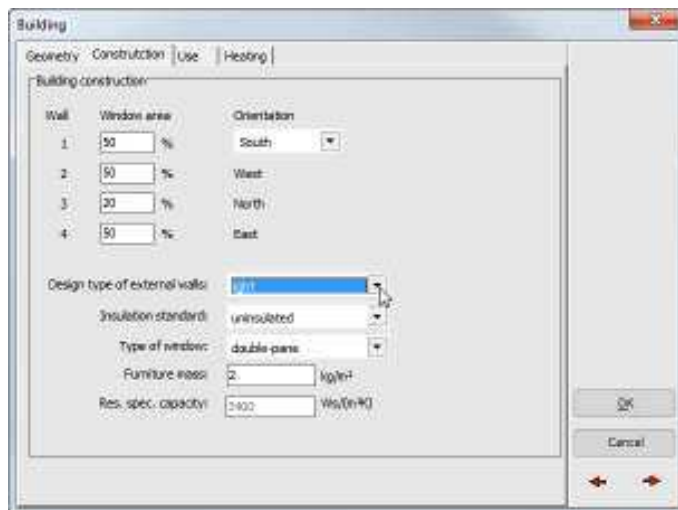

Figure 4.2.1:
Site Data menu

Figure 4.2.2: Example of Site
Data:
Air Collectors, only: Building ›
Construction Dialog

4.3 Set Up a New Project
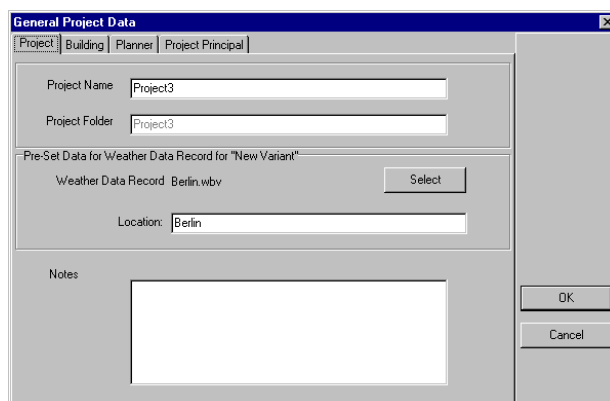
Figure 4.3.1:
Data entry dialog for setting up a
new project

To set up a new project you will need to open the **General Project Data** dialog and enter at least
the reference or name of the project. This will also serve as the name of the project folder, into
which the project 'variants' worked on in the course of the project should be saved. All other
details can be entered at a later date, as and when required.

Exit the dialog with OK to set up the project. You can then define and work on as many project
variants as you wish.

4.4   Design Assistant
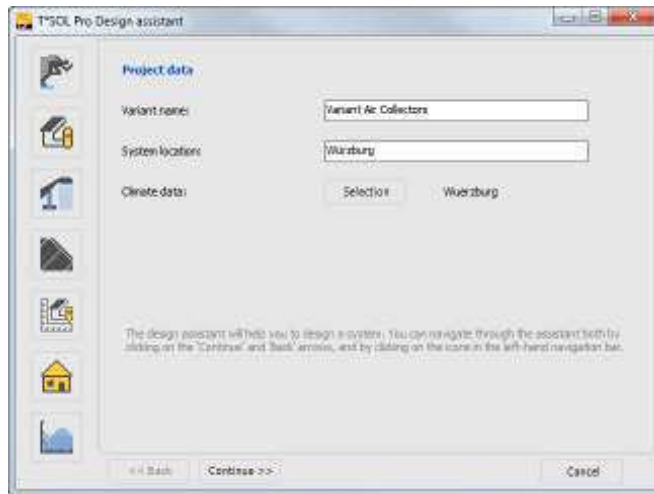

Figure 4.4.1:
Design Assistant

If you do not have a firm idea of the design of your solar system yet, you might use the **Design Assistant** to size your system, rather than manually entering every time.

> **!**   The Design Assistant is available using the default setting region = Europe, only

The Design Assistant leads you through all the necessary stages, including the selection of a suitable collector and storage tank. These components are determined, after entry of the target solar fraction (i.e. the annual solar contribution percentage), by the calculation results of a mini simulation.

By clicking on the **Accept** button, the parameters entered and determined in the Design Assistant are transferred into the system.
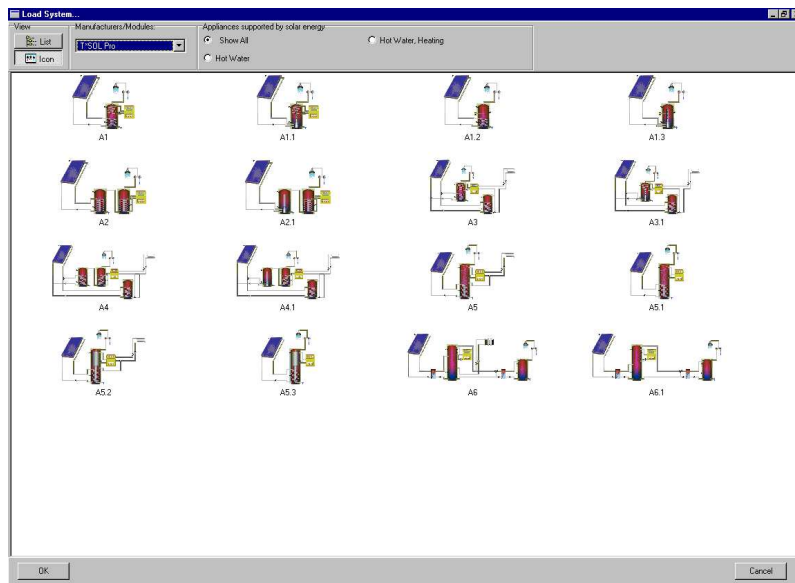
4.5   Select a System

Figure 4.5.1:
Systems Selection
Dialog

If you already know which system components you want to use, you can select these directly from the **System › Select** menu. This gives you an overview of all of the component combinations available with your version of the program.

Select the system you want to use by double clicking on the image or on the list entry. The system will take on the parameters of the currently active project variant. You can view the selection as icons or in a list.

4.6   Enter System Parameters

This menu allows you to enter or change your solar system's component parameters.
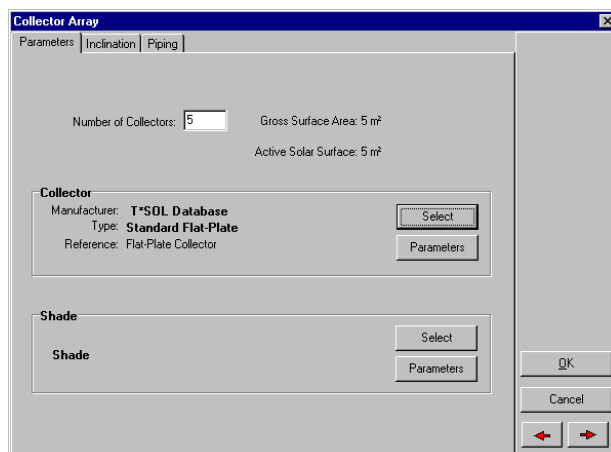

Figure 4.6.1:
Data entry dialog for system components – e.g.
collector array

A number of parameter dialogs are displayed, onto which all the necessary data is entered. Use the red arrow buttons in the bottom corner to move between each component's dialog window.

Another possibility for entering the parameters is via the **Main Dialog**. In the Main Dialog you can also use the red arrow buttons to move between the component dialog windows. You should also note that there may be a number of tabs for each component.

A quick way of reaching the individual parameters for the individual components is via the system schematic. Just position the mouse arrow over one of the components and double click or click with the right mouse key to get to the corresponding dialog (characteristics).

The **Basic Data** in respect of the climatic conditions and the hot water and heating requirements for the actual variant can be modified via the corresponding buttons allocated.

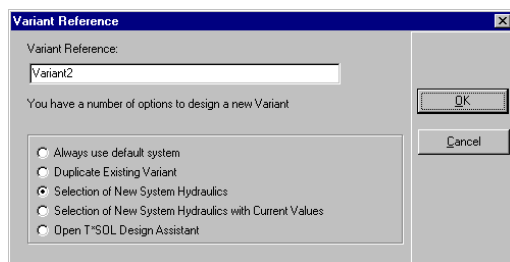## 4.7   Set Up a New Variant

Figure 4.7.1:
Data entry dialog for setting up a new variant

Within each named project you have the possibility of setting up as many variants as you wish, each containing different systems and components. You can open and work on up to six variants at any one time. The variants allow easy comparison of parameter choices while keeping the filing simple.

There are a number of options for setting up a new variant.

4.8   Simulation
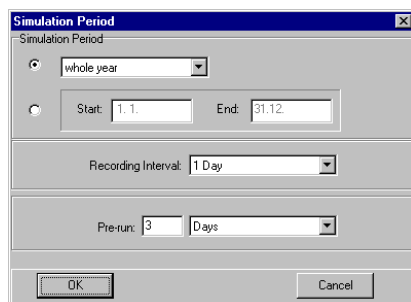
Figure 4.8.1:
Data entry dialog for simulation parameters

The size of the simulation interval sample varies between one and six minutes. What is decisive here is the system inertia resulting from the capacities and energy flows.

For the evaluation of the simulation results, it is often enough to work with values resulting from larger simulation intervals (hourly or daily).

Use the speed button at the top of the screen or the pull down menu to carry out a simulation for the project variant that is currently active.

If you go to the simulation dialog via the pull down **Calculations** menu, you are able to select the simulation period and the recording interval. Depending on the selected simulation period, a number of different recording intervals are offered.

Clicking on the **View** button allows temperature conditions to be observed graphically during the simulation. The exact time of each simulation step is shown in the status bar for the variant in the bottom left corner.

At the end of the simulation a selection dialog opens so that you can view the results (report or graphics) or carry out an economic efficiency calculation.

4.9   Economic Efficiency Calculation

Figure 4.9.1:
Data entry dialog for economic efficiency calculation

In order to carry out an economic efficiency calculation, the results of a simulation carried out over a period of one year must be available.

Click on the button, or access the dialog via the **Calculations › Economic Efficiency** menu. The parameters required to carry out an economic efficiency calculation are initially taken from the *Options › Default Settings menu*, which can be changed as required for the design of special systems. The simulation results are combined with the Site Data to carry out the calculations.

You are able to enter different values for each respective variant. If the changed values are to be used in the simulation results, a warning will appear before saving.

The following values are entered onto the **Parameters** worksheet (each worksheet is indicated by a dialog tab):

The *Lifespan* is the period given by the manufacturer as being the estimated operating life of a system. For the majority of solar systems this is between 10 to 20 years.

The *Interest on Capital* is the interest rate at which the capital for the investment is borrowed from a bank, or the interest that might be charged on the capital used.

The *Price Increase Rates* of the Running Costs and Energy (fuel costs) are important in calculating the Net Present Value.

Changes can be made to the **Investment** worksheet as follows:

The *Investment* can be entered as an absolute amount and as a specific investment cost in €/m² of collector surface area.

The *Subsidy* can be entered as an absolute amount, as a percentage of the investment and as a specific subsidy in €/m² of collector surface area. (Note: the currency used for the calculations in the program is dependent on the currency setting on your computer.)

The **Running Costs** worksheet includes the following parameters:

The *Fixed Running Costs* of the system can be entered as an annual amount or as a percentage of the investment in percent per annum.

The *Pump Running Costs* are the product of the running time produced by the simulation, the pump performance and the specific electricity costs.

From the **Savings** worksheet it is possible to change the *Specific Fuel Price* adopted from the **Options › Site Data** menu, if you want to design a special system.

By changing the values produced by the simulation for the *Solar Yield* and the *Fuel Savings* (the program will warn you before the changes are saved), you can for example determine at which values the system would be economically viable.

On the **Loan** worksheet up to three loans can be defined:

The *Loan Capital* is the amount of credit that is taken out.

The *Term* is the amount of years in which the loan has to be repaid.

In addition, either the *Annual Installment* or the *Loan Interest Rate* has to be entered. In each case the other field is blocked and calculated by the program.

The annual installment is the fixed annual amount with which the loan and interest are repaid over the agreed term.

The loan interest rate is the percentage of interest that has to be paid on the loan. If the loan interest rate if less than the capital interest rate, the loan takes on the function of a subsidy; if it is more, the total costs increase. With identical interest rates they remain the same.

Finally, one all the data has been entered, the Economic Efficiency Calculation provides figures for the Net Present Value of the system and the Cost of Solar Energy.
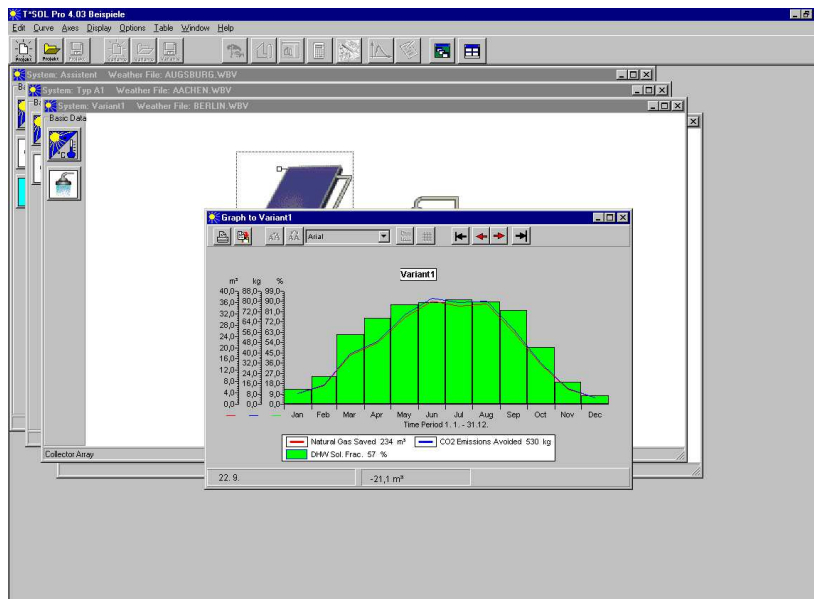
4.10 Evaluate Results

Figure 4.10.1:
Simulation results graph

T*SOL® offers you a two ways of evaluating the simulation results: graphical display and the Summary Report.

The graphical display allows you to select up to eight curves. A graphics window appears with its own menu, so that you can format the graphs as you wish. You can change the break-down of the values, the display interval (from 1 day up to 1 year), font type and style, colour and presentation (line graph or bar chart) of the curves and the guide lines.

The axes can be redefined and the graphic can be given a title. The values can be copied and pasted into other programs for further evaluation.

The **Summary Report** consists of a three-page overview including the system schematic, the entry data and the simulation results. The summary report can be printed via the page preview.

4.11   Options – Defaults – Regions & Units

4.11.1   Options – Defaults – Regions

Figure 4.11.1:
Options › Default settings ›
Localization: Select a region

T*SOL offers a regionalized version for the U.S. market, i.e., having set the option Region = U.S., the program offers not only u.s. units, but U.S. components, offered for sale in North America, only. Select the region Europe, if you wish to use components available there.

