WP1.D1 / SUMMARY REPORT ON TODAY'S SYSTEM TECHNOLOGY

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New Generation of Solar Thermal Systems

CONTENTS

SUMMARY

A detailed survey on the state-of-the-art of technology of the European solar thermal market and on new system concepts and trends has been conducted. The information was supplied (by the project participant of each country, see section *acknowledgements*) in two steps: first a survey form was filled in, secondly an additional questionnaire was submitted in which additional and more clearly specified data was assessed. Both the survey forms and the additional questionnaire are given in appendices. This report summarizes selected results from the survey.

The intention of this report is to serve as a basis for further work in WP1. The goal is to find and evaluate promising system types and concepts with potentially high impact on the solar market. However, this survey-report may be a valuable source of information in itself.

The survey covers 12 countries in southern, central and northern European climates and reveals large differences in the solar thermal technology used in the various countries. The differences in technology and its cost can not be fully explained by the objectively different boundary conditions such as climate, legislation, subsidies, standards, market penetration and industrialisation. Traditions and culture greatly influence (if not dominate) the choice and application of solar thermal technology. This important finding suggests that there is much potential for short and medium term improvement by overcoming cultural differences and by the adoption of technological achievements already present in similar or adjacent countries.

Another important finding is the presence of highly innovative system concepts that promise to cut costs or improve performance, or that add secondary benefits, such as improved integration or simplified installation and commissioning.

Introduction

Starting point
In most countries with significant use of solar heating, there is a periodic assessment of it's importance. However, because the data are assessed and compiled on a national level, there are large differences in the approach, quality, accuracy and completeness of the data.
A recent and rather complete market report which does not emphasize technology, has been published by the Solar Heating & Cooling Program (SHC) of the International Energy Agency (IEA), (/Wei05/). A well recognized, but less recent report, which focuses on some key markets and includes technical information, was prepared and published by the European Solar Thermal Industry Federation (ESTIF) in 2003 (/Bre03/).
Exceptional statistical data on solar thermal energy include technological aspects such as system size (size of the collector arrays), application (SDHW or combisystems) or the type of solar collectors installed (e.g. flat plate or evacuated tube or unglazed collectors). A smaller survey covering solar combisystems (a system combining water heating and space heating) was conducted by Task 26 (solar combisystems) of the IEA SHC. This report (/Wei03/) revealed large differences in solar space heating technology in European countries. However, to the knowledge of the authors, there is no thorough survey of the use of solar thermal energy that focuses on the type of technology employed. The twelve countries with institutions participating in work package 1 of NEGST supplied technology specific data which are summarized in this report. These institutions described the technology of typical systems at the time of the survey and pointed out particularities and trends. Note that for some countries the market for certain types of systems is so small that no data was delivered. This is the case e.g. for hot water systems in Sweden and combisystems in Greece.

Objectives
This survey shall provide insight into the type of technology used for solar heating applications in various countries and climates. The differences between countries shall be identified and evaluated. The report shall serve as a basis for future work in WP1: "The identification of promising system types, their evaluation and improvement."

Limitations
Important limitations of the survey are:

- With a few minor exceptions, it is restricted to small systems used for single family homes.
- The survey covers only a limited number of countries: Austria, Denmark, Germany, Greece, Italy, Norway, Portugal, Spain, Sweden, Switzerland and The Netherlands.
- In many cases, the contributing experts could not rely on hard fact data as sources of information. In several cases figures had to be estimated. Even in those cases where statistical data are available, there may be inherent inaccuracies. For practical reasons the data do not always refer to the same year (mostly 2003, exceptionally 2004).

Even if some of the data provided may not be accurate, the differences encountered and documented are very significant and allow a safe analysis to be made and pointed conclusions to be drawn.

Countries and climates

Energy demand

This European survey includes northern countries such as Sweden and Norway as well as southern countries like Greece and Spain. Figure 1 shows the average cumulative annual irradiation on the horizontal plane and the annual average temperature in the contributing countries. Annual solar radiation ranges from 950 kWh/m² to 1700 kWh/m². Italy, Spain, Portugal and Greece comprise large areas where long periods below the freezing point are exceptions. In most countries, but particularly in Italy, France, Sweden, Norway and Spain there are several important and very different climatic zones.

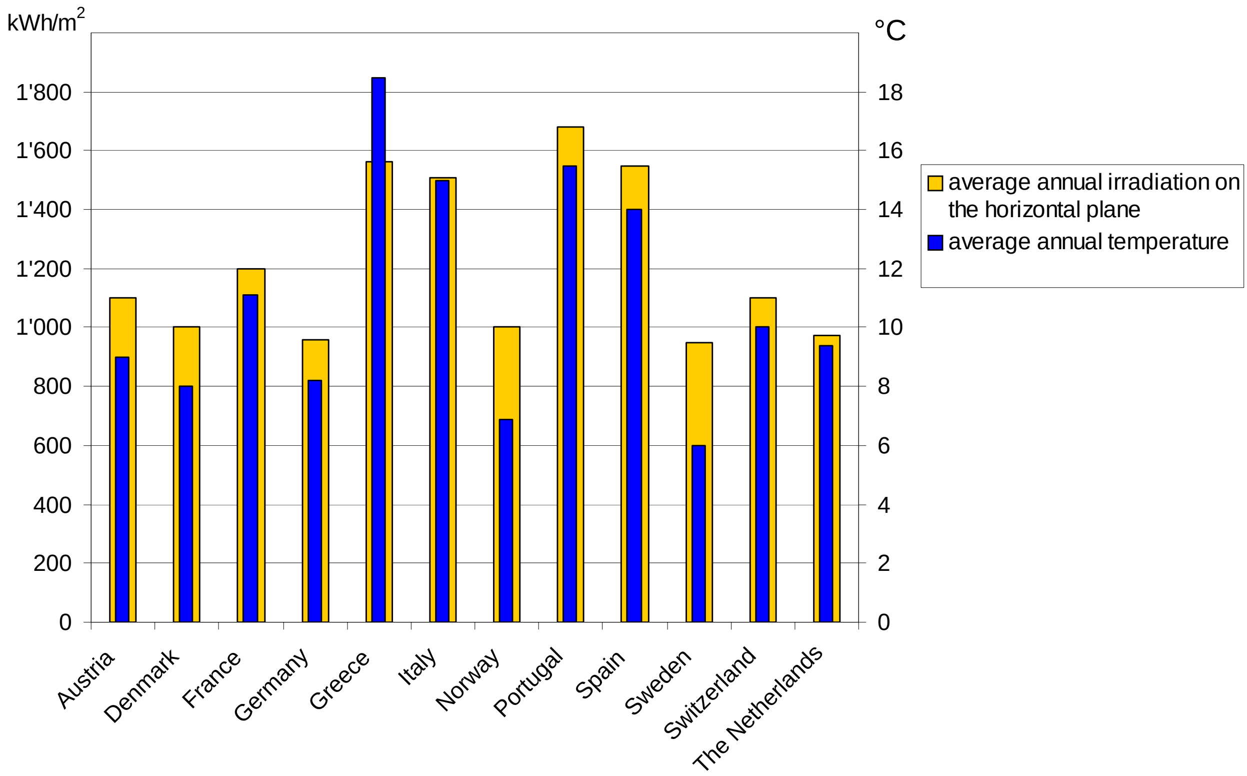


Figure 1: Average annual irradiation on the horizontal surface and average annual temperature in the countries included in the survey. The most populated climatic zones have been considered in the case of Norway, Sweden, Austria and Switzerland; average values in the case of Italy, France and Spain.

The typical heat demand for space heating varies largely from 1500 - 2000 kWh/a in Portugal and Spain to 20.000 – 25.000 kWh/a in Middle and Northern Europe (Figure 2). The average heat demand for domestic hot water heating in single family homes, including hot water circulation, and store losses, if applicable, is as low as about 2000 kWh/a in several countries but more than twice as high in others.