> !   The Design Assistant is available using the default setting region = Europe, only
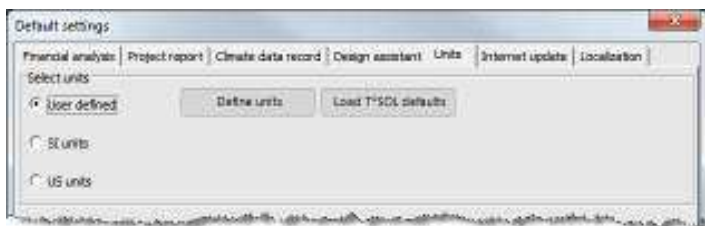
4.11.2   Options – Defaults – Unit Systems

Figure 4.11.2:
Unit system selection dialog

You can have result values displayed in different units in diagrams or project reports. Select between:

- **User-defined units:** While the T*SOL default units usually garantee a good display, you may use the button *define* to chanage individual units.

- **SI units:** All units are displayed according to the international units system. Some values might be presented in unusual low or high numbers.

- **US units:** All units are displayed in U.S. units. This is for lengths, temperatures, and energies.

Group	Abbreviation	Unit selection
Time	Time	s, min, h, d, a
Energy and Power	Thermal energy	J, kJ, MJ, Wh, kWh, MWh, Btu, kBtu, MBtu
	Electrical energy	J, kJ, MJ, Wh, kWh, MWh, Btu, kBtu, MBtu
	Thermal power	W, kW, MW, Btu/hr, kBtu/hr, MBtu/hr, GBtu/h
	Electrical power	W, kW, MW, Btu/hr, kBtu/hr, MBtu/hr, GBtu/h
	Reference energy	J, kWh, MWh, kBtu, MBtu
Dimensions	Lenght	mm, m, km, inch, ft, yd
	Area	m², mm², km², in², sq.ft
	Volume	l, m³, cu.ft, gal
Temperature	Temperature	°C, °F
	Temperature difference	K , deg .F
Other units	Volume flow	l/h, l/min, l/s, gpm
	Velocity	m/s, ft/s
	Weight	kg, lbs
Inverse units	1/Ref. Energy	kWh, kBtu
	1/Area	m² , sq.ft
	1/Volume fluid	l, gal
	1/Volume solid	m³, gal

5   Calculation Examples

Read the following two project examples and at the same time carry out the individual steps in the T*SOL® program.

You will find further project examples in the project folder, which is reached via the menu **File › Open Project** or by clicking on the button.
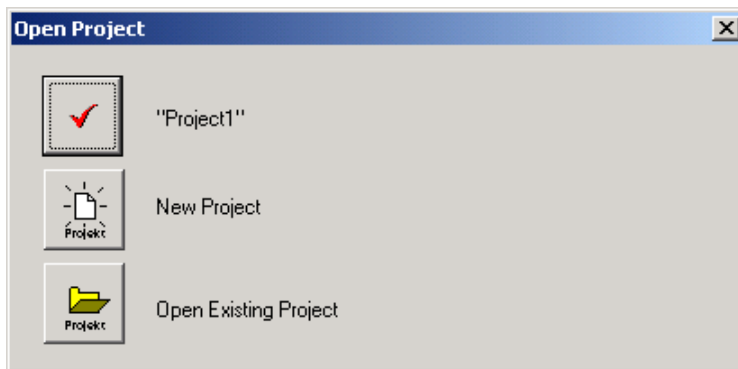
5.1   Set up a New Project

Figure 5.1.1:
Project selection dialog.

When you start T*SOL®, the first dialog window will prompt you to select the project you want to start with.

Click on the *New Project* button in the dialog. If, however, you have already started T*SOL®, you can reach the same stage via the **File › New Project** menu or by clicking on the button in the upper button bar:

Figure 5.1.2:
General Project Data entry dialog.
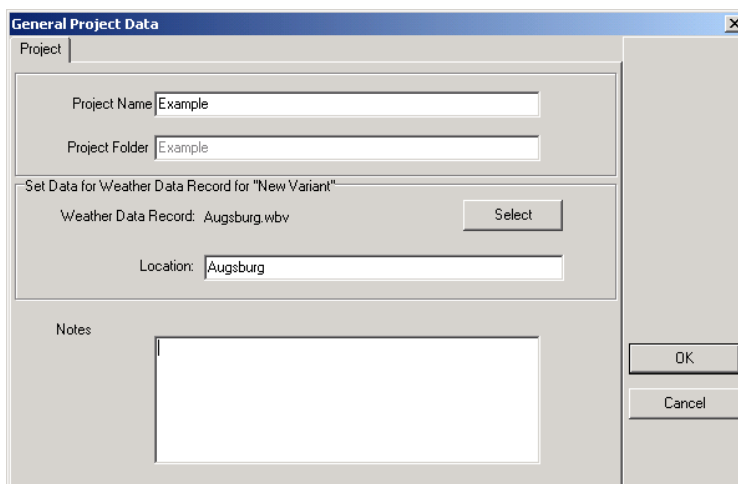
The project name that you enter in the first field is saved as the file name for the project, so you won't have any trouble finding it later on. On this Project Data dialog worksheet, you are already able to define a weather data record by clicking on *Select*. The selected weather data record will then be automatically loaded within this project for each new variant selected.

After confirming the project data with *OK*, a standard system is loaded and the system screen for Variant 1 appears with a diagram of the system.

From here you can start the Design Assistant by clicking on the button in the upper button bar. The system schematic diagram is now of secondary importance.
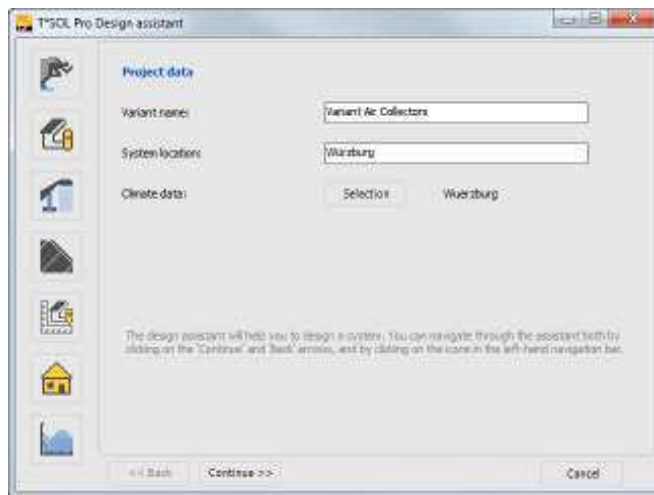
5.2   Using the Design Assistant

Figure 5.2.1:
Design Assistant, first sheet

The Design Assistant is there to help you establish the dimensions of a solar system. It should therefore be used if you are not sure of the size of the collector array and/or the size of the storage tank to be installed. The Design Assistant is an independent part of T*SOL® Professional and the results it produces can be accepted into the main part of T*SOL® - the system screen.

> !   The Design Assistant is available using the default setting region = Europe, only

Project Example:

A renovated block of 6 flats in Augsburg, Germany requires a solar system for hot water supply and the support of space heating. The building has a pitched roof with a 35 degree inclination facing south east and an area of 40 m².

Is this area large enough to provide the target 20% solar fraction of the total energy consumption?

This question is most easily answered by using the Design Assistant.

You are able to use the Design Assistant at any time when working on an existing project – either use the **Calculations › Assistant** menu, or (the faster option) click on the button in the upper button bar. You can then select to replace the dimensions of the currently active project variant with one of the sets of values calculated by the Design Assistant. If you want to design a new variant, use the **File › New variant** menu and click on the command *Open T*SOL Design Assistant*.

For our calculation example, however, we want to design a new project, as the questions regarding collector area and size of storage tank need to be answered right at the beginning of a project.

On the first sheet of the Design Assistant, you start by giving the planned solar system a name. The word *Variant* is used, as it is possible to calculate a number of different system variants within a project.

The weather data record for Augsburg has already been entered, as this was selected in the General Project Data dialog. However, this can be changed by clicking on the button *Weather*. Independent of the weather data record, the location of the building can also be entered, e.g. the street address where the solar system will be installed.

In order to reach a result, we now have to go through the individual worksheets of the Design Assistant, entering the information required. Use the buttons *Continue*, *Back* and *Cancel* at the bottom of the dialog to do this. You can also click on the icons on the left of the dialog to access the individual sheets direct.

5.2.1   System Selection

Figure 5.2.2:
Design Assistant amenities selection.

The next two sheets contain details on system selection. This depends on the planned use of the system. You will have to select whether the system is to be used to supply hot water and/or space heating. For the Project Example above, therefore, you should click on the circle to select *Space Heating*.
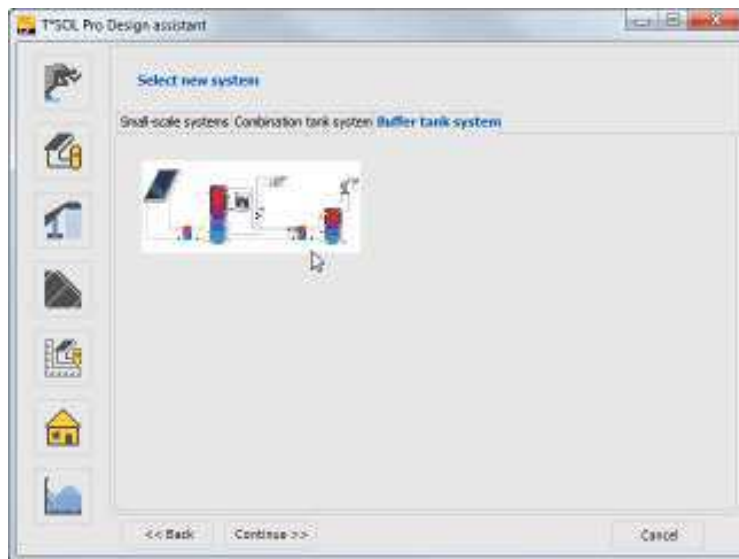
Figure 5.2.3:
Design Assistant system types
selection.

Depending on the selections made on this worksheet, the following sheet offers a selection of system configurations and types. The selection of the various systems is divided into small-scale, combination tank and buffer tank systems. Click on the tabs to view the systems available under each category.

To define the amount of collector area required, the Design Assistant makes use of a shortened simulation procedure on an hourly basis. This procedure is restricted to the use of simple system configurations. Design Assistant does not therefore contain all of the system configurations that you can access from the system screen via the **System › Select** menu.

Back to our Project Example: the requirement is for a solar system to provide hot water and support of space heating for a block of flats. We decide on the DHW System (2 tanks) with Space Heating Buffer Tank (Small-Scale Systems – A4, three tank system) and click on the corresponding diagram. This highlights the system and we click on *Continue*.

5.2.2   Define Consumption

Figure 5.2.4:
Definition of hot water requirement
in the Design Assistant.

Two worksheets need to be completed here: hot water and heating consumption.

You have a choice of two ways of entering the hot water consumption. If you know what the average daily consumption will be, you can click on the circle and then enter the amount direct. If you do not know, then you can enter the estimated or actual number of people that will be using the system. A figure for the absolute consumption will then be calculated based on the number of people via a pre-set specific consumption figure. The specific consumption per person can be entered and changed from the system screen via the menu **Options › Default Settings › Design Assistant**.

Our building contains 6 flats. If the calculation is based on 2.5 occupants per flat, this gives a total figure of 15 occupants for the block (enter 15 in answer to the question *No. of people to be supplied*?). As hot water secondary circulation is usual in many blocks of flats we should click on the corresponding circle, so that circulation losses depending on total consumption will be included in the calculation. The desired hot water temperature and the cold water temperature should be entered here and can also be pre-set under **Options**.

Click on the tab labelled **Space Heating** to get to the worksheet for the space heating requirements.

Our building has a floor space of 480 m², which we enter as the area to be heated in the first entry field. We also have the possibility here to enter the heating energy requirement (e.g. according to DIN 4701) or, as this value is often not known, to let the program calculate it via internal codes, after entering the building heating standard (this calculated value can then be seen from the system screen). In our case we need to remove the tick (by clicking on it) for *Is the space heating energy requirement known?* and then make the selections illustrated below.

To provide a figure for the annual space heating requirement, which T*SOL® calculates for every hour of the year, you will need to enter the standard external temperature.

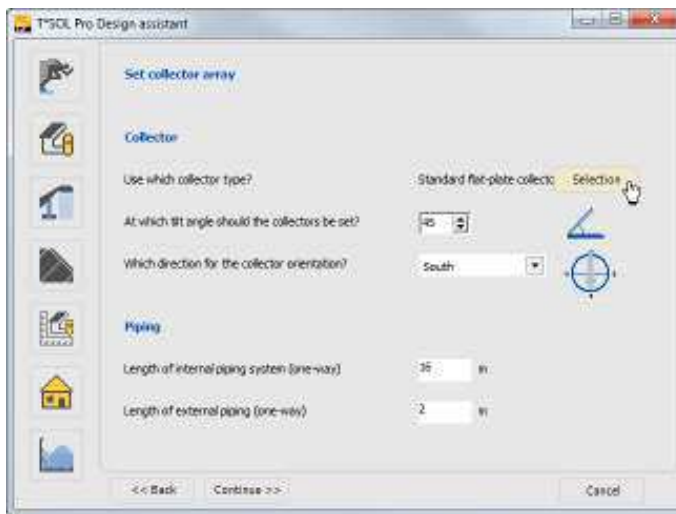### 5.2.3   Define Collector Array and Design Targets

Figure 5.2.5:
Definition of the collector array in the
Design Assistant.

To start with, the Design Assistant uses the standard flat-plate collector from the T*SOL® database. This corresponds to a simple collector with an area of 1 m². You can, however, select any collector of your choice from the database by clicking on the collector button or, from the system screen, select your preferred standard collector under **Options › Site Data**.

The tilt angle and orientation of the collector array need to be entered next. The values for the piping are based exclusively on the collector loop. The single length of piping should be entered. The heating losses and hydraulic resistance of the piping are calculated from these values.

After clicking on the *Continue* button, the Design Target needs to be entered. In our Project Example a solar fraction of 20% of the total energy consumption (hot water and space heating) is required. We have selected natural gas as our fuel for auxiliary heating.

By clicking on *Continue*, we are provided with a selection of storage tanks that the Design Assistant recommends for our system. Each of the recommended tanks can be changed by opening the database and making a new selection. For each of the three buffer tanks recommended, we can carry out a variation calculation by clicking on *Variation*.
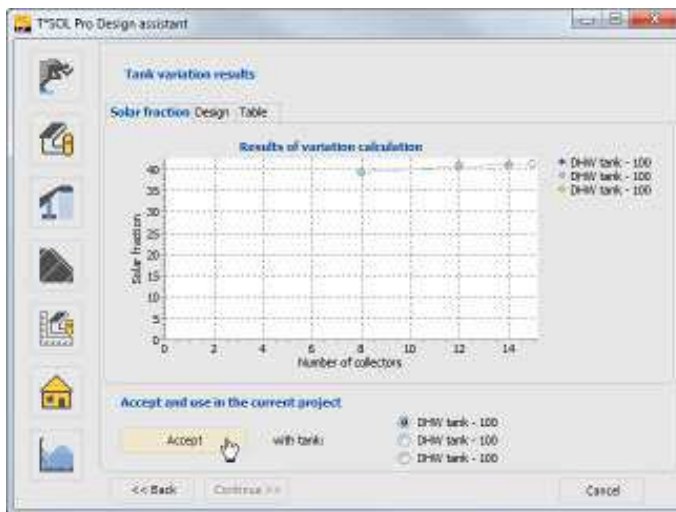
Figure 5.2.6:
Graph of simulation results in the Design Assistant.