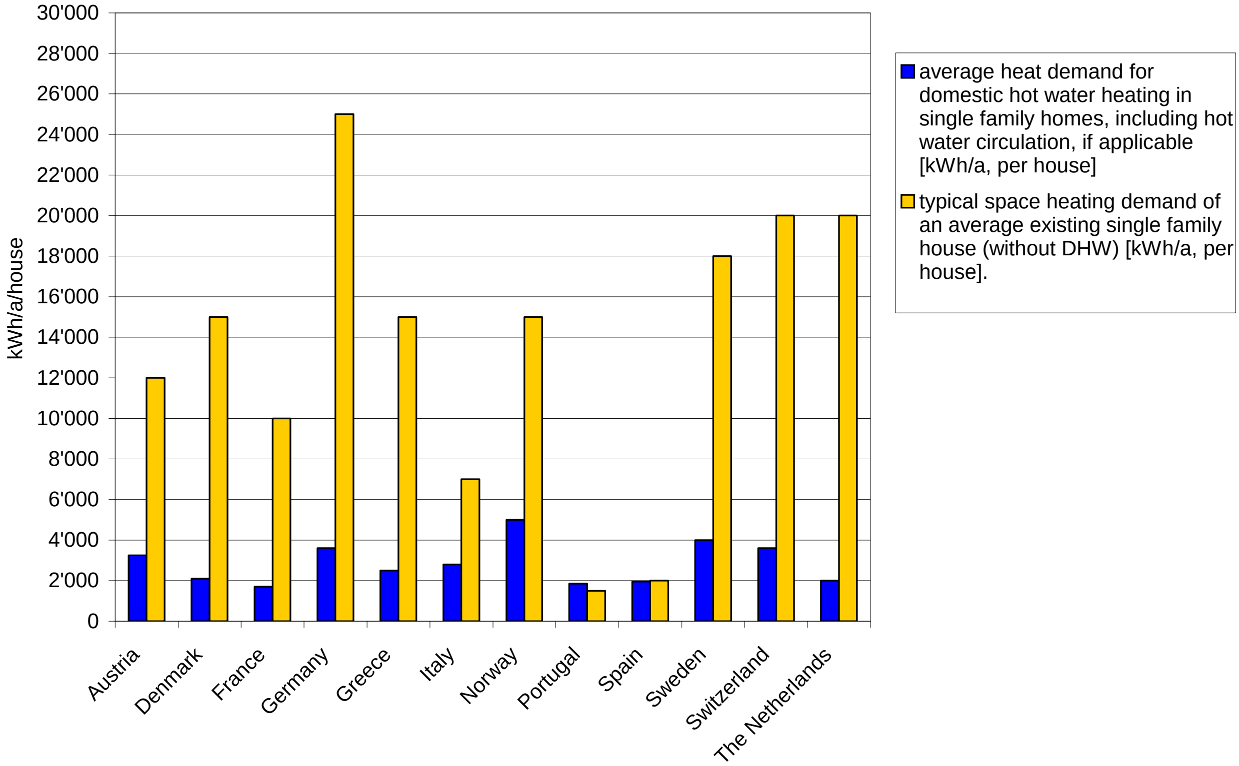


Figure 2: Average heat demand for domestic hot water and space heating. Note that most of the figures had to be estimated. Also different assumptions were made (heat demand according to measurements or according to standards or regulation, or heat consumption). This is particularly true for the Southern European countries, where central space heating systems are not common. (E.g. 1'500 kWh/a of space heat demand are reported for Portugal. This is three times the average consumption: According to a study the consumption is about 500 kWh/a, but in Portugal, only about one third of the floor surface of single family houses is heated.)
Note that in sunnier climates the energy consumption for DHW preparation, storage and distribution is relatively low (the average value of Greece, Italy, Portugal and Spain is approximately 2500 kWh/a and house, whereas, on average, the figure is much higher (approximately 3500 kWh) in the countries with low solar irradiation (Austria, Denmark, Germany, Norway, Sweden, Switzerland, The Netherlands). Fig. 2 is based on data from the additional questionnaire, not from the original survey form. Also note that the figures for space heating demand do not in all cases correspond to the (estimated) values of space heating demand of houses in which typically solar combisystems are installed. Thus the heat demand does not correspond to the values in Fig. 9b and the heat requirement in the table thereafter.

Solar heating applications

System purpose

In some countries (Sweden and Austria) the application of solar heating very much concentrates on single family homes. These countries have significant supply and consumption of biomass, important rural settlements with individual housing and a large share of self-built solar systems. The share of glazed solar collectors in operation for domestic hot water supply in single family homes is smallest in Spain and Switzerland. But even there it exceeds 50% (see Figures 3a). In Switzerland only 31% of the inhabitants own their homes.

Figure 3a shows that in countries with a similar climate and similar solar thermal energy technology, there are virtually no solar collectors in multi family houses (Greece, Portugal), a moderate share (Italy) or a very large share of over 30% (Spain). Also, the difference between Austria and Switzerland is remarkable. Note also that in the northern countries of Sweden and Norway, SDHW systems have a very small part of the market (<10%).

Solar domestic hot water (SDHW) systems

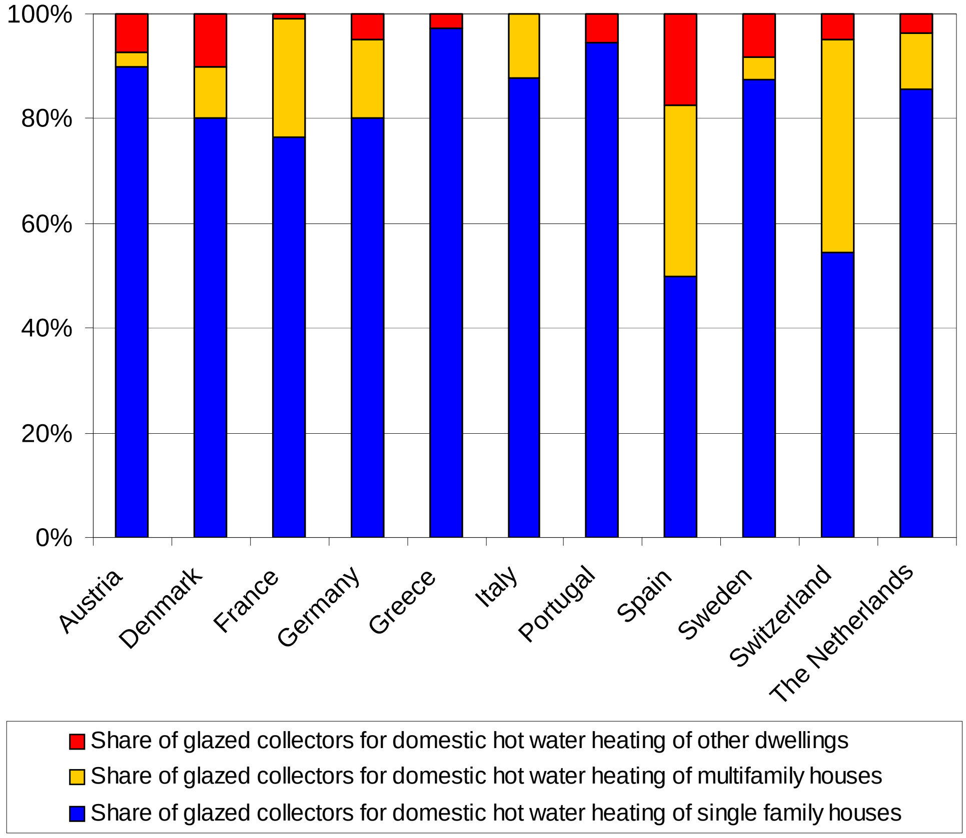


Figure 3a: Glazed solar collectors (flat plate and evacuated tube collectors) for domestic hot water preparation per application (single family homes, multi family homes, others).

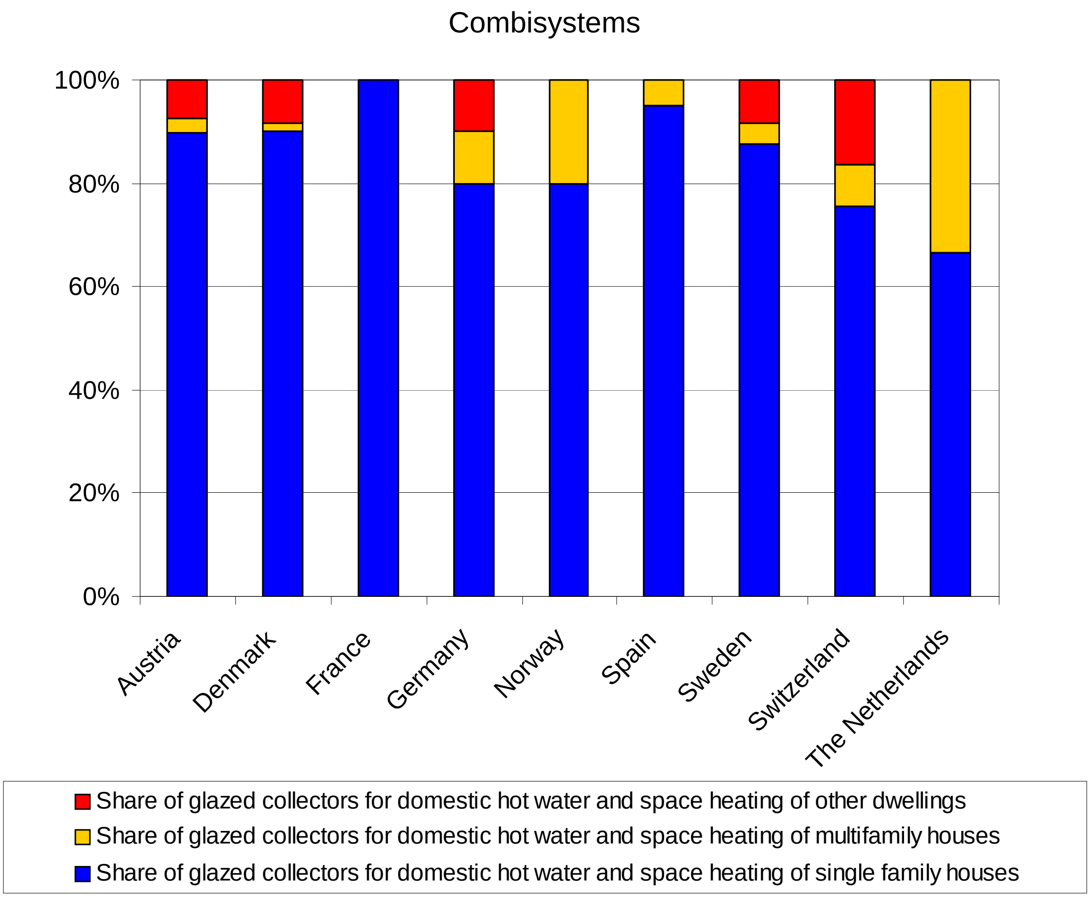


Figure 3b: Glazed collectors in combisystems per application (single family homes, multi family homes, others) in the different European countries.

Figure 3b displays the share of solar collectors installed used for domestic hot water and space heating (combisystems) in different building types. The differences are remarkable, e.g. compare the share of solar collectors in multifamily homes between the Netherlands (>30%) and Austria (<5%). In Greece, Portugal and Italy the market for solar combisystems is too small for reliable data, for which reason no data on combisystems in these countries are given. Also, in Spain the market for combisystems is very small.

Prominence of solar heating

Market aspects

The prominence of solar heating systems is very different among the countries included in this survey. The area of glazed collectors in operation is reported between 0.25 m^2 per capita in Greece, the highest figure, and a mere 0.001 m^2 per capita (or 1 m^2 per 1000 inhabitants) in Norway. Figure 4 shows the installed power capacity in W_{th} per capita. The power capacity is calculated on the basis of the assessed collector area and a conversion factor[1] of 700 W/m^2.