This takes you to a graph of the simulation results, showing the number of collectors required for the three different buffer tank sizes. The collector number with which the target of a 20% solar fraction is reached is shown by a white symbol.

It can clearly be seen that with a 1000 litre tank the target of a 20% total solar fraction will not be reached. On the other hand, the difference between a 2000 litre and a 5000 litre tank is minimal.

The result is clearer still after clicking on *Continue* and the results are then shown in three bar charts.
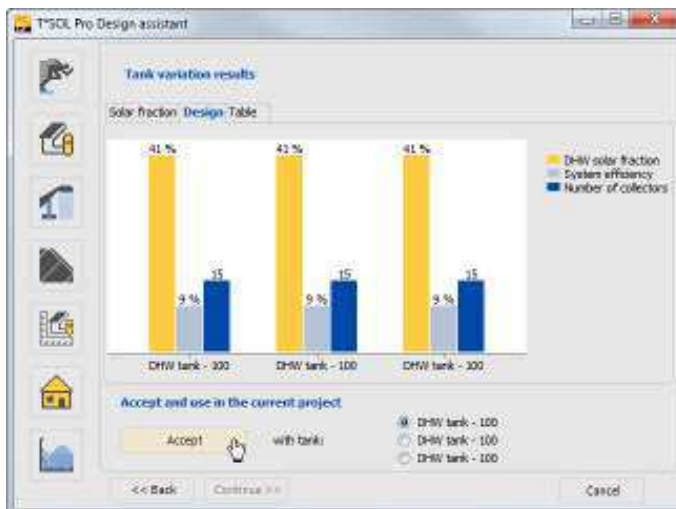
Figure 5.2.7:
Graphical display of simulation results in the Design Assistant.

Included in these charts, in addition to the solar fraction, is a further important evaluation figure, the system efficiency. With an increase in the tank volume, the system efficiency increases and the collector area reduces, with the solar fraction remaining constant.

Since in our Project Example a maximum roof area of 40 m² is available, the collector area even with a large tank volume is too large to fit onto the roof. What can be done?

Let us try again with better quality collectors – evacuated tube collectors.

We therefore click on the collector icon on the left hand side of the Design Assistant screen and this takes us back to the collector selection sheet (Set Collector Array). There we click on *Collector* and select the Standard Evacuated Tube collector from the T*SOL database, and otherwise change nothing, and then click on the icon with the steps on the bottom left of the screen. The results are now completely different.

With a much improved figure of 29% system efficiency, less than 30 collectors are required. We decide on the variant with the 2000 litre tank and click on *Accept into Project* to return to the system schematic screen. The data that has been entered in the Design Assistant has been transferred into the system on the system screen.

Back in the system screen it is now possible to carry out an immediate simulation (click on the Start Simulation button), or to enter new or change existing parameters.

5.3 Configuring a Solar System via the Main Menus

Project Example:

A solar system for the supply of hot water is required for a newly built bungalow in Aachen. The bungalow is to be home to a family of five.

- What size should the collector area be?

- At which tilt angle should the collectors be installed on the flat roof?

- How often does the temperature drop below 35 degrees centigrade in the storage tank?

- How much heating oil can we expect to save?

- Which other measures should be taken into account when building the house?

The following additional details are provided with the house plans:

- The bungalow's longitudinal axis is oriented from the south east to the north west.

- 240 m² floor space.

This type of solar system is frequently used for one and two family houses. As a rule, pre-configured systems are used here, as offered by many collector manufacturers. The configuration of number of collectors, storage tank and other components should then be entered into T*SOL®. For frequently used systems, you can save these as a standard project and then copy into a new project as required and simply change the pre-set data, such as location, collector tilt angle and orientation.

In this case, the calculations using T*SOL® mainly serve to determine the expected primary energy savings, as well as the system's solar fraction. An important result is also the proof that the system is not oversized. When a system is oversized this is shown by the maximum tank temperature frequently being reached, thus leading to high collector temperatures.
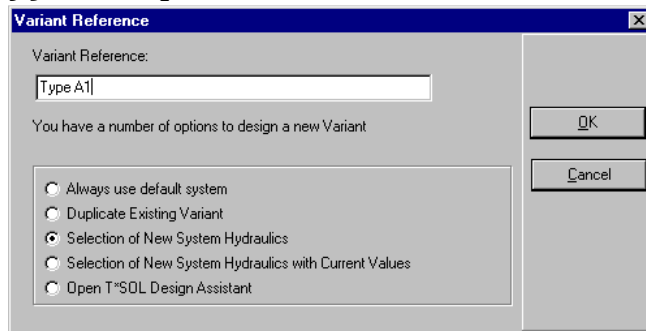
5.3.1   Design a New Variant

Figure 5.3.1:
Dialog for setting up a new variant.

We have already set up a project via the **File › New Project** menu (in this case it is the project named "Examples"). For the above Project Example you will need to set up a new variant of "Examples" via the **File › New Variant** menu. A dialog appears into which you can enter a *Variant Reference* and in which you can select the method for design. We name our variant TYPE A1 and select *…New System Hydraulics*.

After confirming with *OK*, the **Load System** screen opens. The amount and types of systems available for selection and simulation depends upon which of the T*SOL modules you have installed on your computer (Standard, Swimming Pool, SysCat). You can change between icons of the systems and a listing, in order to get an overview. We select the system labelled A1 and load it into our variant with a double click, or a single click and a click on OK, and we are then back in the system screen.

We now need to enter the specific parameters for the location, consumption and system components into the system we have selected. There are a number of ways of doing this:

- individual components can be accessed via the menu commands of the **System definition** menu;

- click on one of the components in the system schematic, to select the system component, and then double click with the left mouse key to get to the component dialog (or click just above or below the system to select the whole system, and then double click to get to the system dialog) or click to select the component/system and then click with the right mouse key and select **Characteristics** from the mini-menu;

- or click on the main dialog button to access the main dialog directly.
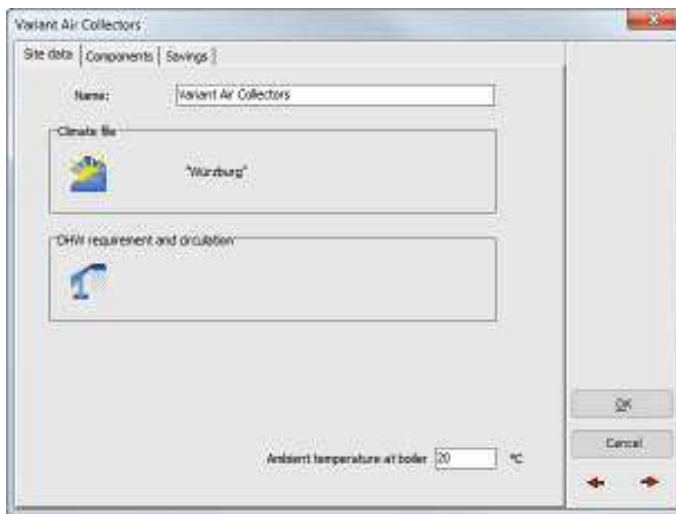
5.3.2 Define Parameters

Figure 5.3.2: Variant menu › System definition › Variant X

For the complete definition of a system, as required in our example, it is best to go direct to the **Main System Dialog**, as this will automatically take you through all the necessary dialogs. In the main dialog you can use the red arrow buttons in the bottom right hand corner to move between the various component dialogs.
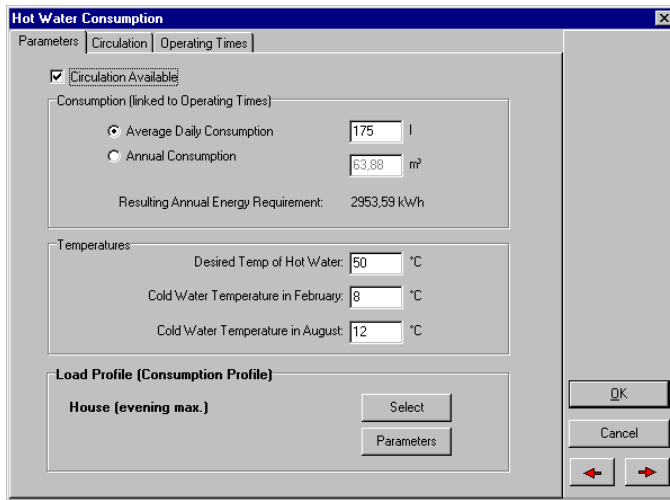
In the *Reference* entry field of the first worksheet in the main dialog, you can enter a new variant name, or amend an existing name. This reference, in this case Type A1, is the name that is shown in T*SOL's® blue title bar and is the reference under which you will be able to find the variant again, eg in the Load Variant dialog. The weather data is also loaded here, the hot water requirement is entered and the ambient temperature for the central boiler plant is defined. This temperature is the reference temperature for the calculation of storage tank losses and secondary circulation losses.

After loading the weather file for *Aachen* from the weather database for Germany (additional weather data for other countries can be installed from the CD), we click on the red arrow to go to the next dialog: **Hot Water Consumption**.

On the **Parameters** worksheet you enter the average daily consumption for the operating period given on the **Operating Times** worksheet - usually the average daily consumption over a year. At the same time, the total consumption for the operating period and the resulting energy consumption are shown. The total consumption figure is dependent on the values entered under Temperatures on the **Parameters** worksheet.

For our example of a bungalow in Aachen, we know that hot water is required for a family of 5. If we assume a high standard, say 35 litres per person per day, we get to a total of 175 litres per day at a temperature of 50 degrees centigrade. This daily consumption will not be spread out equally over the day, but will be required at certain periods in differing volumes. This pattern of use is illustrated in the *Consumption Profiles*. A number of different consumption profiles are available for selection from the database and these can be loaded via the *Select* button.

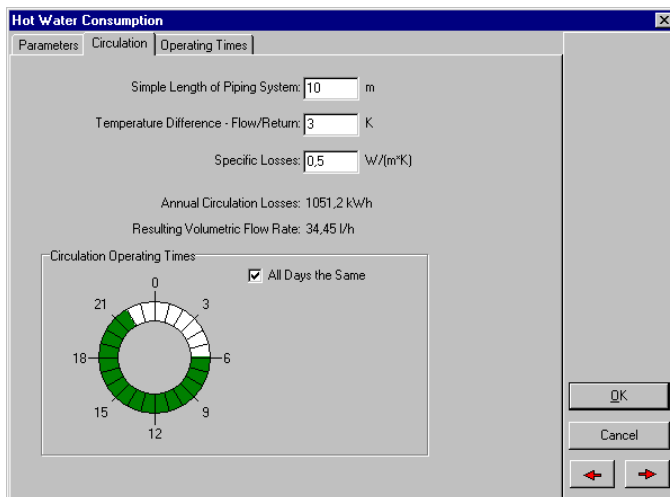Click on the *Parameters* button to check and make changes to the consumption profile.

Figure 5.3.3:
Hot Water Consumption dialog

Our bungalow will have a hot water secondary circulation system. You can take account of this by selecting *Secondary Circulation Available* at the top of the **Parameters** worksheet (Hot Water Consumption dialog). Once selected, a new worksheet will appear, labelled **Circulation**.

Figure 5.3.4:
Secondary Circulation worksheet from the
Hot Water Consumption dialog

On this worksheet, the circulation heat losses are calculated, based on the single length of piping and the specific losses. By changing the temperature difference you can adjust the volumetric flow rate resulting from the circulation pump. Click on the individual hours of the switching timer to adjust the daily running times for the pump. Deselect *All Days the Same* to individually adjust the daily running times for each day of the week.

On the final worksheet of this dialog, **Operating Times**, you can enter (independently from the Consumption profile settings) breaks in the hot water supply, e.g. during holiday periods. During the operating times that are deselected here, the consumption and circulation will be set at zero.

This completes the entries for hot water consumption and we click on the red arrow again to take us forward to the **Collector Loop Connection** dialog. From here you can change the *Volumetric Flow Rate* in the collector loop, as well as the mix of the heat conducting medium, eg in order to simulate a low flow system. In this case, the volumetric flow rate in the collector loop would be

between 10 and 20 l/m²/h. From the **Control** worksheet you can define the parameters for the collector loop pump control, which is set according to specified temperature differences.

By clicking again on the red arrow, or on the *Parameters* button, you come to the **Collector Array** dialog. In the *Collector* section of the **Parameters** worksheet, click on the *Select* button to go to the collector database, from which you can make a selection from the list of manufacturers and collector types. In the header bar, there are drop-down lists of manufacturers and collector types, which assist you in finding the product of your choice quickly and easily.
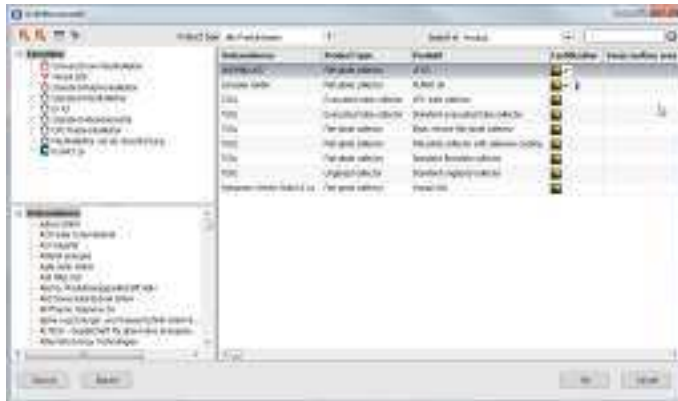

Figure 5.3.5:
Collector selection dialog

Click on the preferred collector, or select and click on OK, to incorporate the collector into your project design. Entering the number of collectors automatically gives the collector area. We decide to start with 7 collectors with a total active solar surface of 7 m². This is the active area that is available to convert the sun's radiation and which forms the basis of test institute calculations to determine the collector coefficient.

On the **Inclination** worksheet you will find the parameters for the orientation and tilt angle of the collector array. The *Azimuth Angle* is the horizontal deviation between the collector surface vertical and the geographical south in the northern hemisphere (or the north in the southern hemisphere). It is 0° when the surface is facing toward the sun's highest point (zenith). In our case the building is in the northern hemisphere and the building's longitudinal axis runs from south east towards the north west. If the collectors are also installed parallel to this axis, the collector vertical (perpendicular to the active surface) points towards the south west. The azimuth is, therefore, in our case the angle between the south and south west, that is +45 degrees.

As our example deals purely with hot water supply, we can install the collectors at a tilt angle to gain the maximum possible irradiation. The absolute values for irradiation are given at the bottom of the dialog. For a south west orientation, a tilt angle of 30 to 35 degrees results in maximum irradiation values. For the time being, it is however more effective to select the steeper angle. Thus you can answer the architects question regarding the tilt angle – 35 degrees from the horizontal. At a later stage, we will be able to optimize this angle by carrying out a number of simulations with different angles and then comparing the results.

In the case that you already have information regarding the length of piping from the water heating system to the roof, the single length should be entered on the **Piping** worksheet. If this value is not known, the pre-set values can be adopted.

Click on the red arrow to go to the next dialog, the **Bivalent Domestic Hot Water Tank**. As our calculation will be based on hot water consumption of 175 litres, we select a storage tank of double size, i.e. 350 litres, which you can load from the database by clicking on the *Select* button.