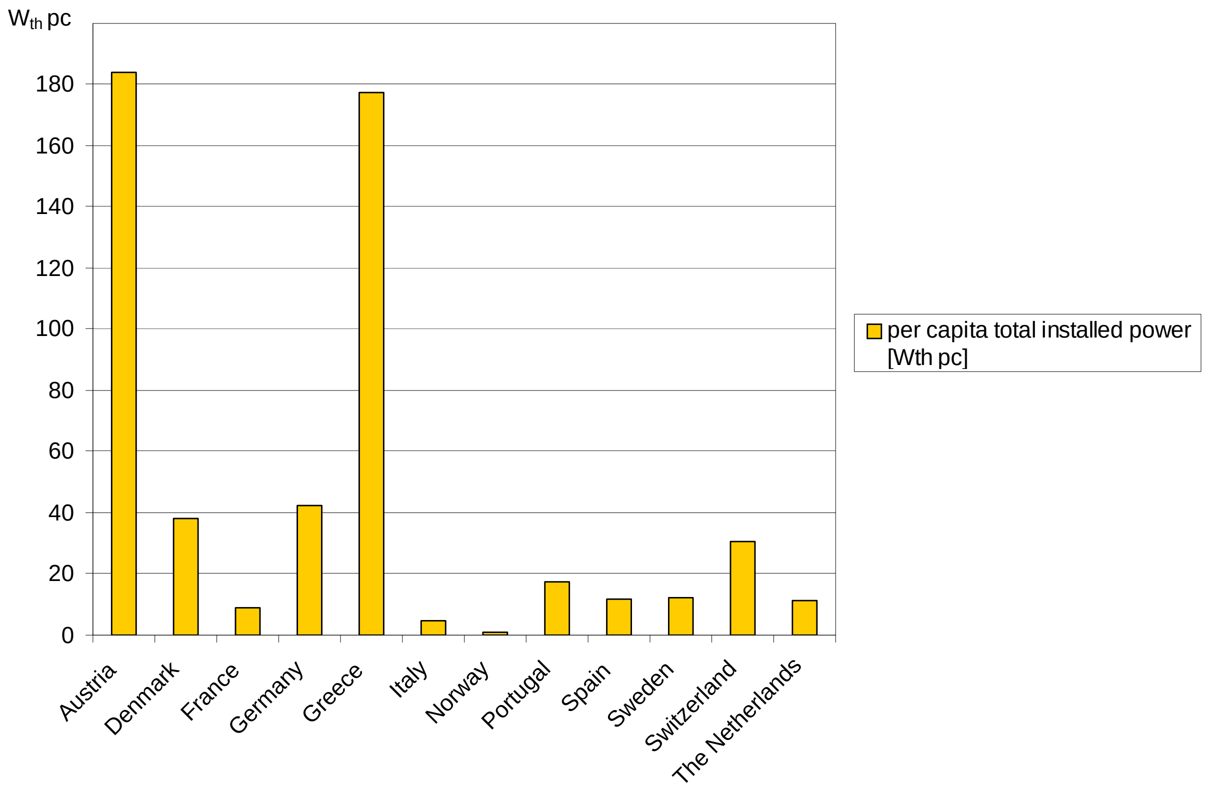


Figure 4: Per capita installed solar collector power capacity in the 12 European countries participating in NEGST.

The same degree of variability can be observed in the expansion of solar thermal energy utilization: During the period of study (2003 – 2004) the per capita area of annually installed solar collectors varied between 1 m^2 and 20 m^2 per 1000 inhabitants.

The development of the national markets in the European countries are strongly dependent on governmental regulations and subsidies. The trend over the past five years of the annual increase in installed capacity of glazed solar collectors per inhabitant are illustrated in figure 5. To comment on the negative trend in Norway, it must be noted that the solar thermal market in this country is very small due to the availability of vast amounts of low-cost hydroelectric power.

The negative trend in Denmark is one example of the effect of discontinued governmental support. Subsidies for solar systems were stopped in December 2001. In Greece the trend is negative, probably because of a saturation of consumer demand. In some countries the market

[1] as per convention by IEA-SHC

[3] The effect of sunnier climate on solar thermal energy utilization is not only as positive as it may seem. In warmer (and sunnier) climates the energy required for domestic hot water preparation is clearly lower than in countries with less solar irradiation (see Fig. 2). Among other things a higher mains water temperature contributes to a lower DHW-load. In addition, in warm and sunny places the space heating demand is much smaller, sometimes negligible. A small load has a positive effect on the relative solar gain (solar fraction) but it has a negative effect on solar energy gain in absolute quantity (kWh).

stagnated in recent years on a high level (Austria) or on a low level (Switzerland and Portugal). The highest increase took place in France with 35%, albeit from a relatively small value. Also, in Spain, Italy and Germany the average market development exceeds 12.5% p.a.

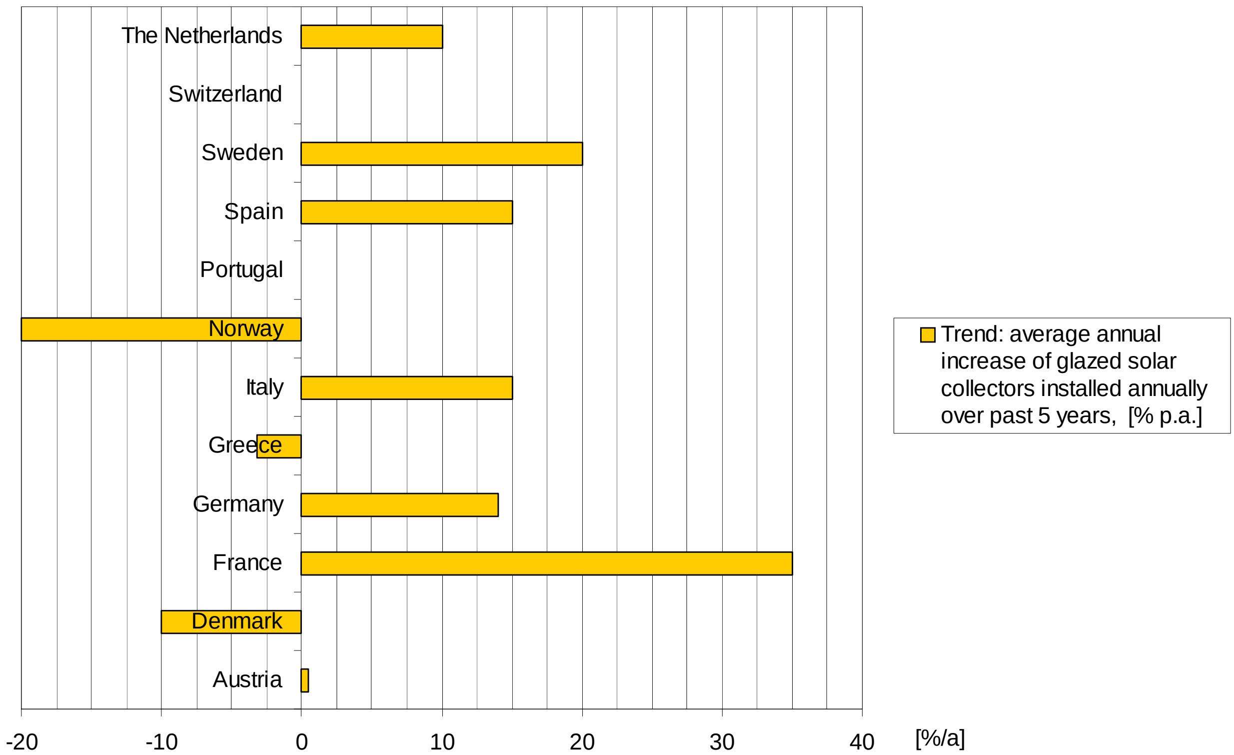
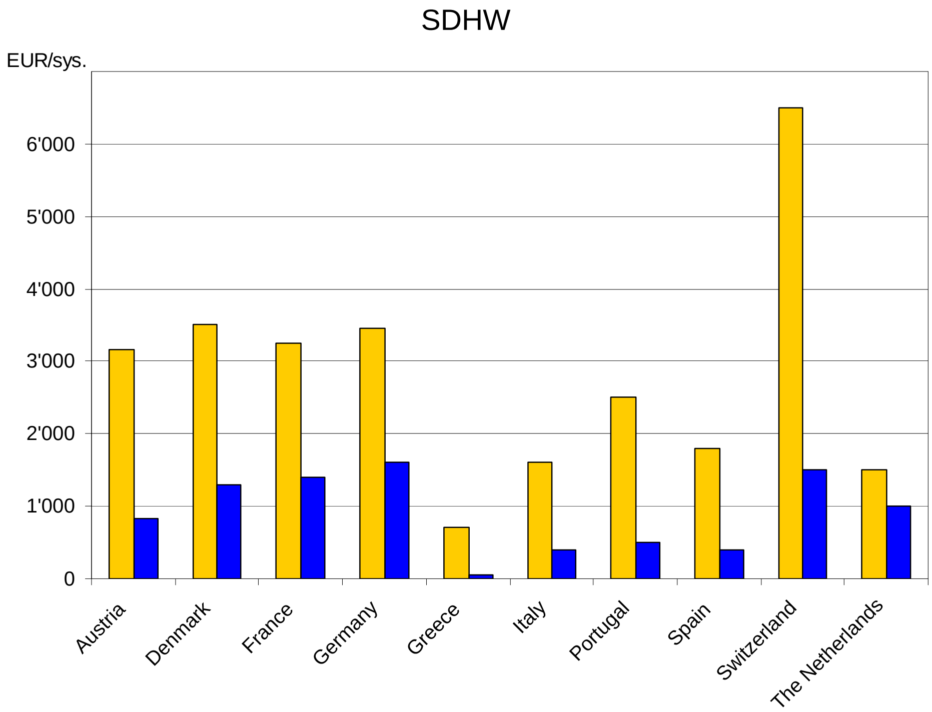


Figure 5: Average annual change in number of m² of glazed collectors. Trend over the past five years. Note that for most countries the most recent year considered in the survey is 2003 (France 2005).Since 2003, due to increasing oil prices, the average trend is certainly more positive.

System costs

Another interesting aspect is the costs of systems and their installation shown in figure 6. There is also a high variation among the European countries. The systems are most expensive in Switzerland (pumped solar water heater with about 5 m² of solar collectors and a 400 - 500 l tank) and the least expensive systems are marketed in Greece (thermosyphon solar water heater, 2.4 m², 150 l). Note that the cost depends on the size and type (technology) of the systems. But, even if technology and size correspond, the differences in the prices of solar systems and their installation are high. For example, in Austria, Germany and Switzerland, the average system sizes and the technology used is similar. Nevertheless, the investment per system is different. The cause for low cost figures for systems in the Netherlands (particularly the combisystems) is due to the relatively small size of the systems and the concentration of the solar thermal technology providers. Only a few manufacturers are present which offer comparably small, highly prefabricated products.



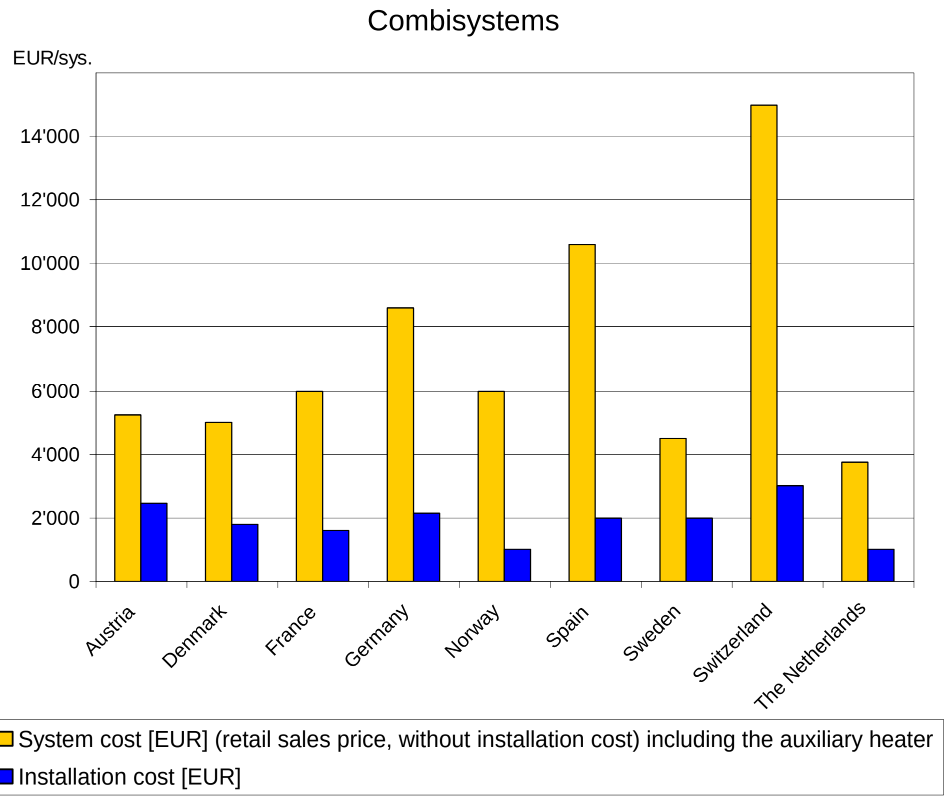


Figure 6: Average System costs (retail sales price, without any auxiliary heater, without installation, without VAT) and installation costs (without installation or commissioning of any auxiliary heater) for SDHW and combisystems. Note that the installation cost for Norway as specified in the chart is additional cost only. The collector is designed to substitute conventional roof- or facade modules. The additional cost stated and considered in the case of Norwegian combisystems is Euro 1000. The bar graphs are based on data from the additional questionnaire, not the survey form.

Integration into buildings

Solar collectors of pumped systems are most often installed just above the tiles of inclined roofs. Sometimes the collector array replaces the tiles. The thermosyphon systems present in southern countries are often mounted on a support structure placed on a flat or above an inclined roof.

The necessity for improved integration of the system components installed indoors depends on the housing traditions, which vary substantially between countries. In central and northern European countries (Austria, Germany, Switzerland) the tank and auxiliary heater tend to be installed in the basement whereas in the Netherlands there tends to be no basement, which suggest that these systems should be small, compact and silent. The solar systems may be installed in rooms near or adjacent to the living or sleeping rooms. In Germany, there is a trend to install the tank in the attic. Thermosyphon systems are mostly roof mounted, hence require little or no constructive integration.

State of the System technology

System types

There is a significant variation between technology designs of solar thermal systems used in the participating countries (see figure 7). In the southern countries like Greece, Italy, Spain and Portugal thermosyphon systems dominate. In all countries the share of thermosyphon systems is either overwhelming (southern European) or insignificant (central European and Scandinavian countries). The highest share of thermosyphon systems is in Greece with around 99%. The dominant technology in central Europe and the northern countries are pumped systems. The share of systems of the type integrated collector storage is marginal in all countries.

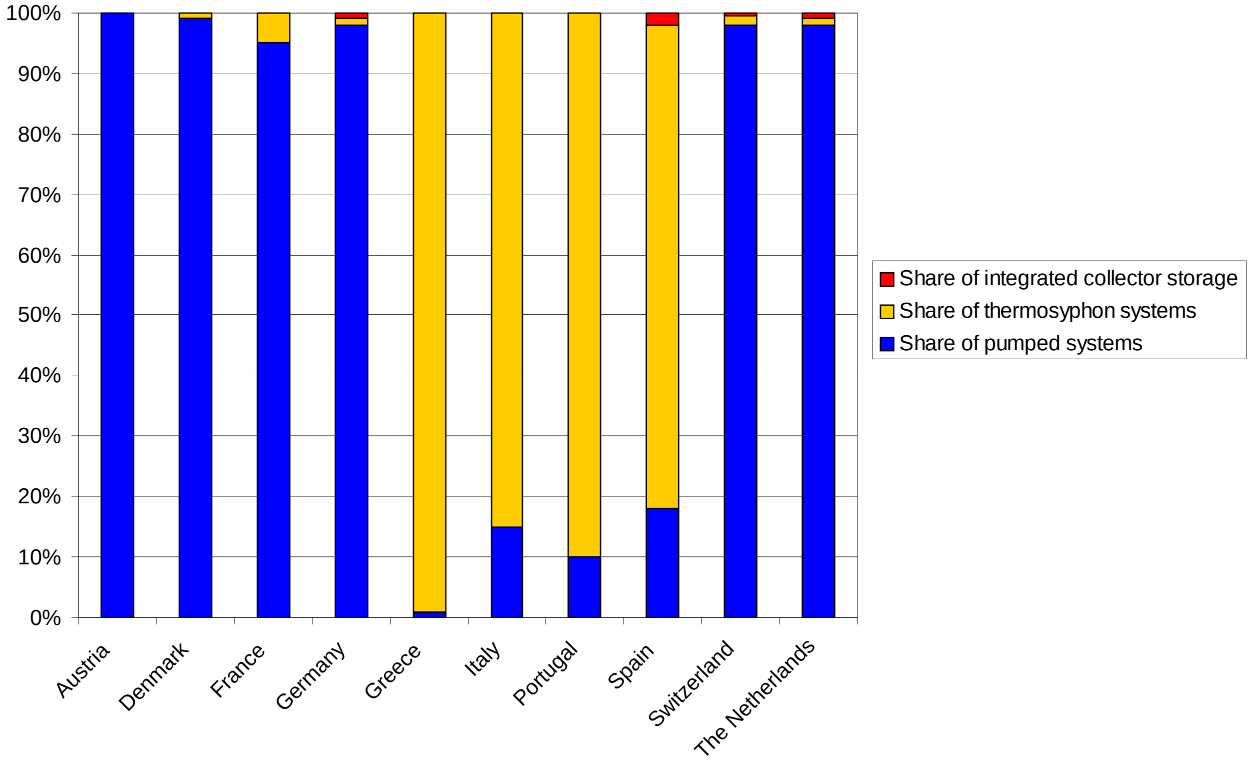
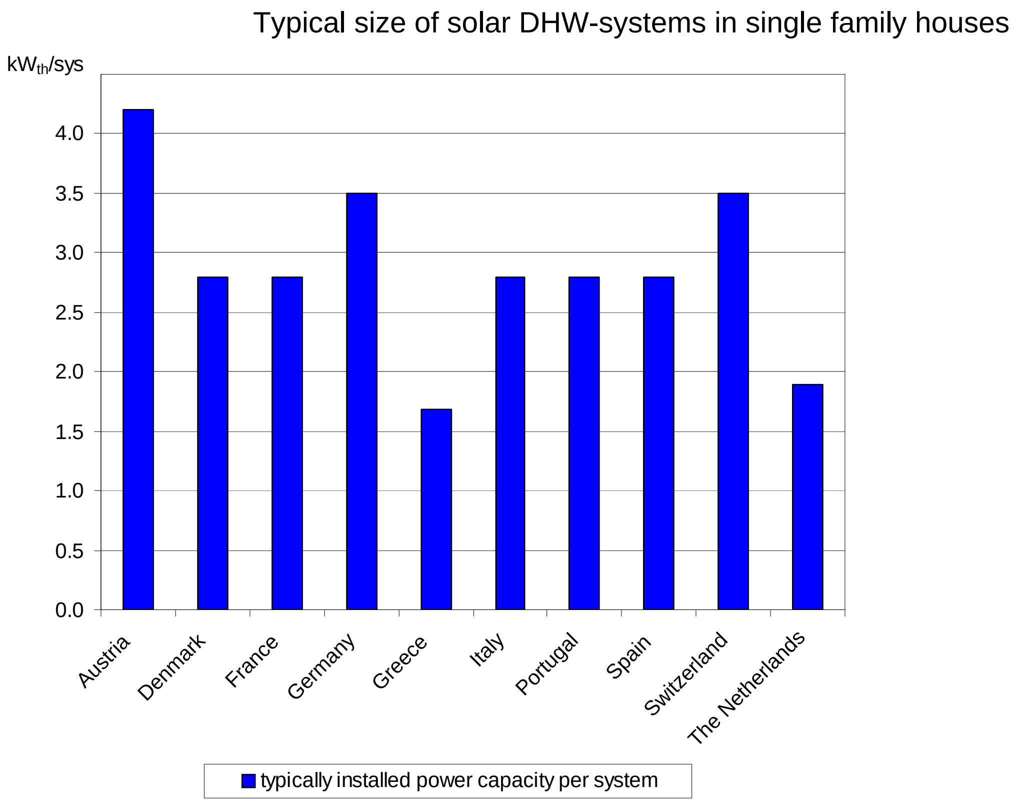


Figure 7: Share of system technology in the participating countries for solar water heating.