If you want to use a storage tank that is not included in the database, you are able to change the tank volume after loading. The tank will then be saved in the project with the data as amended.

We do not need to make any further entries for the storage tank, and the Control settings also remain unchanged. The pre-set value for the *Desired Temperature of Tank* of *0 K* (Kelvin) on the **Control** worksheet, means that the upper-tank temperature corresponds to the desired temperature of hot water, which, in this case, we set at 50 °C.

A further click on the red arrow brings us to the **Boiler** dialog. The architect's plans show a floor space of 240 m². As we need to define a heating boiler, but a calculation of the heating requirement is not available, we can estimate the required power at 240 m² * 50 W/m² = 12 kW and load a correspondingly sized heating oil boiler from the database (via the *Select* button). We leave the pre-set value for the boiler's *Nominal Output* unchanged.
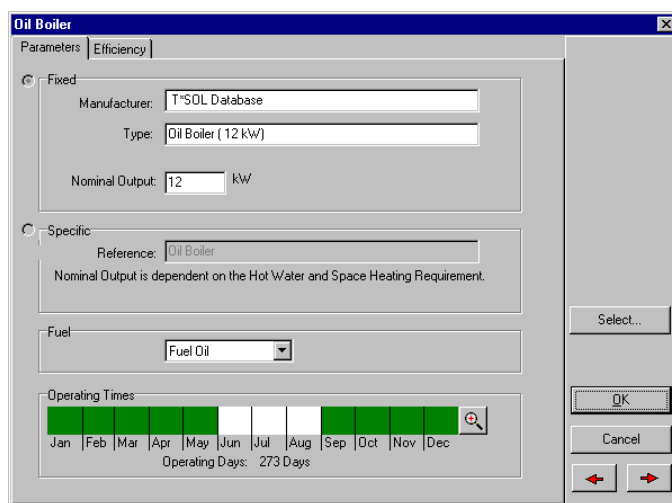

Figure 5.3.6:
Dialog for the definition of the boiler.

As we want the solar system to provide hot water in summer without the use of a boiler, we click on the months of June, July and August under *Operating Times*, (they change from green to white), so that boiler operation is halted during these months.

We have now reached the end of the dialog chain and can exit the main dialog by clicking on *OK*.

5.3.3   Simulation

After entering the parameters for your solar system, you are now in a position to calculate the system operating conditions over a period of a year by running a simulation. The simulation can be started in two ways: either click on the *Start Simulation* button in the button bar (calculator symbol) or via the main menu **Calculations › Simulation** (which will open the **Simulation Period** dialog prior to simulation).

On the **Simulation Period** dialog, the *Simulation Period* is pre-set at 1 whole year, and the results *Recording Interval* at 1 day. Both settings will suffice for our first simulation. *The Pre-run* of 3 days means that the simulation runs for 3 days before the first data is recorded (on 1 January).

Simulation, with the pre-set values, can be started direct by clicking on the *Start Simulation* button in the button bar.

From the **Simulation Period** dialog, the simulation is started by clicking on *OK*. Once the simulation has started you are able to click on the *View* button and observe the system's

temperature fluctuations. Click on the button again to return to fast mode and once the simulation has been successfully completed, the following dialog will appear:
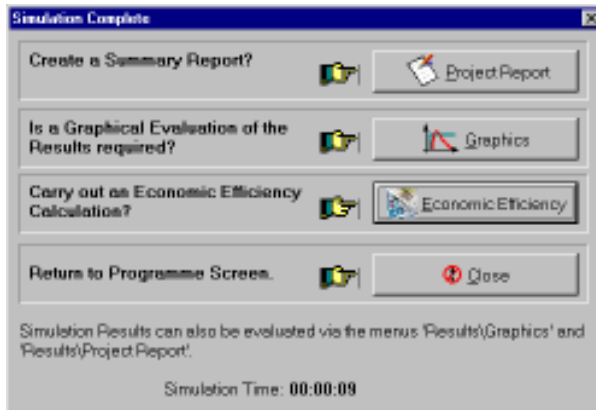
Figure 5.3.7:
Selection dialog at end of simulation.

5.3.4   Evaluation using Graphics Presentation

An initial evaluation of the system is always possible via the *Project Report*. If you create this report, the first page will show a summary of the most important dimensions, the solar fraction and the system efficiency. On this page we are also given the answer to the question of heating oil savings: the solar system makes annual savings of approx. 400 litres of heating oil.

On the second page, the values for the basic parameters are given and on the third page there are two graphics to assist in evaluation of the system.

The first graphic shows the course of the solar contribution over a period of 1 year in weekly intervals. The second graphic shows the maximum temperatures that the collectors reach on every day of the year. If you experience difficulties in printing these graphics with your printer, you can produce the report in PDF format using Acrobat Reader® via the **Options › Site Data › Project Report** menu. Once a report has been created it can be accessed via the **Results › Project Report** menu.

In order to answer the question regarding daily storage tank temperature, click on the *Create Graph* button or go to the **Results › Graphics** menu.
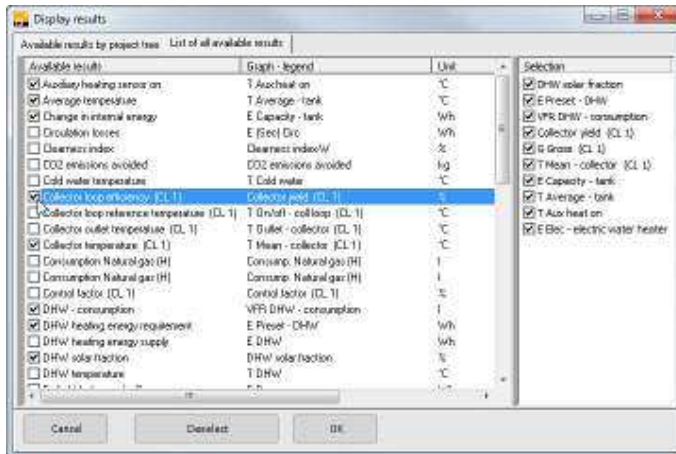
Figure 5.3.8:
Selection dialog to produce a
results graph

First of all, you select from the results that are available for each component listed in the project tree in the left-hand section. With the Bivalent DHW Tank, information on the upper-tank temperature is given if *Sensor: Auxiliary Heating On* is selected.
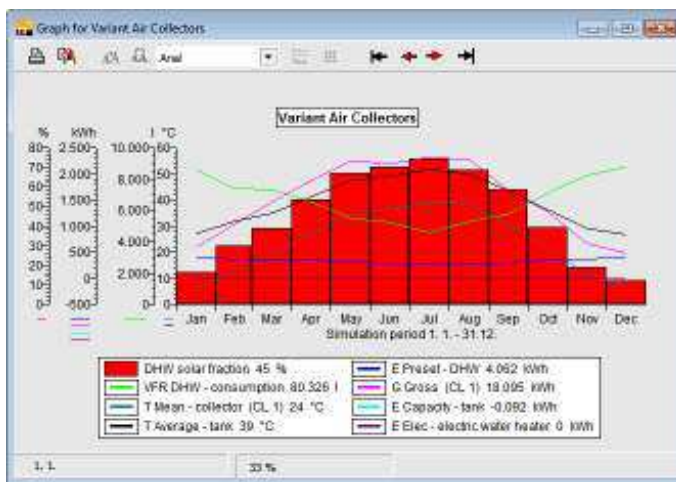
Figure 5.3.9:
Graphic presentation of
simulation results

On clicking OK, a graph is produced plotting the mean monthly temperatures. Daily temperature values can be set by double-clicking on the x-axis or, via the **Axes › X-Axis** menu.
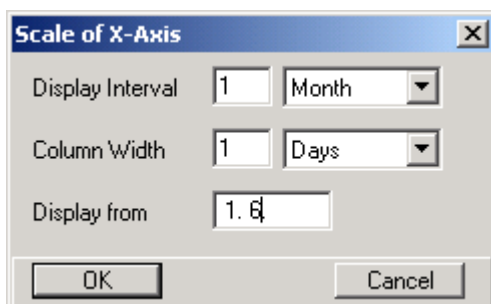
Figure 5.3.10:
Sizing the x-axis for a daily temperatures graph

You can select the *Display Interval* and the value for the *Column Width* here. With a setting of Month, Days and *Display from:* 1.6, as illustrated above, the daily tank temperature is shown from

1st June. You can change the display interval with the red arrow button and jump to the next month.

The graph therefore gives the answer to the question of the number of days that the tank reaches a temperature of 35 degrees. The evaluation is even simpler if you convert the graph into a table via the **Table** menu.

A more precise measure of the temperature course can be gained if the temperature break-down is shown in hourly intervals. However, in order to do this it is necessary to record the values in hourly intervals during simulation. Go back to the **Calculations › Simulation** menu and set the *Recording Interval* at 1 hour. Carry out a new simulation and then you will be able to study temperature changes by the hour! To do this, select a *Display Interval* of 1 day for the x-axis.

Continue with this example and consider how the number of days can be reduced in which the temperature falls below 35°C. Change individual parameters, such as storage tank size, tilt angle and collector area! Run another simulation and evaluate the results.

Finally, the architect is asking you about additional building requirements. Recommend that hot water connections for a washing machine and dishwasher be built into the system. With these machines the hot water consumption is increased by 20-40 litres daily, which can be supplied by the solar system, and therefore save valuable energy.

6   MeteoSyn

With the **MeteoSyn** (meteorological synthesis) climate generator you can produce the hourly data required to simulate a solar system in T*SOL from monthly mean values for radiation and temperature.

You can open the four dialog windows in succession using the **Continue** and **Back** buttons, or you can click on the corresponding icon in the navigation bar.

Start

Location Data

Monthly Values

Hourly Values

6.1   Welcome
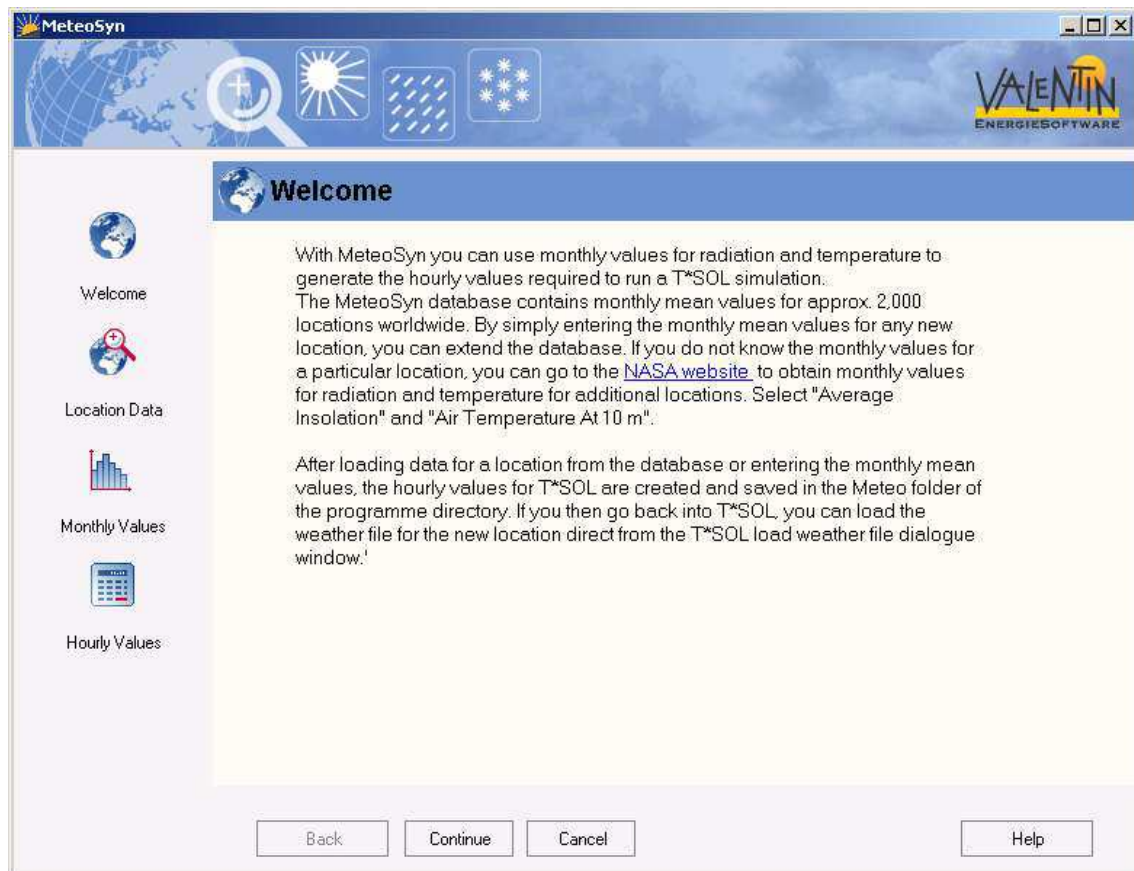
A detailed description of **MeteoSyn** and how it is used with T*SOL is given in the dialog window, which also contains a link to a website where you can obtain additional weather data.

6.2   Location Data

This is where you select the location you want to generate weather data for. You can:

- load a location from the database delivered with the program
- or you can create a new location.

You are only able to save a location in hourly format for use in the MeteoSyn database if you select **Define New Location.** If you select **Location from Database**, you will need to select the country and location from the lists provided. The weather data record generated for T*SOL is then created in either case in the **Hourly Values** dialog. The database delivered with the program contains monthly values for approximately 2,000 locations worldwide.

Location names that appear in **green** are user-defined locations, which can be amended and deleted.

You should always enter the county/state and postal/zip code, as these will be helpful when you want to use the sort facility in T*SOL's load weather data file dialog.

You will also need to enter the **Lowest Outside Temperature.** This value is required to calculate the annual heating energy requirement. In Germany the DIN 4701 standard ambient temperature should be entered. Otherwise the lowest daily average temperature, e.g. as used in sizing the heating system.

The **Temperature Range** is the **Difference** between the highest monthly average value for the highest hourly daily temperature and the lowest monthly average value for the lowest hourly daily temperature. The monthly mean values for the highest hourly daily temperature - or the monthly mean values for the lowest hourly daily temperature - is calculated from the hourly temperature values, where the lowest or highest hourly temperature is determined for each day and the average for each month is then calculated.

Temperature Range   =

> Monthly max($_j$ (Daily max ($T_{i,j,k}$)) / (Days per month))
>
> -
>
> Monthly min($_j$ (Daily min ($T_{i,j,k}$))/ (Days per month))

with **i** as the hourly, **j** as the daily and **k** as the monthly running index.

A **Time Zone** is an area in the world where the same time is valid. Ideally, they run along the degrees of longitude from the North/South Poles. For political reasons, however, the time zones for many countries deviate from the ideal time zone. The actual time zone for the location needs to be entered.

In MeteoSyn, time zones are counted from 0 westwards up to 23.

Greenwich Mean Time (GMT) = time zone 0

Central European Time (CET) = time zone 23

Click on **i** (next to the Time Zone field) for a map showing the world's time zones.

6.3   Monthly Values

The monthly values are shown here, if the locations come from a database.

If you want to define a **New Weather Data** you should enter the values here and then save the location.

Only user-defined locations can be deleted or overwritten.

If you have selected **Define New Location** in the previous dialog window, you can enter the **Data Source** in the input field provided. This entry then appears in the project report.

If known, you can enter the **Measured Period (Years),** which should be input in whole years. This period is also shown in T*SOL's load weather data file dialog and appears in the project report.

Monthly mean values should be entered in W/m² under **Global Radiation**.

Continue to the **Hourly** dialog to create a T*SOL weather data record.

6.4   Hourly Values
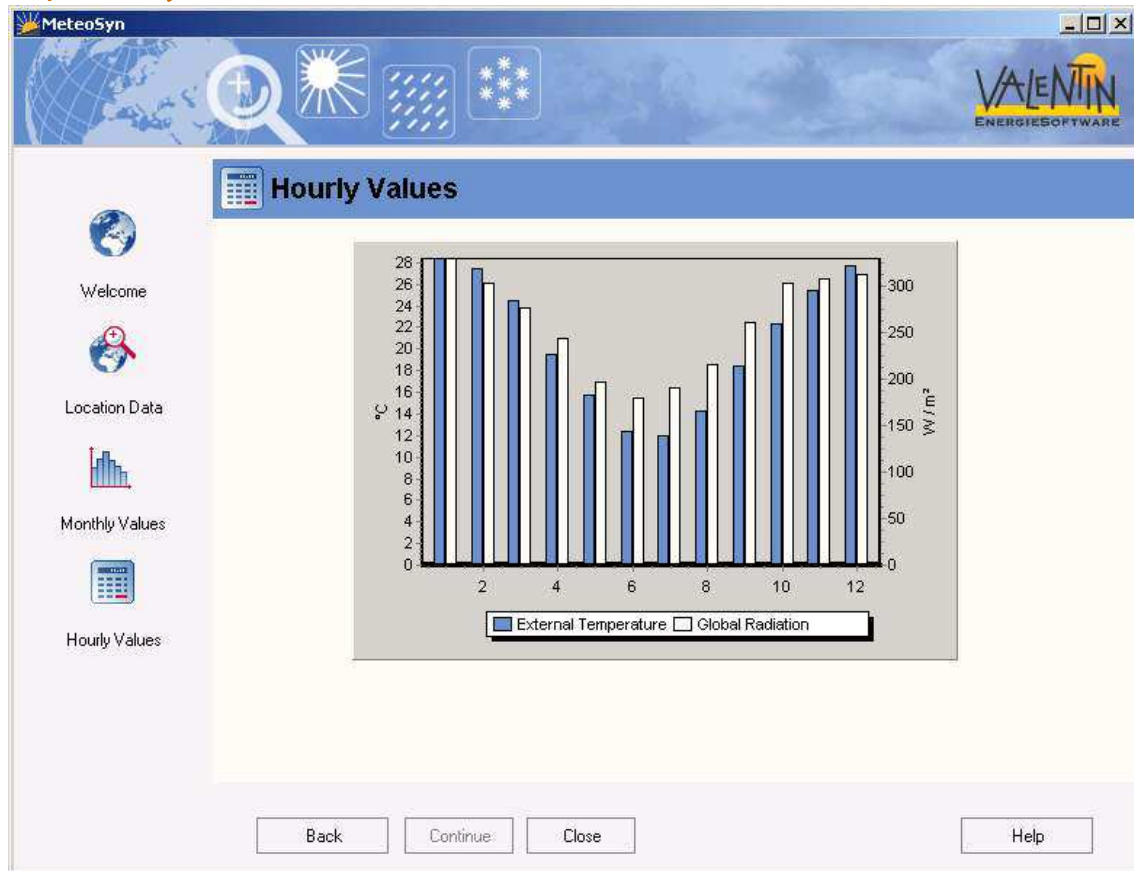
In this dialog you will need to save the weather location that you have created. When you confirm by clicking on **Save,** hourly weather data is generated in file format with the ending **.wbv,** and this is saved into T*SOL's standard weather directory.

If you then go back into T*SOL, you can load the newly created weather file directly from T*SOL's load weather data file dialog.

This file, containing the hourly values required to carry out a simulation with T*SOL or PV*SOL, remains permanently in the **Meteo** directory. The file appears in the Select Weather File dialog, automatically under the country name that is selected in the MeteoSyn Location Data (5.2) dialog.

7   Appendix

7.1   Heat Transfer Coefficient Overview

This table matches the building construction and design types with heat transfer coefficient values. The lower the U value, the less heat transmission losses are due, which make one part of the heating demand.

➔ See for reference: 4.2 Enter Site Data

Construction Type	Design type	Insulation	U value [W/K]
External Wall	heavy	high	0,22
External Wall	heavy	standard	0,39
External Wall	heavy	uninsulated	1,70
External Wall	light	high	0,13
External Wall	light	standard	0,17
External Wall	light	uninsulated	0,22
External Wall	medium	high	0,23
External Wall	medium	standard	0,43
External Wall	medium	uninsulated	3,05
Ground	light/medium/heavy	high	0,58
Ground	light/medium/heavy	standard	1,09
Ground	light/medium/heavy	uninsulated	8,42
Ground floor heating	light/medium/heavy	high	0,30
Ground floor heating	light/medium/heavy	standard	0,58
Ground floor heating	light/medium/heavy	uninsulated	8,42
Roof	heavy	high	0,16
Roof	heavy	standard	0,24
Roof	heavy	uninsulated	4,32
Roof	light/medium	high	0,13
Roof	light/medium	standard	0,18
Roof	light/medium	uninsulated	3,16
Roof with cooling	heavy	high	0,16
Roof with cooling	heavy	standard	0,24
Roof with cooling	heavy	uninsulated	4,32
Roof with cooling	light/medium	high	0,13
Roof with cooling	light/medium	standard	0,18
Roof with cooling	light/medium	uninsulated	3,16

7.2 Hot Water Demand Tables ASHRAE

ASHRAE 1991 Applications Handbook - Chapter 44, Service Water Heating

Table 7 - Hot Water Demands and Use for Various Types of Buildings

Type of Building	Maximum Hour	Maximum Day	Average Day
Men's dormatories	3.8 gal (14.4 L)/student	22.0 gal (83.4 L)/student	13.1 gal (49.7 L)/student
Women's dormatories	5 gal (19 L)/student	26.5 gal (100.4 L)/student	12.3 gal (46.6 L)/student
Motels: No. of units[a]			
20 or less	6.0 gal (22.7 L)/unit	35.0 gal (132.6 L)/unit	20.0 gal (75.8 L)/unit
60	5.0 gal (19.7 L)/unit	25.0 gal (94.6 L)/unit	14.0 gal (53.1 L)/unit
100 or more	4.0 gal (15.2 L)/unit	15.0 gal (56.8 L)/unit	10.0 gal (37.9 L)/unit
Nursing homes	4.5 gal (17.0 L)/bed	30.0 gal (113.7 L)/bed	18.4 gal (69.7 L)/bed
Office buildings	0.4 gal (1.5 L)/person	2.0 gal (7.6 L)/person	1.0 gal (3.8 L)/person
Food service establishments:			
Type A - full meal restaurants and cafeterias	1.5 gal (5.7 L)/max meals/hr	11.0 gal (41.7 L)/max meals/hr	2.4 gal (9.1 L)/max meals/hr
Type B - drive-ins, grills, luncheonettes, sandwich and snack shops	0.7 gal (2.6 L)/max meals/hr	6.0 gal (22.7 L)/max meals/hr	0.7 gal (2.6 L)/max meals/hr
Apartment houses: No. of apartments			
20 or less	12.0 gal (45.5 L)/apt.	80.0 gal (303.2 L)/apt.	42.0 gal (159.2 L)/apt.
50	10.0 gal (37.9 L)/apt.	73.0 gal (276.7 L)/apt.	40.0 gal (151.6 L)/apt.
75	8.5 gal (32.2 L)/apt.	66.0 gal (250 L)/apt.	38.0 gal (144 L)/apt.
100	7.0 gal (26.5 L)/apt.	60.0 gal (227.4 L)/apt.	37.0 gal (140.2 L)/apt.
200 or more	5.0 gal (19 L)	50.0 gal (195 L)/apt.	35.0 gal (132.7 L)/apt.
Elementary schools	0.6 gal (2.3 L)/student	1.5 gal (5.7 L)/student	0.6 gal (2.3 L)/student
Junior or senior high schools	1.0 gal (3.8 L)/student	3.6 gal (13.6 L)/student	1.8 gal (6.8 L)/student

[a] Interpolate for intermediate values.   [b] Per day of operation.

Table 8 - Hot Water Demand per Fixture for Various Types of Buildings
(Gallons of water per hour per fixture, calculated at a final temperature of 140° F)

per ASHRAE 1991 Applications Handbook - Chapter 44, Service Water Heating

	Apartment House	Club	Gym-nasium	Hospital	Hotel	Industrial Plant	Office Building	Private Residence	School	YMCA
1. Basins, private lavatory	2	2.6	2	2	2	2	2	2	2	2
2. Basins, public lavatory	4	6	8	6	8	12	6	-	15	8
3. Bathtubs	20	20	30	20	20	-	-	20	-	30
4. Dishwashers[a]	15	50-150	-	50-150	50-200	20-100	-	15	20-100	20-100
5. Foot basins	3	3	12	3	3	12	-	3	3	12
6. Kitchen sink	10	20	-	20	30	20	0	10	20	20
7. Laundry, stationary tubs	20	28	-	28	28	-	-	20	-	28
8. Pantry sink	5	10	-	10	10	-	10	5	10	10
9. Showers	30	150	225	75	75	225	30	30	225	225
10. Service sink	20	20	-	20	30	20	20	15	20	20
11. Hydrotherapeutic showers				400						
12. Hubbard baths				600						
13. Leg baths				100						
14. Arm baths				35						
15. Sitz baths				30						
16. Continuous-flow baths				165						
17. Circular wash sinks				20	20	30	20		30	
18. Semicircular wash sinks				10	10	15	10	15		
19. DEMAND FACTOR	0.30	0.30	0.40	0.25	0.25	0.40	0.30	0.30	0.40	0.40
20. STORAGE CAPACITY FACTOR[b]	1.25	0.90	1.00	0.60	0.80	1.00	2.00	0.70	1.00	1.00

[a] Dishwasher requirements should be taken from this table or from manufacturer's data for model to be used, if this is known.

[b] Ratio of storage tank capacity to probable maximum demand/hr. Storage capacity may be reduced where an unlimited supply of steam is available from a central street steam system or large boiler plant.

For more up-to-date information on usual hot water demand and many other consumption references, see http://www.ashrae.org/ and the publications of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

7.3   List of Adjustable Parameters

With reference to system B5, swimming pool and combination tank system for hot water and heating

Components	Parameters	Default Value
System	Item	Variant ...
	Ambient temperature	20 °C
Control	DHW priority switching	no
Savings	Reference system	no
	Efficiency	78 %
	Fuel	Natural gas H
Climate	File	Berlin
	Location	Berlin
Hot water	Consumption	160 l/d
	Target temperature hot water	50 °C
	Cold water temperature February	8 °C
	Cold water temperature August	12 °C
	Profile	Detached house evening peak
	Circulation	no
Circulation	Simple length piping	10 m
	Temperature difference	3 K
	Specific losses	0,3 W/(m*K)
	Operating times all days equally	yes
	Daily operating times	6 - 22 hours
Operating times	Operating times DHW preparation	365 d
Heat		
Heat requirement	Standard building heat flow requirement	6 kW
	Heated effective area	130 m²
	Inside room temperature	21 °C
	Standard outdoor temperature	-12 °C
	Heating limit temperature	14 °C
	Construction type	Medium-heavy building
External heating	Relation window area / gross floor area N / O / S / W	2 / 5 / 10 / 7 %
	Window type	Double thermopane glazing
	Inside external heating amount	5 W/m²
Heating	Operating times	August - May
	Reduced times all days equally	yes
	Reduced times	23 - 6 hours
	Reduction by	5 K

Components	Parameters	Default Value
Connection Collector Loop		
Collector loop	Heat transfer medium	Water-glycol mixture
	Glycol share	40 %
Combination tank	Volume flow	40 l/h/m² collector area
	Collector loop pump on	8 K
	Collector loop pump off	3 K
Swimming pool	Volume flow	40 l/h/m² collector area
	Collector loop pump on	8 K
	Collector loop pump off	3 K
	External heat transfer medium	
	Temperature difference	5 K
Control	Sequence of connections	1. Swimming pool 2. Combination tank
Collector Array	Number of collectors	12
Orientation	Orientation angle	30 °
	Azimuth angle	0 °
Piping	Simple pipe length	
	inside	8 m
	outside	1 m
	between collectors	200 mm/collector
	Thermal conductivity of insulation	
	inside	0,045 W/(m*K)
	outside	0,045 W/(m*K)
	between collectors	0,045 W/(m*K)
	Nominal size of piping	
	Manifold	18 mm
	between collectors	15 mm
	Thickness of insulation	
	inside	20 mm
	outside	20 mm
	between collectors	20 mm
Collector	File	Standard flat plate collector 1 m²
Shading	File	none
Storage Tank	Type	Combination tank (int. heat exchanger)
	Volume	800 l
	Number	1
	Relation height / diameter	2
	Insulation	
	Strength	100mm

Components	Parameters	Default Value
	Thermal conductivity	0,045 W/(m*K)
Control	Target temperature rel. to DHW target temperature	10
	Auxiliary heating	
	Limited loading times	no
	Switch-on temperature	-3 K
	Switch-off temperature	3 K
	Maximum temperature limit	90 °C
	Switch on deflector valve	5 K

Auxiliary heating	Type	Gas condensing boiler
	Rating	9 kW
	Fuel	Natural gas H
	Operating times	365d
Efficiency	Heating	
	Efficiency	91 %
	with return temperature	60 °C
	Efficiency	101 %
	with return temperature	30 °C
	DHW heating	70 %

Heating Loop	high temperature heating Loop	
	Flow temperature	60 °C
	Return temperature	40 °C
	Low temperature heating Loop	
	Flow temperature	40 °C
	Return temperature	25 °C
	Percentage of HT loop	0 %

Swimming pool	Type	Open-air pool
	Freshwater intake	83,33 l/d
	Number of bathers	2 /d
	Auxiliary heating	no
	Freshwater temperature February	8 °C
	Freshwater temperature August	10 °C
	Season	15.5. - 15.9.
	Operating start 10 days earlier	yes
	Refill pool	no
Pool	Pool shape	Rectangular
	Length	8 m
	Width	4 m
	Average depth	2 m
	Tile colour	Light blue
	Wind protection	Partly available
	Geographical environment	open

Components	Parameters	Default Value
	Target temperature	22 °C
	Max. swimming pool temperature	32 °C
	Covering available	no
Covering	Eff. Swimming pool covering	90 %
	Type of covering	Shutters non-transparent
	Covering times all days equally	yes
	Daily covering times	19 - 7 hours
Room climate	Room temperature	25 °C
	Rel. humidity	60 %
Solar yields	Including energy input	Complete
	Considered up to	28 °C

7.4   ITW System Layout

This **solar system with combination storage tank for hot water and space heating** is labelled an **ITW system layout**. This means that this combination storage tank and, where available, its controller have been measured and tested by the Institute for Thermodynamics and Heat Engineering (ITW) at the University of Stuttgart.

In the T*SOL mathematical model, the system parameters have been adjusted by parameter identifications such that the simulation results agree with the measurements.

The adjusted parameters in this system are therefore fixed and not changeable. In this system, this concerns the entire storage tank, the control parameters of the collector array, and the performance controller of the collector loop pump.