System size

Large differences can be found in design and dimensions too. The typically installed collector area (reflected here in the solar power capacity, 1 m^2 = 0.7 kW) and the tank volume vary considerably. In the Netherlands, tank volumes are small and collector areas of DHW systems are moderate. The collector areas for combisystems are small. In Austria, the tank volume and installed collector areas are largest. Figure 8 illustrates the typically installed power capacity for SDHW and combisystems. The installed typical power capacity associated with combisystems ranges from 3.5 kW_{th} to 14 kW_{th}. Combisystems have no relevant share in the southern countries of Greece, Italy, Portugal and Spain even though at least in some parts of these countries there is a short heating season and significant space heating demand. The highest installed power capacity can be found in Norway, where one particular type of combisystem with polymer collector and high degree of building integration dominates the small market. In Austria combisystems with one (combi-)tank and combisystems utilizing two tanks (one of which is a DHW-store) are present. The two-tank type has a share of about 35% of the combisystems installed. Thus, Austria is the only country with a significant share of systems with two separate tanks. New installations, however, tend to have one combined tank.



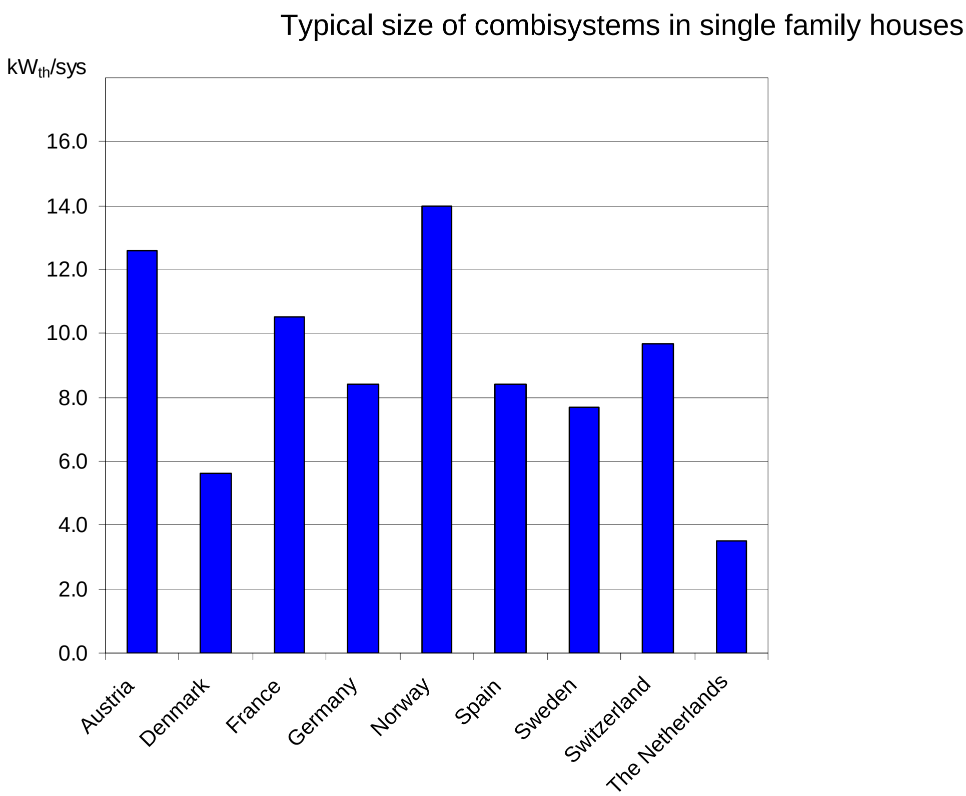


Figure 8: Typically installed power capacity per system in the participating countries. Convention of m² to power: 0.7 kW/m². The bar graphs are based on data from the additional questionnaire, not the survey form.

Auxiliary energy

In the following table the share of complementary heat source for SDHW systems and combi-systems are shown. Note that virtually all data is based on assumptions and estimations.

Countries	SDHW				combisystems			
	electricity	oil	gas	biomass	electricity	oil	gas	biomass
Austria	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Denmark	--	50[1]	30[1]	20[1]	--	50	30	20
France	49	15	33	3	24	23	42	11
Germany	10	40	45	5	5[2]	90		5
Greece	99	1	--	--	--	--	--	--
Italy	30	--	70	--	--	--	--	--
Norway	100	--	--	--	90	--	5	5
Portugal	60	--	40	--	--	--	--	--
Spain	40	--	60	--	25[3]	50	20	5
Sweden	100	--	--	--	15	5		80[5]
Switzerland	50[4]	34	11	5	20[2]	52	18	10
The Netherlands	--	--	100	--	--	--	100	--

[1] always combined with electricity
[2] heat pumps
[3] electricity and heat pumps
[4] including heat pumps (10%)
[5] mostly with electric heater as auxiliary during the summer

In central Europe gas and oil are predominant energy carriers for auxiliary heating of solar domestic hot water systems (**SDHW-Systems**). In Switzerland heat pumps produce an estimated 10% of the auxiliary heat required by small solar water heaters (with a marked trend upwards). Electricity is also a significant auxiliary energy source. In more southern countries the share of electricity for auxiliary heating is higher. In the Netherlands and Germany mostly gas is used, whereas in more northern countries the proportion of electricity for heating is higher again. Denmark, for example, uses the combined energy of oil/electricity, gas/electricity and biomass/electricity with the electricity being the summer backup.

The auxiliary energy supply for **combisystems** is similar to SDHW-Systems. In the other Scandinavian countries electricity, besides biomass, is the main energy source for domestic hot water and space heating. Germany uses 90% oil or gas and a minor, but growing proportion of biomass and heat pumps for auxiliary heating.

With virtually all of the pumped solar water heater systems, the auxiliary heater is separated from the tank and the heat is transferred to the tank by an immersed heat exchanger. In most cases, electrical resistance heaters are always integrated into the storage tank.
Integrated heaters (boiler-tank combinations) are more common with combisystems. In most countries with a significant fraction of combisystems both concepts are available, but the systems with separated boilers are more popular. In Austria, Germany and Switzerland about 10% of the boilers are integrated into the tank. In the Netherlands the boilers are separated or integrated, but in virtually all cases physically attached to the solar heat store.

Efficiency and yield

In the case of energy systems that utilize a non-billable energy source such as solar radiation, efficiency defined as solar gain (or net energy supplied to the storage tank, respectively) per solar radiation received is an issue of academic, but not of practical interest. It is not a suitable indicator for any kind of commercial rating or comparison of systems or products. Therefore such a technical comparison is not pursued in this report. An indicator of interest, however, could be called *effectiveness on investment* and defined as total net energy saved (annual energy saved multiplied with the anticipated system lifespan of 20 years) per initial investment. Figure 9 shows the effectiveness on investment for state of the technology of solar thermal systems in various countries.

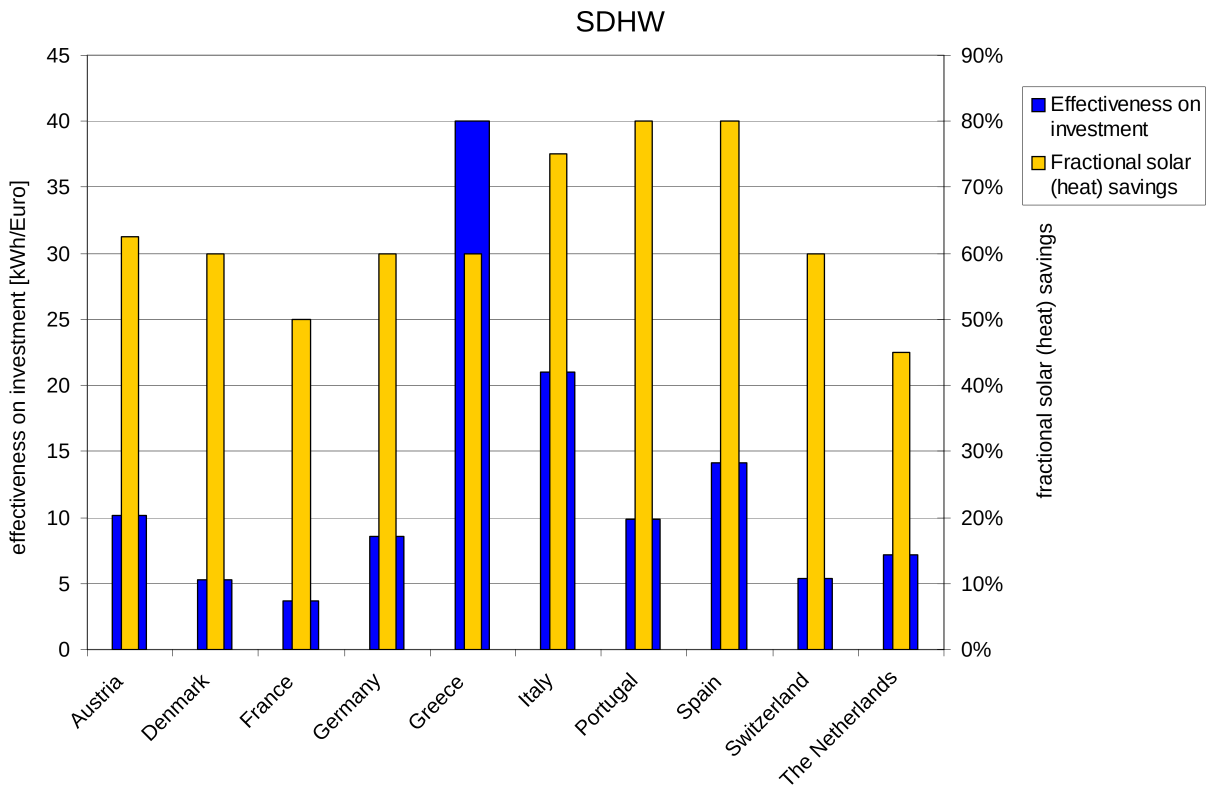


Figure 9a: Effectiveness on investment for typical SDHW systems installed to date in single family houses. It is defined here as the energy saved per Euro of investment (material and installation). The lifetime is assumed to be 20 years for all systems. Note that small values for solar fraction and heat requirement were stated for France (see table below), which results in a poor effectiveness on investment.

The following table shows the numbers used for the calculation of the effectiveness on investment in the bar-graph above:

	Solar fraction [-]	**Heat requirement** [kWh/a]	**Initial Investment** [EUR]	**Effectiveness on investment** [kWh/EUR]
Austria	0.63	3'244	4'000	10.14
Denmark	0.60	2'100	4'800	5.25
France	0.50	1'700	4'650	3.66
Germany	0.60	3'600	5'050	8.55
Greece	0.60	2'500	750	40.00
Italy	0.75	2'800	2'000	21.00
Portugal	0.80	1'850	3'000	9.87
Spain	0.80	1'950	2'200	14.18
Switzerland	0.60	3'600	8'000	5.40
The Netherlands	0.45	2'000	2'500	7.20

Table to Fig. 9a: The values above originate from the additional questionnaire, not from the survey form. This data was used to calculate the effectiveness on investment of SDHW systems.

The initial investment includes installation cost, but no auxiliary heater (nor any installation cost associated with the auxiliary heater. It does not include VAT. The system lifespan is assumed to be 20 years. The effectiveness on investment is calculated by multiplying the solar fraction with the heat requirement and the system lifespan and divided by the initial investment, the cost of material and installation. In case of the solar domestic hot water systems (SDHW) the heat requirement is the heat *needed for DHW-preparation (including storage and circulation, if applicable).*

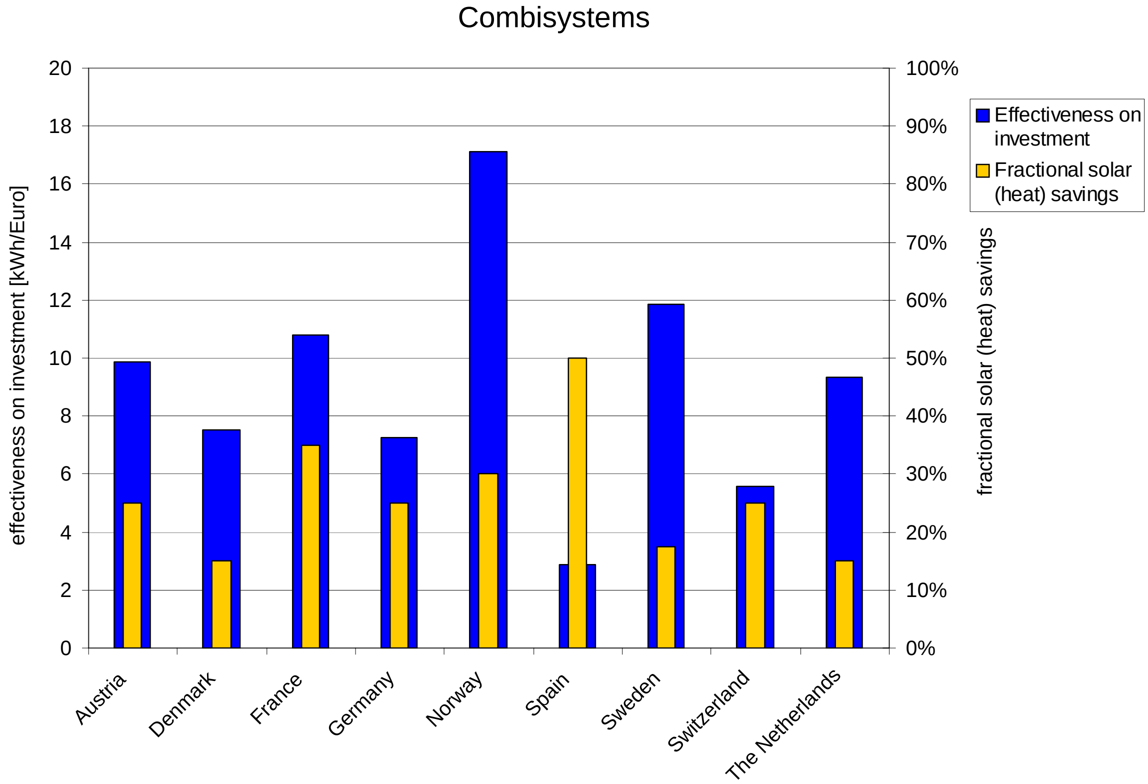


Figure 9b: Effectiveness on investment for typical combisystems installed to date in single family houses. It is defined here as the energy saved per Euro of investment (material and installation). The lifetime is assumed to be 20 years for all systems.

The following table shows the numbers used for the calculation of the effectiveness on investment in the bar-graph above:

	Solar fraction [-]	**Heat requirement** [kWh/a]	**Initial Investment** [EUR]	**Effectiveness on investment** [kWh/EUR]
Austria	0.25	15'244	7'708	9.89
Denmark	0.15	17'100	6'800	7.54
France	0.35	11'700	7'600	10.78
Germany	0.25	15'600	10'750	7.26
Norway	0.30	20'000	7'000	17.14
Spain	0.50	3'600	12'600	2.86
Sweden	0.18	22'000	6'500	11.85
Switzerland	0.25	20'100	18'000	5.58
The Netherlands	0.15	14'750	4'750	9.32

Table to Fig. 9b: The values above originate from the additional questionnaire, not from the survey form. This data was used to calculate the effectiveness on investment of solar combisystems The system lifespan is assumed to be 20 years. The heat requirement includes the heat required for both DHW-preparation (including storage and circulation, if applicable) and space heating of a house suitable for the installation of a typical combisystem.

For Spain, a very small heat requirement but a high number for the initial investment was indicated. The resulting very low effectiveness on investment is surprising. A high cost per performance ratio is typical for a small market situation. The share of solar combisystems is very small in Spain.

Operation strategy of collector loop
The difference in operation of the collector loop is marginal within the countries with similar system concepts. Pumped systems are mostly pressurized and operate with low or high-flow. In some countries, for example Switzerland, the low-flow concept dominates. There, an estimated 75% of all newly installed combisystems operate with a low flowrate in the collector loop. In Germany, the two concepts are equally popular. Drain-back systems are widely used in the Netherlands as in the predominant system in Norway and is gaining popularity elsewhere. The possibility to use water in drain-back systems is always used in Norway and the Netherlands, whereas in all other countries (where the drain-back concept is not yet widely spread), there seems to be a reluctance to do without antifreeze, even if the drain-back principle is applied.

Installation techniques and installation time
Thermosyphon solar water heaters are factory made off-the-shelf products and as such are comparably easy to install. The remarkably low installation cost reported for Greece (a mere 50 EUR) demonstrates this fact. With pumped systems, there is a strong trend towards a high degree of prefabrication, which reduces the efforts for installation, possible problems with the installation and the starting-up of the system. An example of such a system from Austria is presented in the next chapter (page 17). In countries where pumped SDHW-Systems are present, factory-made, easy-to-install products are available and are being installed in slowly increasing numbers. With combisystems there is a trend towards prefabrication too. Small and very small systems make their appearance in the Netherlands (page 19) and Germany (page 18). An example of a Dutch system of this type is presented in the following chapter. In the case of a German small combisystem (/Vail05/, /Im06/), not documented in this report, the solar energy gain is limited to water heating alone. However, these small systems include everything needed for complete annual DHW-preparation and space heating. Typically all components except the solar loop pipes and solar collector array are incorporated in a standard size (60x60 cm) cabinet.
Along with the trend towards drain-back systems, the installation and commissioning can be simplified. The drain-back vessel is often factory-filled. With this, any special procedure for filling the collector loop can be avoided.
In Germany, a trend can also be observed for the use of a non-pressurized plastic tank /Rot05/ for both SDHW and combisystems, which is lightweight and thus somewhat simplifies the installation. The polymer collector used predominantly in Norway is also lightweight and eases installation on the roof. In addition the collector circuit is non-pressurized and thus does not require a qualified plumber for connection to the store.

Innovations and trends

Austria

SOLution

Figure 10: Example of a solar domestic hot water system, largely prefabricated /SOL05/

Denmark, Sweden

Figure 11: Hydraulik Scheme REBUS SCS-Concept – Two units /REB05/

Germany

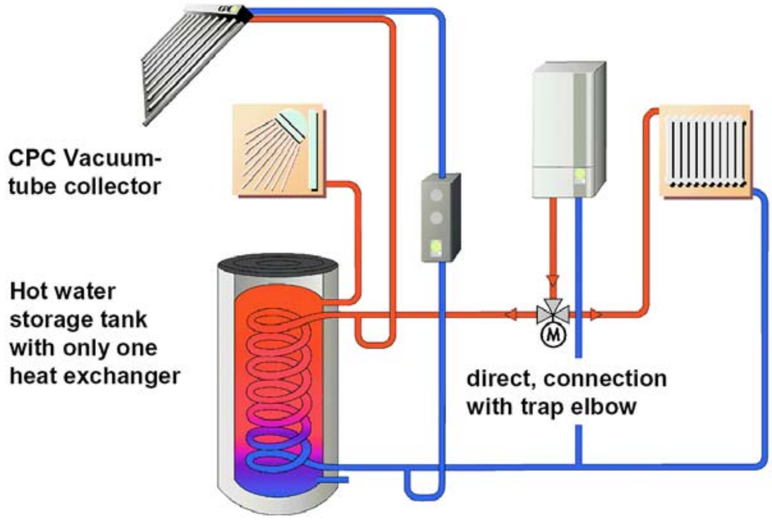


Figure 12: Direct connected solar loop to the conventional heating system. Paradigma CPC Aqua /Par05/

Spain

Figure 13: An integrated collector storage (ICS) for areas with high solar radiation. The costs in comparison to thermosyphon systems are low and in comparison with pumped systems even ultra-low /Sol05/.