As a result of testing by the ITW and the subsequent validation procedure for the simulation, this system holds the status of a "tested company system".

Manufacturer	Test report no.	Tested components
Broetje GmbH	04STO98 and 03CTR08	Combination storage tank and matching controller
BBT Thermotechnik (Buderus)	04STO98 and 03CTR08	Combination storage tank and matching controller
Feuron GmbH	03STO94	Combination tank
Ratiotherm GmbH	03STO91	Combination storage tank and matching controller
Teufel und Schwarz GmbH	02STO83, 02CTR07, and 03CTR09	Combination storage tank and matching controller
Wagner Co. GmbH	03 STO88 and 03CTR11	Combination storage tank and matching controller
Max Weishaupt GmbH	04STO97	Combination storage tank and matching controller

7.5   Company Systems

7.5.1   Solahart Systems
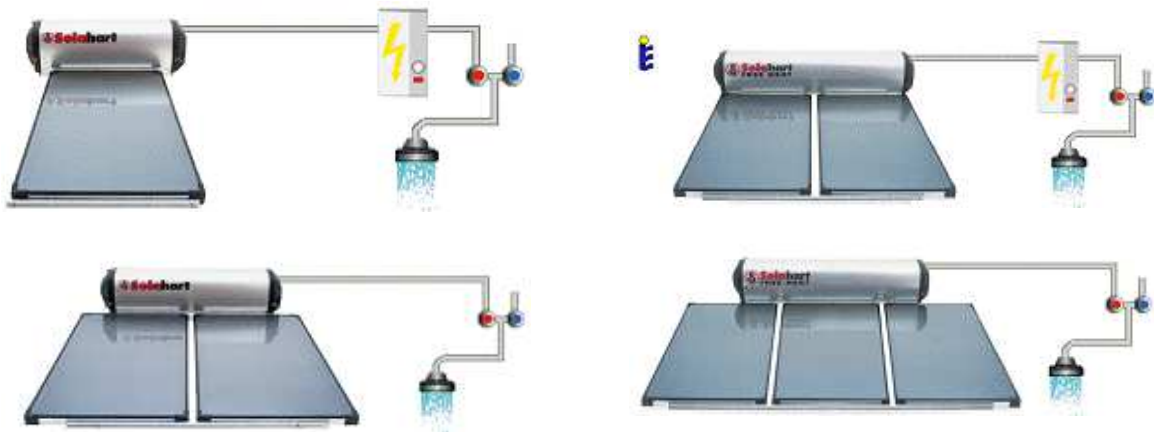
These system types are exclusively offered by Solahart. They comprise thermosyphon systems with optional downstream flow heater. Further information can be obtained from **www.solahart.com**.

7.5.2   Viessmann Systems
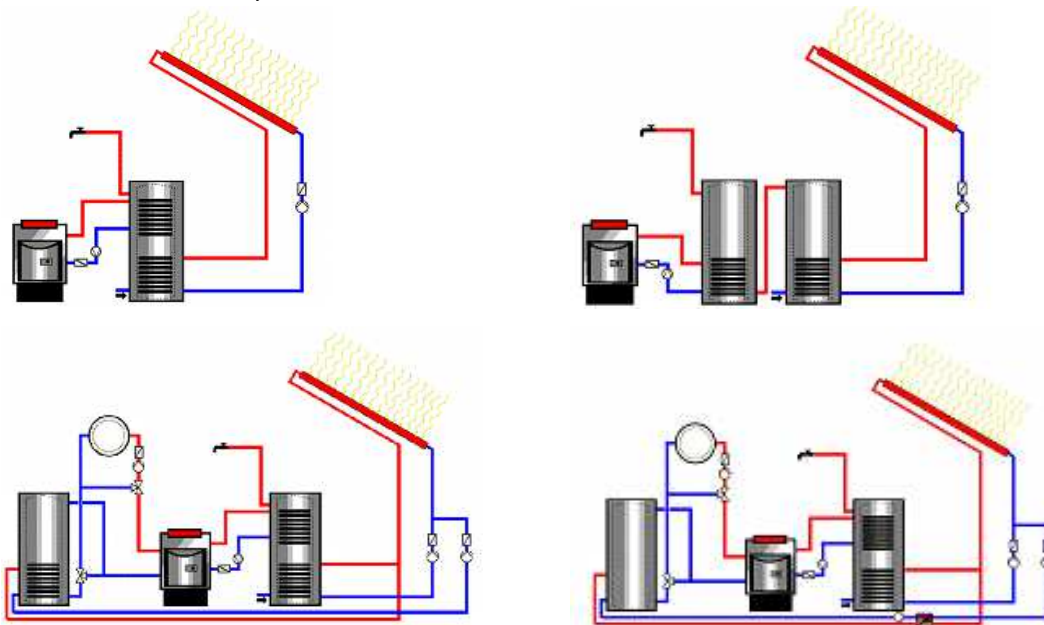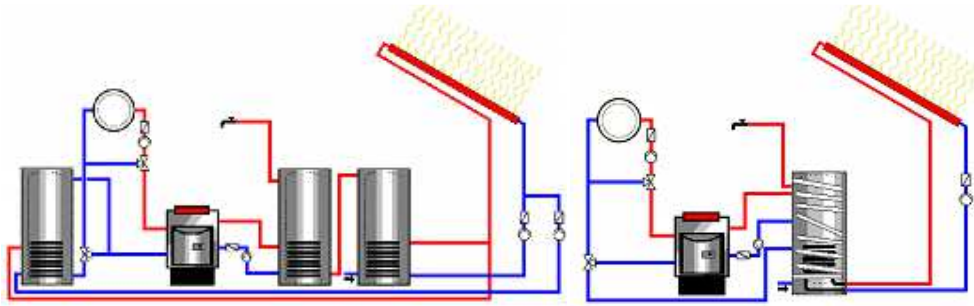
These system types are exclusively offered by Viessmann. Viessmann collectors, storage tanks, and condensing boilers can be individually selected. Further information can be obtained from **www.viessmann.com**.

7.5.3   **Wagner Systems**
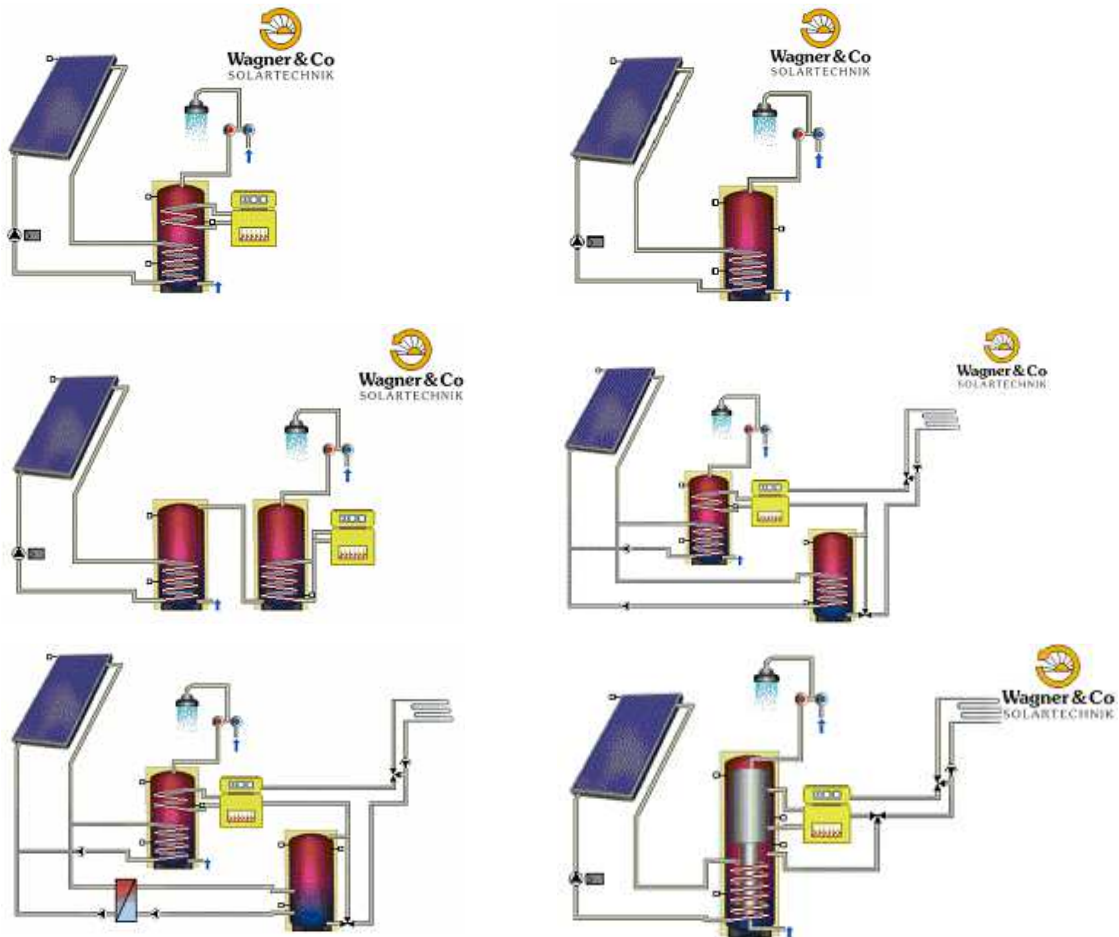
 These system types are exclusively offered by Wagner Solartechnik. Wagner collectors, storage tanks, and condensing boilers can be individually selected. Further information can be obtained from **www.wagner-solartechnik.de**.

7.5.4 Beretta Sylber und Vokera Systems

BER A1

BER A10

BER A3

BER A5.2

BER B.1

BER B.3

BER B5.2

SYL A1

SYL A10

SYL A3

SYL A5.2

SYL B.1

SYL B.3

SYL B5.2

VOK A1

VOK B.1
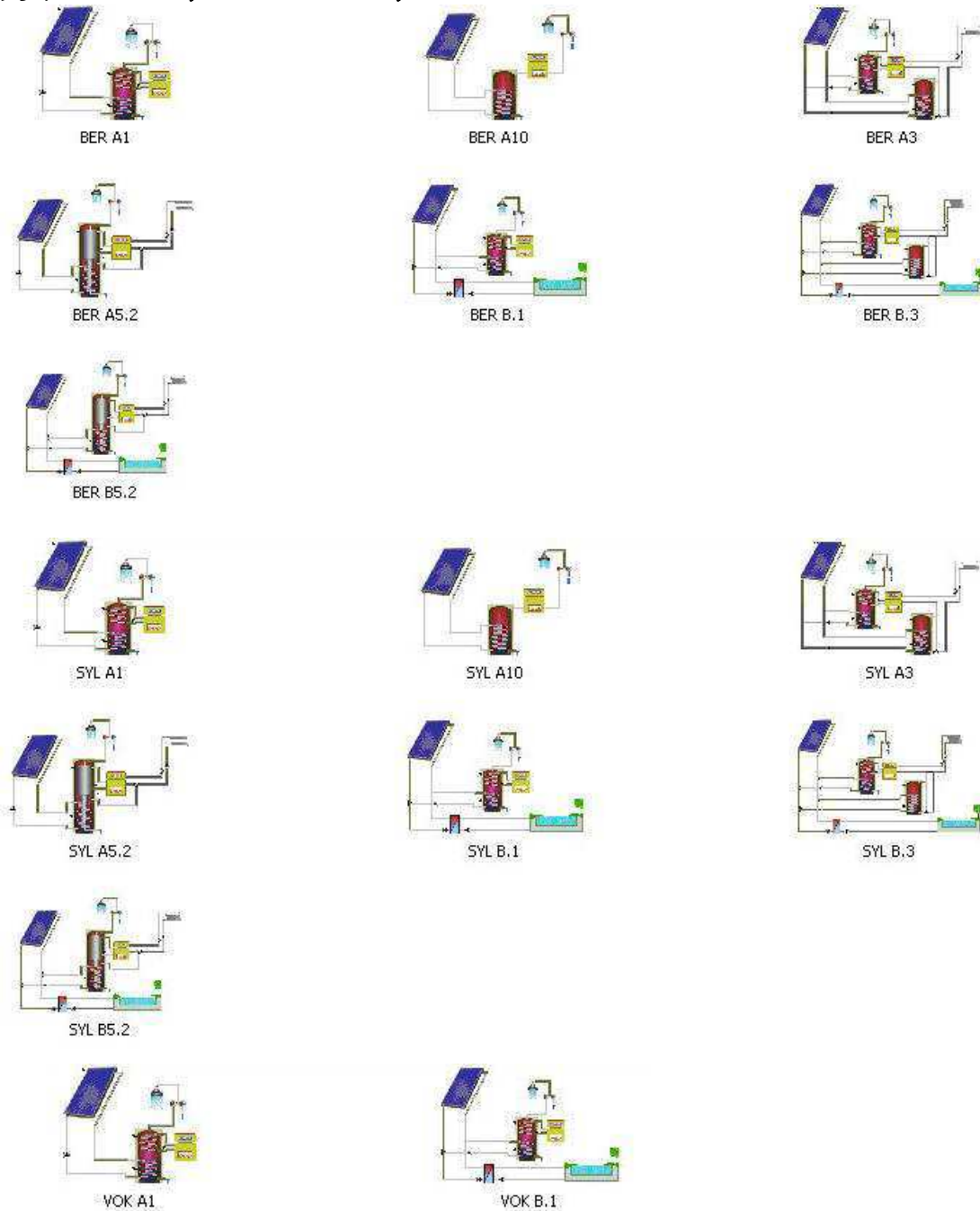
These system types are exclusively offered by Beretta Sylber und Vokera. The company's collectors, storage tanks, and condensing boilers can be individually selected. Further information can be obtained from the company's websites: **www.sylber.it, www.berettaclima.it** and **www.vokera.co.uk**.

7.5.5   Riello and Thermital Systems

RIE A1

RIE A1.2

RIE A2

RIE A3

RIE A5.2

RIE A6

RIE A7 a

RIE A7 b

RIE B1

RIE B3

RIE B6.1

RIE B6.2

RIE C4

These system types are exclusively offered by Riello and Thermital. The company's collectors, storage tanks, and condensing boilers can be individually selected. Further information can be obtained from the company's websites: **www.riello.com** and **www.thermital.it**.

THE A1

THE A1.2

THE A2

THE A3

THE A5.2

THE A6

THE A7 a

THE A7 b

THE B1

THE B3

THE B6.1

THE B6.2

THE C4

These system types are exclusively offered by Riello and Thermital. The company's collectors, storage tanks, and condensing boilers can be individually selected. Further information can be obtained from the company's websites: **www.riello.com** and **www.thermital.it**.

7.5.6 Vaillant Systems

Vaillant A1

Vaillant A2

Vaillant A5.2

Vaillant B1

Vaillant B5.2
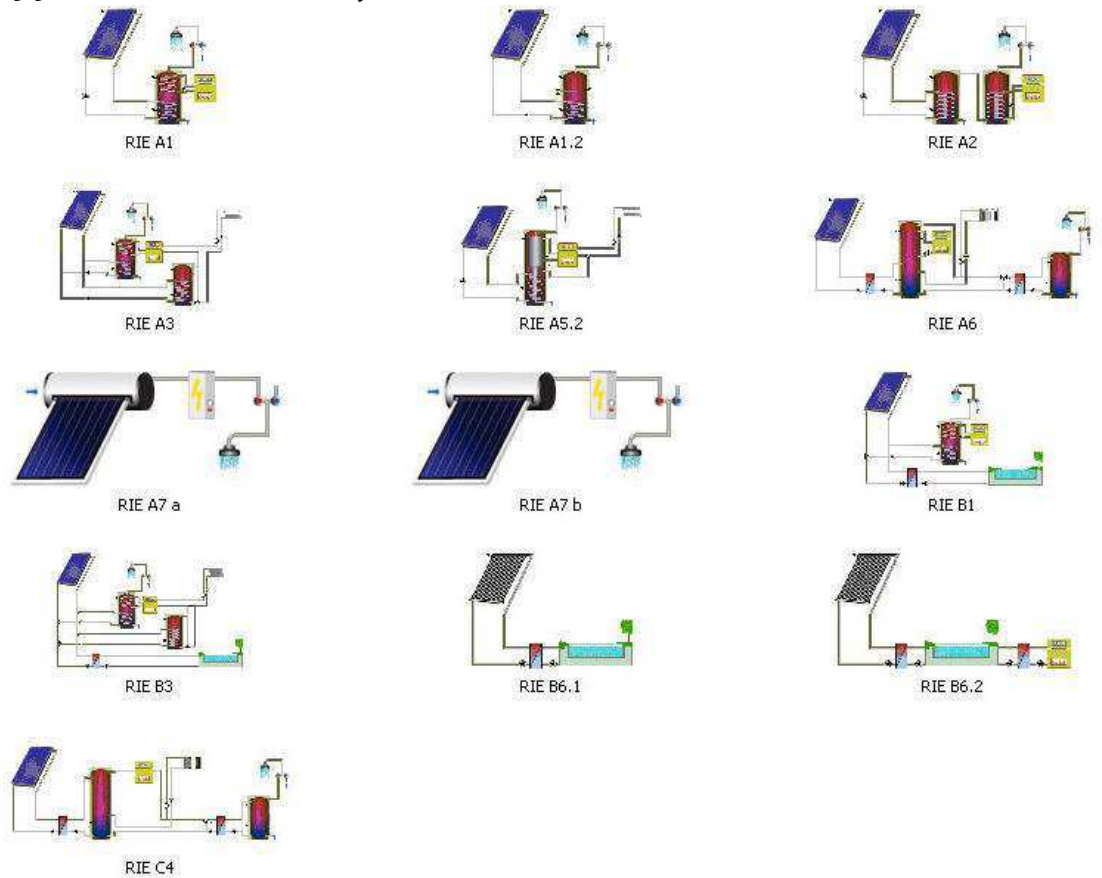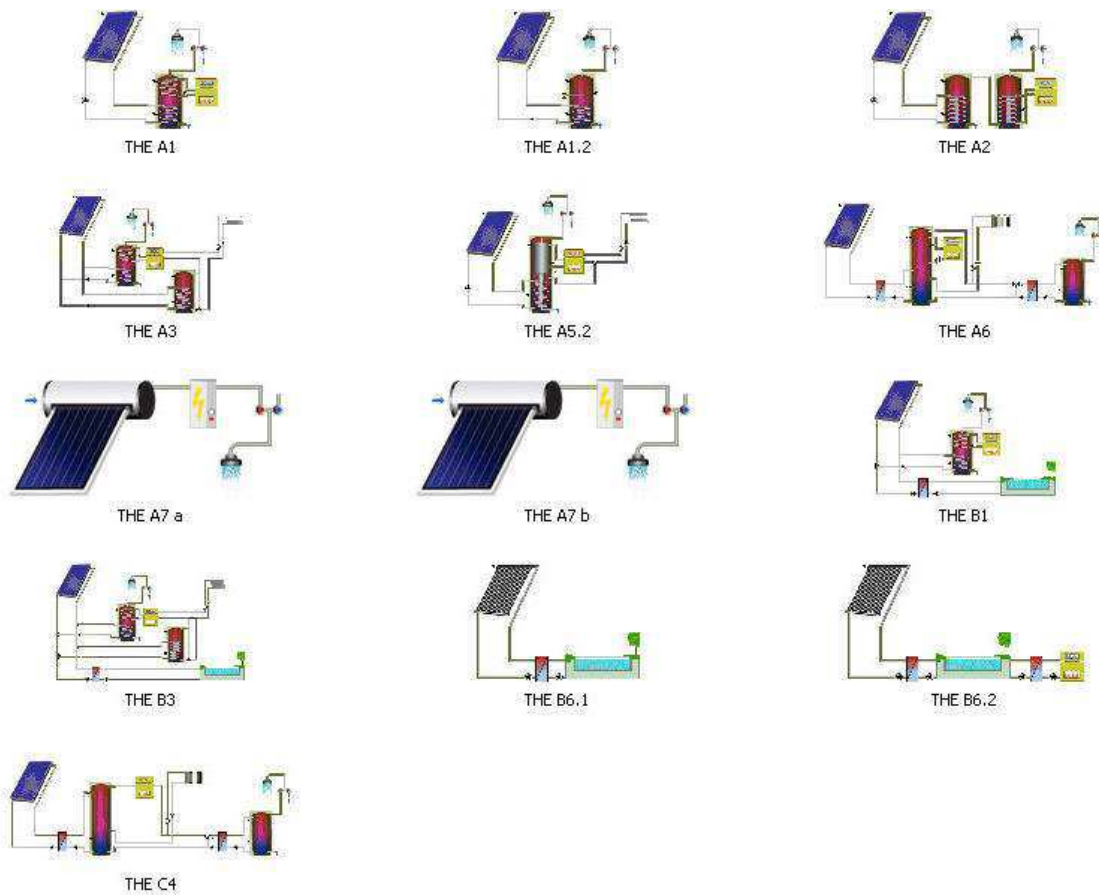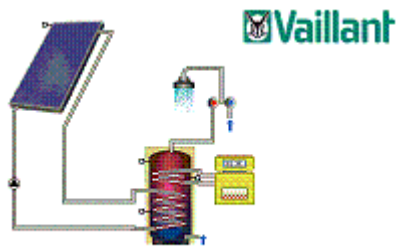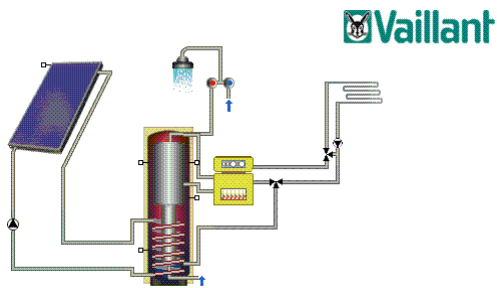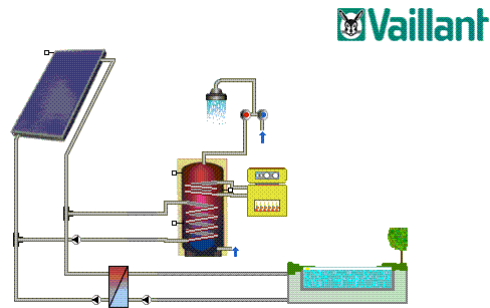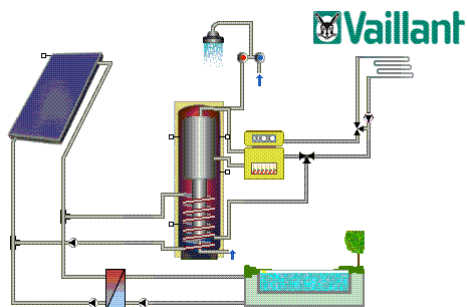
These system types are exclusively offered by Vaillant. Vaillant collectors, storage tanks, and condensing boilers can be individually selected. Further information can be obtained from **www.vaillant.de**.

7.6   Glossary

Active solar surface, m²

The specific collector parameters are not usually related to the gross surface area but to the active solar surface, derived from the testing centre reports. Depending on the testing centre, the active solar surface of flat plate collectors is either the absorber area or the ⋯⟩ aperture area. With evacuated tube collectors (e.g. with mirror constructions and vertically-standing absorbers), the active solar surface is often a purely theoretical value.

Annual heating requirement, Q_h
[kWh/a]

The total heat which must be supplied to the rooms of a building within one year to maintain a target temperature (building energy).

Annuity, A

A series of equal payments, allowing for ⋯⟩ lifetime and interest rate, for repayment of a capital debt. It is the product of annuity factor and investment sum.

Anti-Legionnaire's switch, LEG

The guidelines of the German Association for Gas and Water specify that the entire content of the storage tanks and the piping in systems with a drinking water storage tank size of 400 liters and domestic hot water pipe content of over 3 liters must be heated to 60° once a day. The hot water storage tank is loaded in adjustable intervals in systems with an anti-Legionnaire's switch.

Aperture, A_a (m²)

Largest projected area through which unconcentrated solar irradiation enters the collector. In flat plate collectors, the area of the collector covering through which solar irradiation can penetrate the inside of the collector housing (light penetration area). In evacuated tube collectors, the aperture is the product of the length and width of the absorber strip and the number of tubes. If evacuated tube collectors are fitted with a reflector (⋯⟩ CPC), the aperture is equal to the product of the length and width of the mirror surface

Auxiliary heating, AuxH

Ensures that the ⋯⟩ target temperature is reached even when there is insufficient irradiation. Where applicable, it also supplies the heating loop. Usually refers to the boiler.

Balance, (B)

⋯⟩ Energy balance

Balancing,

⋯⟩ Energy balance

Base load, [W, kW]

Minimum load / output an energy supply system must make available constantly during a period of use.

Boiler, Boil

Serves to convert chemical energy into heat.

Boiler efficiency, η [-]
> The boiler efficiency describes the relationship between the energy used by the boiler and the energy produced over a specific period of time.

Buffer tank, PSP
> A storage tank filled with domestic hot water, usually in steel. The heat is transferred either internally via a serpentine pipe or outside the tank by means of an external heat transfer medium.

Building energy requirement, Q_b [kWh/a]
> Generic term for heating requirements, cooling requirements, energy requirements for hot drinking water, lighting, humidification.

Calculation of pollutants
> The solar system's CO_2 emissions savings are calculated. This is based on the emissions factors of the fossil fuel under consideration for heat generation. The emissions factors used here depend on the (saved) fuel. ($\cdots\rightarrow$ fuel savings) $\cdots\rightarrow$ CO_2 emissions

Capital value, V_0
> Sum of all $\cdots\rightarrow$ cash values of investments, subsidies, savings, operating costs, and loan costs (each signed). The interest rate used is equal to that which would apply when borrowing capital for the investment from a bank or at which the capital used could yield interest.

Cash value, [€]
> Discounted future payments at the start of the period under consideration. A cash value is positive if it can be recorded as revenue and negative if the amounts represent costs. Items calculated are investments, subsidies, savings, and operating costs. $\cdots\rightarrow$ capital value

Circulation, Circ
> Circulation can be used for hot water preparation. This increases comfort (hot water is immediately available, even with long piping systems), but is also coupled with losses. Appendix user guide T*SOL 154 Dr. Valentin EnergieSoftware GmbH.

Climate, C
> Climate is the current atmospheric conditions or a sequence of atmospheric conditions at a specific place which run their course over a specific period of time.

Climate data
> The climate data supplied with the program (for numerous locations) contains hourly median values for global radiation, outdoor temperature, and wind speed.

CO_2 emissions, [g, kg]
> (Carbon dioxide) is the quantitively most significant greenhouse gas (GHG) released by human activity (in particular combustion of fossil fuels). $\cdots\rightarrow$ Calculation of pollutants

Collector, Coll
> Technical device for converting radiation energy into heat energy. Common types are flat plate and evacuated tube collectors.

Collector array, CA
> The collector array consists of the collectors and the piping.

Collector loop, CL
> Circuit containing the $\cdots\rightarrow$ collector or the $\cdots\rightarrow$ absorber and which is responsible for transporting heat from the collectors to the storage tank or heat transfer medium.

Collector loop connection

The collector loop connection represents the connection between the ⋯⟩ collector array and the storage tank by flow and return.

Collector loop efficiency

Quotient of the energy emitted from the collector loop and the energy irradiated onto the collector area (active solar surface)

Compound parabolic concentrator, CPC

Compound parabolic concentrator, reflectors used in evacuated-tube collectors for enlargement of the ⋯⟩ aperture area in a geometrically optimized form as a parabolic trough.

Controller

The controller has the responsibility of ensuring optimal operation of the system. Control parameters can be set for various components. For storage tanks, for example, target temperatures, switching temperatures.

Cooled

Costs

Consumption of goods to create and sell services and other goods.

Daily consumption, [l]

The average daily domestic hot water consumption. This is usually 35-45 liters per person and day at a water temperature of 50°.

Declared value for thermal conductivity, λ [W/(mK)]

Value of the ⋯⟩ thermal conductivity of a construction material or product under specific external and internal conditions which can be considered typical of the behavior of this product when installed in a component.

Site Data, Def.

Design temperature, °C

Temperature determined by the relevant climate zone as per DIN EN 12831 supplement 1 table 1a. The design temperature is the maximum (necessary) temperature of the heating water which suffices at the lowest winter temperature for the heating system to provide the building with required amounts of heat.

Deverter / injection system

Special version of a control circuit. Particularly useful when the user is far away from the output but if required needs hot water promptly (often RLT)

DHW consumption, DHW con

DHW requirement

⋯⟩ Daily consumption

Diffuse radiation, G_{diff} [W/m²]

Part of solar irradiation which strikes a horizontal or tilted surface via scattering through air molecules and mist particles or reflection on clouds.

DIN V 18599

"Energy efficiency of buildings, calculation of net, final, and primary energy requirements for heating, cooling, ventilation, domestic hot water, and lighting" Basis of calculation for the EnEV 2009 certifications for residential and non-residential buildings

Direct radiation, G_{dir} [W/m²]

Part of solar irradiation which strikes a horizontal or tilted surface without changing direction.

District heating, DistHeat

Heat supply for heating buildings and drinking water. In district heating, waste heat created during power generation (cogeneration) is used, among others. Transfer of heat is predominantly effected via underground piping.

DKE, DKE

German Commission for Electrical, Electronic & Information Technologies of DIN and VDE. Organization in Germany responsible for creating standards and safety regulations in the field of electrical engineering, electronics, and information technology.

Domestic hot water, WW

Domestic hot water typically refers to warm drinking water and in contrast to heating or buffer tank water can be consumed.

Efficiency, Eff

The ⋯⟩ collector loop efficiency and the ⋯⟩ system efficiency are calculated.

Electric heating element, el HE

Electrical auxiliary heating in the storage tank

Electrical power, P_{el} [W, kW]

The electrical power states how much electrical energy is used in a specific unit of time.

Energy, E (Joule)

Energy is the ability to perform work. The forms of energy are divided into mechanical energy (kinetic and potential energy), thermal, electrical and chemical energy, radiation energy, and nuclear energy.

Energy balance

Comparison of incoming and outgoing energy flows in a system: the sum of energy supplied, energy released, and the storage of energy by the heat capacity of the system components must be equal to zero. Balancing is not carried out wholesale for the entire system but for the individual system components.

Energy balance scheme

⋯⟩ Sankey graph

Energy input, E, Q_{zu} [Wh, kWh]

Energy supplied to a component, e.g. irradiation, heat supply at the heat exchanger or heat transfer by mass flow due to consumption or circulation.