Switzerland

Figure 14: Selective, unglazed collectors (energie solaire, Toiture Solaire AS). The collectors are part of the building and can be used for SDHW /Ene05/ especially in areas with limited wind.

The Netherlands

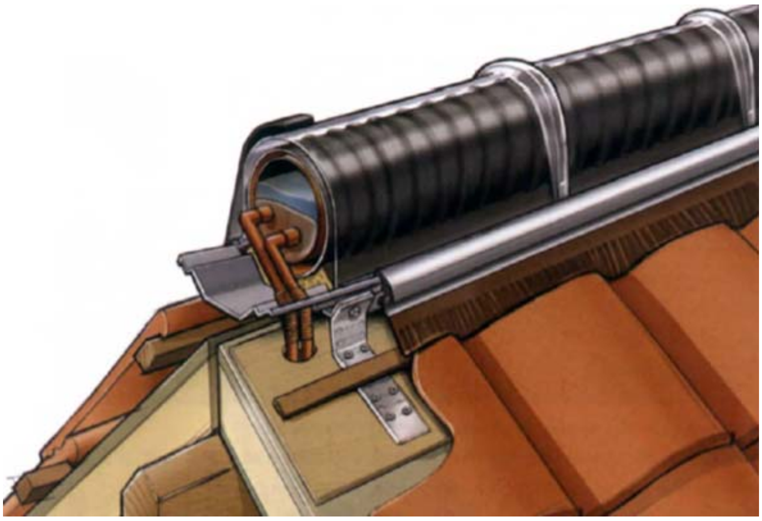


Figure 15: System with an innovative collector, solar ridge. Inventum, Eko-Nok /Inv05/

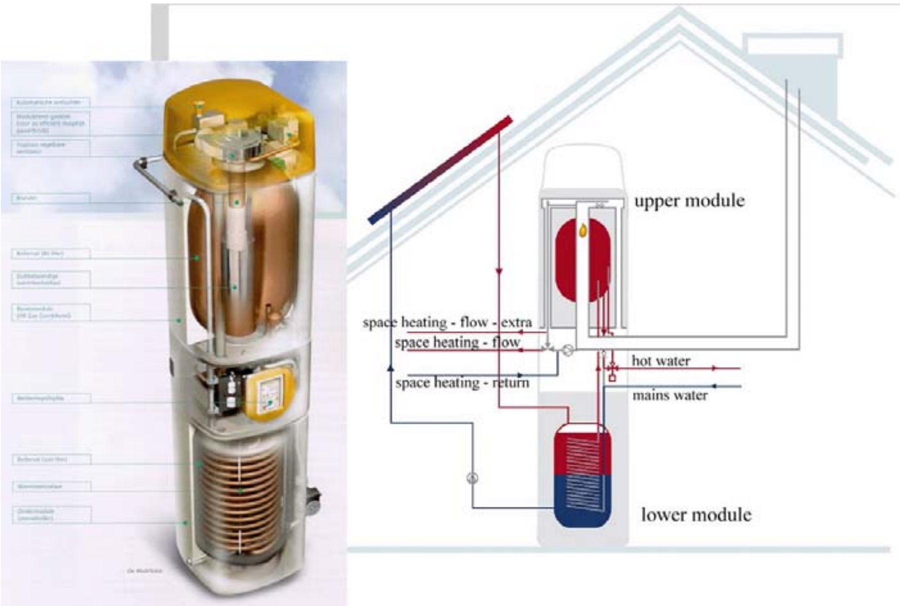


Figure 16: Example of a compact solar heating system. Daalderop, Multisolar /Daa05/

Comments, conclusions and recommendations

Comments

There is an established predominant type of technology within each of the countries surveyed, but there are no obvious predominant types on a European scale. National borders still seem to act as obstacles for the dissemination of technology.

- In those countries where thermosyphon systems are being marketed (Greece, Italy, Portugal, Spain), that type of system is predominant and pumped systems are scarce. This is true, even if the country includes areas with a colder climate (e.g. Italy), which would suggest a substantial proportion of pumped systems.
- In some countries the solar heating systems are virtually all combisystems (Sweden, Norway). In other countries there are almost no combisystems (Greece, Portugal, Italy), even if there is substantial space heating demand in much of the country. For example, in the northern part of Italy the annual average ambient temperature is around 12°C and family homes typically require around 10'000 kWh of energy per year for space heating.
- In the Netherlands, most solar thermal systems are of the drain-back type, whereas in the other countries that technology is rarely used.
- Typical system size is not only dependent on climate, as shown by the differences between the Netherlands (typically small system size) and Austria, where the typical system size is several times larger than in the Netherlands.
- In some countries solar thermal systems are comparably expensive, whereas in others with a similar technology, the systems are substantially less expensive. For example, in Austria the systems tend to be larger, but clearly less expensive than in Switzerland. If solar thermal systems employed for provision of the same energy service are compared for different countries, the price differences (e.g. between Greece and Switzerland) are striking.

The boundary conditions for solar thermal energy utilization are different in the countries investigated. Some of them are measurable and objective. Even though this survey did not aim at finding the reasons for technological differences, some important differences are listed here:

- The most obvious difference is the climate: However, it was found that, among the influences on the propagation of solar thermal energy technology, the importance of climate is often overestimated[3] (/Bre03/). Care should also be taken not to overestimate the influence of the climate on the type (quality, design, costs) of the technology chosen.
- Market development (underdevelopment, development or saturation) and the causes thereof:
  – Energy prices
  – The structure of energy pricing and energy taxation (oil vs. gas vs. electricity). For example, if electricity is expensive, but for practical reasons, normally used to prepare hot water, solar water heating is likely to be economical.
  – Type and amount of public support through subsidies and tax exemptions, regulations and information campaigns (e.g. if as in many cities in Spain, it is mandatory to cover a prescribed fraction of the domestic hot water load by means of solar energy, systems that only just fulfil this requirement will be preferred. Or, as in Germany, if collectors are required to have a certain efficiency for a certain application, in order to be eligible for subsidies, inexpensive unglazed collectors are not marketable, even in cases where that technology is economically favourable. Also, if there are substantial subsidies allocated to the collector area (Germany), systems with relatively large collector areas are likely to appear.)
- Restrictions through standards, norms and guidelines. For example in the Netherlands there used to be a regulation requiring the protection of drinking water from glycol by a double wall, which was one of the major contributing factors to the development of the water filled drain-back technology. The regulation has now been taken away but the successful drain-back technology remains to be predominant.

Additional, but less tangible influences, may be important for the dissemination of solar thermal energy technology, but are more difficult to quantify or assess.

- Public acceptance of solar thermal technology and a particular type of technology.
- Traditions and practice of workmanship (e.g.: It is difficult to introduce solar space heating in places where direct electrical heating is traditionally used and still common practice. Also, it is challenging to introduce solar space heating in places, where space heating is welcome, but not yet widespread, as in colder regions of the Mediterranean.)
- End user expectation (quality, aesthetics) and purchasing power (wealth).
- Structure of the provider side (number of providers of solar thermal systems).
- Consumer side of the market: Presence of a do-it-yourself attitude (home owner/ builder).
- Leading (and misleading) influence of "experts". (e.g. in Switzerland, guidelines established by experts have led to relatively large tank volumes.)

Conclusions

Even though this survey is restricted to Western European countries, a relatively small part of the world, large differences can be observed among the solar thermal technologies being used. National boundaries seem to act as technological boundaries, if not as technological barriers. There is an established state of the technology in each of the countries, but whatever the reasons for the large technological differences encountered among different European countries may be, it is hard to believe that mostly objective reasons have caused these differences. This suggests that there is much potential for short and medium term improvement by overcoming these ("technico-cultural") differences and by the adoption of technological achievements already present in other countries.

- There are a lot of lessons to be learned from each other.

Germany, which has the strongest and fastest growing market (ca. +500 MW/a, +700 m^2/a) is the driving force for innovation. There, important innovation is often ignited and promoted by the industry, whereas in small markets innovations are more likely to made by experts and research institutions. There is an obvious correlation between market size and market development on the one hand and technico-economic improvement through innovation on the other. Figure 18 shows the development of end user prices of solar water heaters in Germany. This graph strongly suggests that the system cost development depends on the market development. Also the bar-graphs of Figures 17a and 17b support this conclusion: In countries with a well developed market, the system prices tend to be lower than in countries with a smaller number of installed collectors per capita. However, the observed correlation does not explain to what extent low prices lead to high sales or vice versa.

- Public support of solar thermal installations not only leads to more installations, but also boosts innovation and therefore leads to more economic systems.