Energy output, Q_{ab} [Wh, kWh]

Energy (heat) transferred from one component (collector loop, storage tank etc.) to another component or the environment.

Energy produced by solar system, Q_{ab} [Wh, kWh]

Comprises the energy transferred to the standby tank from the solar tank due to consumption and any existing return circulation control in the solar tank.

Energy supply
> ···⟩ Energy input

External financing
> Part of the capital commitment is covered not by personal capital but by taking out loans. If the loan interest is higher than the capital interest, borrowing incurs further costs.

Final energy requirement, Q_E [kWh/m²a]
> Calculated amount of energy available to the system technology (heating system, ventilation and air-conditioning system, hot water heating system, light system) to ensure the set inside temperature, heating of warm water, and desired lighting quality over the whole year. This amount of energy includes the auxiliary power required to operate the system technology. The final energy is transferred at the "interface" of the building's external envelope and thus represents the amount of energy required by the user for use as intended under normative boundary conditions. The final energy consumption is therefore stated by energy sources used.

Flow, FL
> Flow generally denotes the warmer string in a heat loop. In a solar loop, flow corresponds to the pipe from the collector to the storage tank.

Fresh water requirement
> here: the domestic water supplied to the swimming pool for filling.

Fresh water station
> Hygienic domestic hot water heating with the help of a plate heat exchanger in a continuous flow process, compact station with heat exchanger, pump, controller.

Fuel consumption
> The calculation of fuel use (natural gas, oil, wood pellets, district heating) is derived from the energy transferred to the auxiliary heating heat exchanger via the fuel's heat equivalent and the auxiliary heating efficiency.

Fuel price, [€/kWh]
> The price for the stated final energy valid at the time of calculation. It must be entered in the currency given in Windows' country settings.

Fuel saving, [€/a]
> Fuels are primarily used to generate heat. In addition to reducing heat loss, the use of solar heat generates fuel savings. The program converts the available solar heat at any one time, using the respective auxiliary heating efficiency and the corresponding heat equivalent of the energy source, into fuel savings.

Global irradiance, G (W/m²)
> Hemispherical irradiation onto a horizontal surface.

Gross collector area, A_G (m²)
> Surface area of the collector excluding devices for attachment and the piping connection. Usually width by length. Calculated by the external dimensions of the collector; the specific collector parameters are not usually taken from the gross area but from the ···⟩ active solar surface.

Heat consumption, Hcon

Heat exchanger, HE
> Heat exchangers are used when heat is to be transferred between different heat transfer media. Internal and external heat exchangers are differentiated.

Heat gains, Q_s, Q_i
> Comprise the solar heat gains (dependent on the window area, type of window, and inclination) and the internal heat gains (e.g. produced by electrical appliances).

Heat load, Φ_{HL} [W, kW]
> ⸱⸱⸱} Standard heat load

Heat loss rate, [W/K]
> Product of heat transfer coefficient and the surface of the heat exchanger. The value is equal to the quotient from transferred power and median logarithmic temperature difference at the heat exchanger.

Heat losses
> Thermal losses occur through piping, radiation, and convection of heat in a collector. With selective absorber coatings, good thermal insulation or a vacuum, thermal losses can potentially be kept as low possible.

Heat requirement, Q_h [kWh]
> The heating capacity required to maintain a target room temperature in a building (net energy).

Heat requirement, HR
> ⸱⸱⸱} Standard building heat flow requirement

Heat transfer coefficient, U [W/(m²K)]
> The heat transfer coefficient of a component describes the heat flow (heat lost) on a temperature difference of one Kelvin per square meter of the component. This is the crucial heat insulation property of outdoor components. The smaller the heat transfer coefficient, the better its insulation efficiency.

Heat transfer coefficient (heat loss coefficient) of the collector, k_1 [W/(m²K)], k_2 [W/(m²K²)]
> States how much heat the collector releases to its environment per square meter of active solar surface and temperature difference in Kelvin between the collector median temperature and the environment. It is split into two parts, the simple and the quadratic part. The simple part (in W/m²/K) is multiplied by the simple temperature difference, the quadratic (in W/m²/K²) by its square. This results in the typically stated efficiency parabolic curves.

Heat transformer
> ⸱⸱⸱} Heat exchanger

Heating cost
> Calculated from the quotients of ⸱⸱⸱} investment, ⸱⸱⸱} operating costs, and the heat generated (taking into consideration ⸱⸱⸱} lifetime and ⸱⸱⸱} capital interest).

Heating flow, Q dot, Φ_{th} [W]
> Represents a quantitative description of heat transfer processes. The heating flow is an amount of heat (heat output) transferred in a given time; direction of flow always from area of higher temperature to area of lower temperature.

Heating loop, HL

A self-contained system for distributing heat from the heat generator to the user, flow and return flow temperatures are dependent, among others, on the transfer system to rooms to be heated. Two heating loops with different design temperatures can be defined in T*SOL, a high temperature heating loop for radiators and a low temperature LT heating loop for underfloor heating.

Heating network, HN

Concentration of heating requirements in heating output units of varying size in the form of district or local heating networks.

Heating temperature limit, T_{HG}

Minimum / maximum outdoor temperatures at which the heating is switched on or off. The heating temperature limit is dependent on the insulation class of the building.

High temperature circuit

A heating loop with high flow and return temperatures, e.g. for use in radiators and similar.

Incident angle modifiers, K_θ

Describe the reflection losses when the sun is not perpendicular to the collector area.

Installation

The installation of the collector array is determined by the ⤳ tilt angle and the ⤳ orientation angle (azimuth). From the tilt angle and orientation angle, the ⤳ radiation processor calculates the irradiation on the tilted surface for a specific location.

Investment

Typically long-term, targeted capital commitment to generate future yields. Investment costs here correspond to the system costs, less any subsidies.

Irradiation model

The values saved in the ⤳ climate data for global radiation are divided into diffuse and direct parts according to the Reindl model.

Irradiation processor

Calculates irradiation on the tilted area from the ⤳ installation and ⤳ orientation angle of the collector array, taking into consideration the diffuse and direct parts.

Life (of loan)

Period of time agreed for repayment of a loan.

Lifetime

The period of time stated by the manufacturer in which the system should remain operable.

Load profile, [W, kW] [%]

Hot water consumption dependent on time. The calculation is based on the definition of different daily, weekly and annual profiles.

Loading loop, LL

⤳ Storage charging loop

Loading time, [h]

Describes the period required for the storage tank to be loaded fully (supply of energy).

Loan capital

The amount of the loan taken out. It bears interest and must be repayed.

Loan interest
> The amount of interest that has to be paid on a loan. If the loan interest rate is lower than the capital interest rate, borrowing a loan results in income from interest.

Local heating, LH
> Local heating describes the transfer of heat between buildings over relatively short distances in comparison with district heating.

Low temperature circuit
> Heating loop with low flow and return temperature, e.g. for use with underfloor heating

MeteoSyn
> Program for generating climate data.

Nominal size, [-]
[mm]
> States the diameter of a pipe. DIN nominal piping sizes are used to calculate the collector loop piping widths. The term DN (diameter nominal) states the internal diameter. With copper piping, the outer diameter and the wall thickness of the material are stated.

Off, off
> Switch in a program dialogue box.

On, on
> Switch in a program dialogue box.

Operating costs, [€/a]
> Costs arising from operation of the system, e.g. maintenance costs, electricity costs. The ····⫽ cash value and the ····⫽ annuity of the operating costs are derived from the ····⫽ capital interest, ····⫽ rate of price increase, and the ····⫽ lifetime.

Operating period, (h)
> Each respective component is active during the operating period. A component is not active during the specific time periods (hours, days or months) that have been switched off.

Orientation angle, α (°)
> (azimuth) Describes the angle of deviation of the collector area from the south in the northern hemisphere. It is 0° when the surface is facing due south. The azimuth is positive when facing west and negative when facing east. An orientation due west corresponds to a value of +90° and an orientation due east is -90°.

> Pay-back time, Period of time required until the total of returns on an investment (static payback method) or its ····⫽ capital value (dynamic payback method) reaches the amount of the investment. Here: the period of time the system must operate for the investment to yield a capital value of zero. The program does not calculate pay-back times of over 30 year.

Primary, Pr

Primary energy requirement, Q_P [kWh/a]   [kWh/(m²a)]
> Calculated amount of energy which, in addition to energy content of the required fuel and the auxiliary power for the system technology, also includes amount of energy resulting from upstream process chains outside the building in extracting, converting, and distributing the respectively used fuels. - available in table form.

Primary loop

Heating loop in the heat generator with high temperatures for transferring heat with a heat transfer medium to the ⸱⸱⸱⸲ secondary loop.

Process heating, PH

Process heating is the heating required for a large number of technical processes and procedures (drying, cooking, melting, forging etc.). The process heating must typically be generated by combustion processes or electric current, can however in the best case be recovered in part as waste heat.

Proportional energy saving

as DIN EN 12976

Rate of price increase, [%]

The prices for non-renewable energy sources are rising as a result of growing demand and increasingly scarce supplies. The development of operating costs and energy consumption play a crucial role in calculating the capital values of investments. Appendix user guide T*SOL 152 Dr. Valentin EnergieSoftware GmbH.

Redirection valve, RV

⸱⸱⸱⸲ Three-way valve

Return, R

The return commonly describes the cooler string in a heating loop. In a solar loop, the return is the pipe from the storage tank to the collector.

Sankey graph

Graphic representation of energy or material flows using arrows, in which the width of the arrows is proportional to the width of the flow.

Savings

The simulation results include the reference fuel savings made during the simulation period through the use of the solar system.

Secondary loop

Heat consumer

Secondary loop

Contains the medium to be warmed, is heated by the ⸱⸱⸱⸲ primary loop.

Simulation

Test of the influence of ambient conditions, user behavior, and the various components on the operating conditions of the solar system with the help of computer calculations

Simulation period

Total period of time for which the simulation is to run. Simulation periods of between one day and one year are possible

Simulation range

Time interval between two successive calculation steps. It varies between 1 and 6 minutes depending on the system and is set automatically.

Solar azimuth, α_s

Deviation of the respective position of the sun from the south, constantly changes as a result of changes in the sun's position, is 0° at 12.00 p.m. CET

Solar cooling, SC
> With the help of heat generated solar thermically, solar cooling is used to generate cooling or open sorption-based air-conditioning in a closed absorption or adsorption process.

Solar fraction, SolFr, f
> The proportion of energy transmitted by the solar system to the standby tank to the total amount of energy transmitted to the standby tank (from the solar system and auxiliary heating).

Solar heat
> Solar heat describes the conversion of solar energy into available heating energy.

Solar storage tank
> The solar tank is the storage tank or part of a tank that is loaded from the collector array.

Solar yield, (kWh/m²)
> Energy released by the collector loop within a specific period of time.

Space heating, Heat
> All technical elements and systems which serve to generate, store, distribute, and transfer heat.

Specific heat capacity
> The amount of heat per m² of active solar surface that the collector, including its heat transfer medium content, can store at a temperature increase of 1 Kelvin. Benutzerhandbuch T*SOL Anhang Dr. Valentin EnergieSoftware GmbH 153

SRCC
> Solar Rating and Certification Corporation - USA

Standard heat load, Φ_{HL} [W, kW]
> Standard DIN EN 12831 (August 2003) describes the calculating procedure to determine the output of the heat generator and the heating surfaces required under normal design conditions to ensure that the required standard indoor temperature is reached in the rooms used in the building.

Standard heat requirement, $Q_{N,Geb}$ (W; kW]
> Former term for heating load
> The standard heat requirement is the basis for the dimensioning of the heat generator (boiler, solar system ...). It states the required heating output to maintain the desired indoor temperatures (e.g. 20°C) in all rooms at the design outdoor temperature.

Standard outdoor temperature, Θ_e
[°C]
> Outdoor air temperature used to calculated standard heat loss. It represents the lowest two-day median the air temperature has reached or dropped below 10 times in 20 years.

Standby storage tank,
> A system storage tank which is used exclusively for storing domestic hot water pre-heated to the target temperature (e.g. System A2).

Storage charging loop,
> Pump circuit for charging the storage tank ···} storage charging system

Storage charging system,
 Storage tank heating from bottom to top by means of a charging pump (storage charging loop), the heating surface can be located inside or outside the storage tank.

Storage model,
 Representation of loading and unloading processes
 The stratified storage model uses storage layers of variable strength. The number of layers in not fixed but adjusted during simulation.

Storage regrouping
 Heat transport from the solar storage tank to the standby tank. When activated, storage regrouping occurs when a higher temperature is present in the solar storage tank (top) than in the standby tank (top).

Storage tank, ST
 To bridge weather-related and/or seasonal fluctuations in irradiation, storage tanks are used to buffer heat. The volume of the storage tanks is governed by the heating requirement and the period of time to be bridged.

Stratification
 Facility enabling layered loading of storage tanks. Typical stratifications are e.g. convection chimneys with radial openings.

Sun height, angle of elevation, γ_s
 Angle of the sun to the horizontal

Suneye
 Device to determine an optimal location for the solar system with the help of annual irradiation graphs and sun-active time of day data.

Supplementary heating
 ⋯⟩ Auxiliary heating

Supply/removal, (on/off)

Swimming pool, SP

Swimming pool water heat requirement
 The total amount of energy generated by the solar system and auxiliary heating for the swimming pool.

System efficiency
 Quotient of the available energy generated by the solar system and the energy irradiated onto the collector surface (active solar surface). It is a benchmark for the system's efficiency.

Target temperature
 The minimum temperature of domestic hot water If the target temperature in the upper layer of the tank is not reached, the ⋯⟩ auxiliary heating is switched on.

Target value, Targ

Temperature, T (°C)
 The temperature is a material property and describes the ability of a body to generate internal energy in the form of heat.

Thermal buffer store, Contains heating water for heat storage.

Thermal conductivity, λ [W/(mK)]

The thermal conductivity states the amount of heat passing through one square meter of a 1m-thick layer of building material in an hour when the temperature difference between the two surfaces is 1 Kelvin.
Criterion for assessing the quality of insulating material.

Thermal engineering

Thermal engineering describes all aspects of energy conversion, storage, and transfer in machines and apparatus with the exception of electrical energy.

Thermal equivalent

Conversion process making energy sources comparable by their heat content (heating value).

Thermosyphon system

Operation in a closed circuit according to the gravity filtration principle without the use of pumps or controls.

Tilt angle, β (°)

(inclination) Describes the angle between the horizontal and the collector surface. This is 0° when the collectors are flat on the ground and 90° when they are vertical.

Value for the energy requirements of a system , e_P
[-]

The value for the energy requirements of a system describes the ratio of primary energy absorbed by the system technology in relation to the available heat released by it. The smaller the value, the more efficient the system. In residential buildings, the value for the energy requirements of a system also takes account of preparation of a standard amount of hot water.

VDE

(German) Association for Electrical, Electronic & Information Technologies

Volumetric flow rate, V_P– Flow, [l/h], [l/m²h]

The movement of a volume of a medium in a unit of time through the cross-section of a tube. The volumetric flow rate for the collector array is stated in l/h and can be specified either absolutely or relative to the collector area.

Zero-loss collector efficiency, η_0

States the proportion of radiated energy absorbed by the collector on vertical incidence when the median temperature of the heat transfer medium in the collector is equal to the ambient air temperature.

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