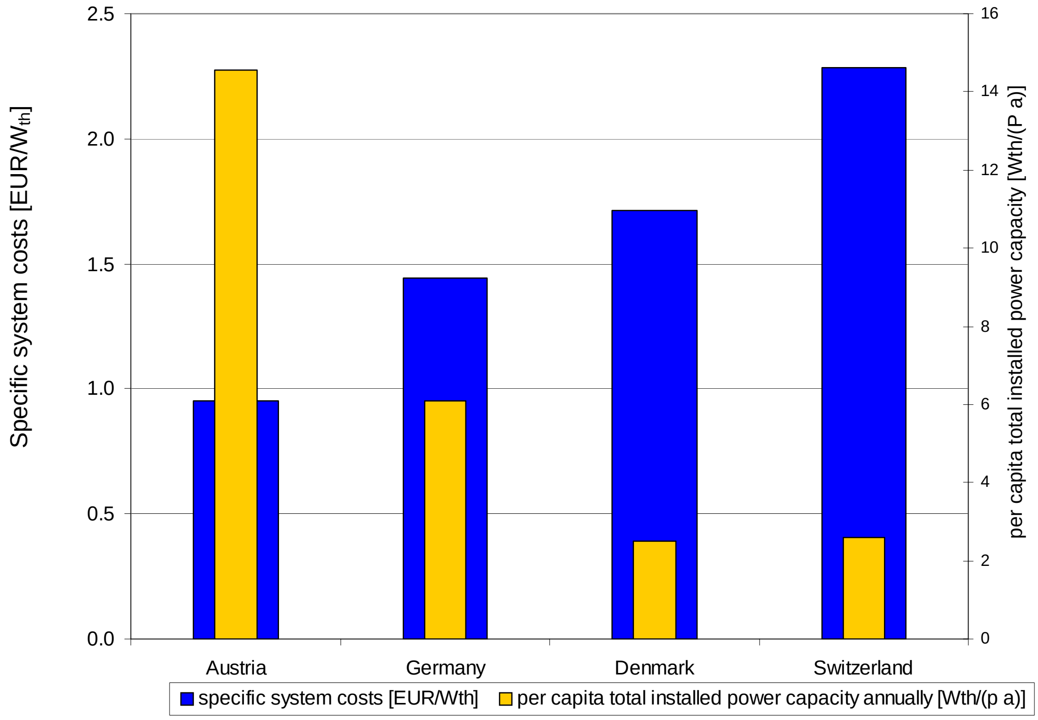


Figure 17a: Yearly installed solar thermal power capacity per capita and the typical system costs per installed power capacity for solar domestic hot water systems (SDHW) in central European countries with similar technology. The graph suggests that in countries with well developed markets (Austria), the system costs are significantly lower than in others.

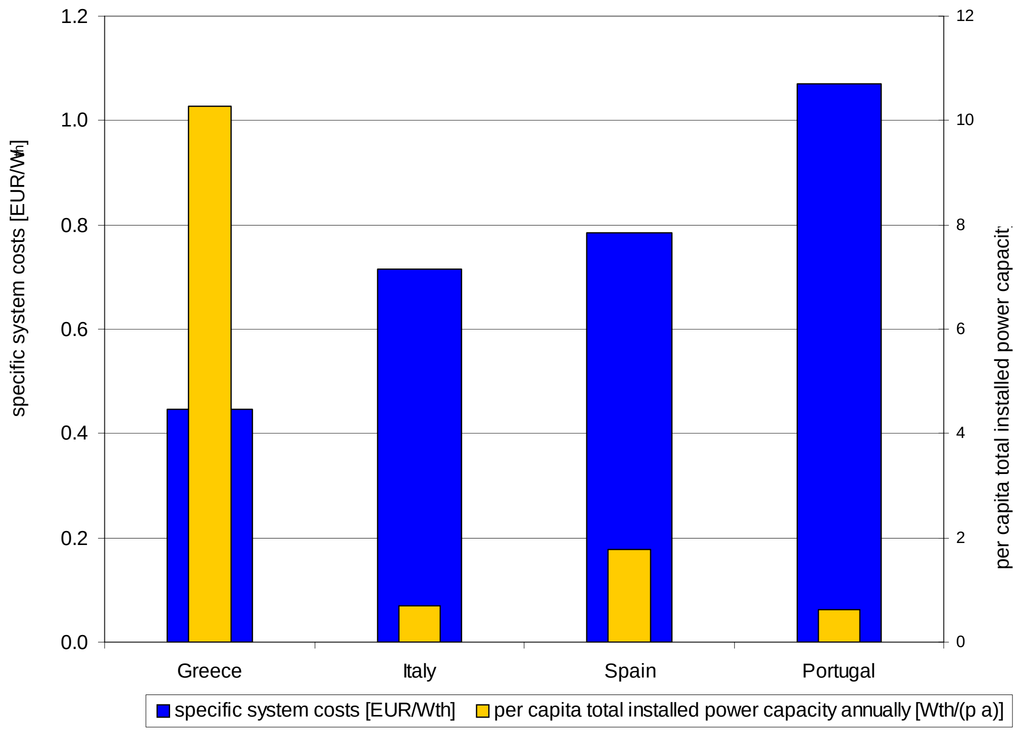


Figure 17b: Yearly installed power capacity per capita and the typical system costs per installed power capacity for solar domestic hot water systems (SDHW) in the Mediterranean. In these countries thermosyphon systems are the technology of choice. With the exception of Italy, the system cost (retail sales prices plus installation) is low, if the market (the per capita annually installed solar thermal power) is large. In both figures 17a and 17b, the system cost does not include any auxiliary heater, nor VAT. The cost data used for this graph is from the additional questionnaire, not from the survey forms.

Thermal solar energy technology is far from being fully developed.

➢ The potential to further reduce cost is enormous.

An indication of this potential is given by both the difference in specific system cost (Fig. 17a, 17b) and the development of prices for solar thermal energy systems (Example Germany, Fig. 18).

➢ There is a large potential and opportunity to further develop the market.

The large differences in the per capita installed solar thermal capacity in the countries considered in this survey (Fig. 4) suggest that there is a remarkable potential for solar thermal energy utilization (and a business opportunity). Even if only solar water heating and space heating is considered, there is a large potential and opportunity to further develop the market both by exploiting the existing markets (e.g. with more economic systems) as well as accessing new markets and niches with a different type of system (e.g. solar water heaters in Sweden, solar combisystems and systems for multifamily houses in Greece and Portugal).

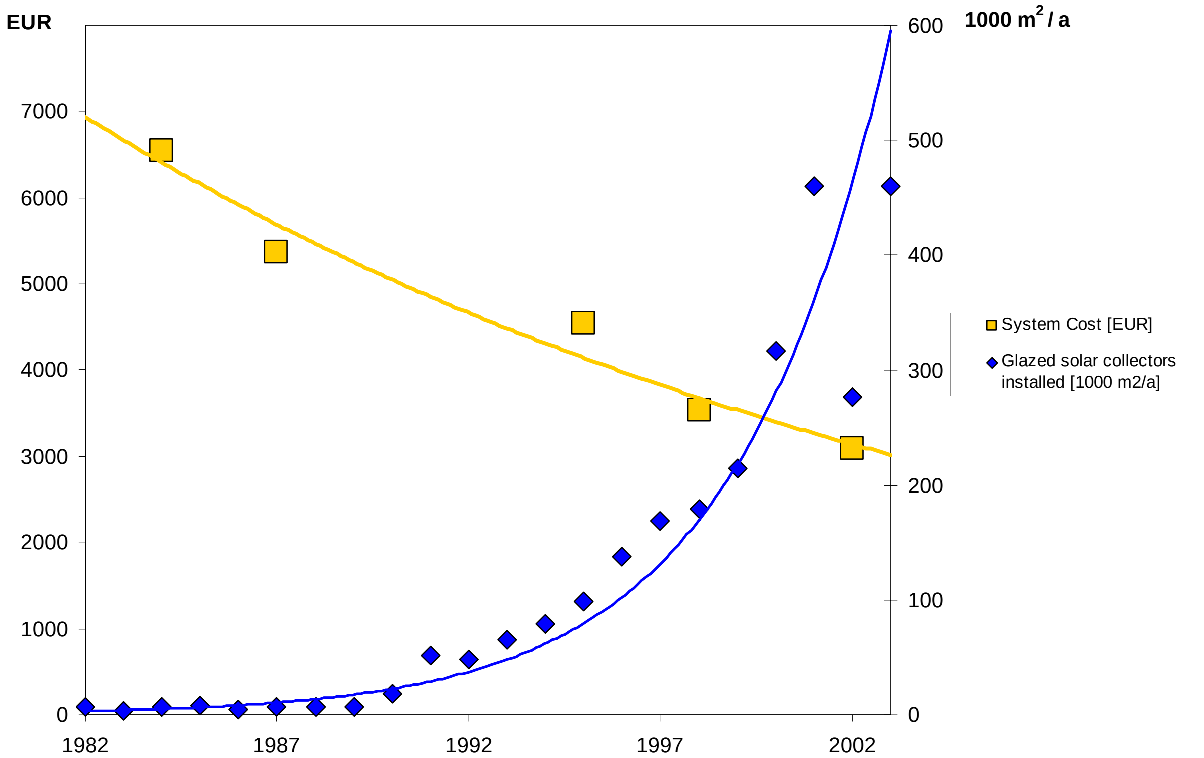


Figure 18: System cost development of solar domestic hot water heaters for single family homes in Germany (in real monetary value as per 2002) and the total installed collector area (glazed collectors) over the last two decades. [conversion factor: German Marks to Euro: 0.51129] Sources: Data for system cost: Stiftung Warentest. Data for collectors installed annually: /Bre03/.

Recommendation

A more thorough study of low-temperature solar thermal technology, which should comprise a larger part of the world and which could aim at the identification of reasons for the technological differences, would without doubt yield valuable information for stakeholders in the fields of technology, politics, research and financing.

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Appendix Blank Survey Form

NEGST WP1 – Market survey of today's system technology

National assessment form

A Principles, scope and procedures

- The national survey form covers the situation per country in the most recent year with available data.
- It shall assess what is newly (annually) installed to date not what is produced.
- It focuses on standardised systems (factory made or nearly factory made, or multiple installations of small custom-made systems or small systems that are installed in variants). **Small here means that it could be installed in a single-family home**, regardless whether it actually is installed in a single family home. The sections beyond D do not cover large custom-built installations such as those for multifamily buildings.
- The survey is mostly restricted to domestic low-temperature heating applications (DHW or space heating). Cooling or industrial applications are only covered for completeness.
- Text in blue colour are example entries.
- Text in red colour are comments to clarify the procedure of filling in the form.
- Fields marked "(mandatory)" or "(m)" must be filled in. If no data is available please supply an estimated figure or your best guess. If you absolutely do not dare to guess please state so, but do not leave any field marked "m" empty.
- Wherever possible and important, state the source of information, or mention "estimate" if there is no reliable source.
- Fill in all fields in order for us to make sure nothing was forgotten. If inevitable or where the information is not relevant use a placeholder such as "not significant" or "not applicable" ("n.a."). If large sections are not relevant (e.g. if in a country there are virtually no solar combisystems) mention this and leave out the whole section or fill in all fields of the respective section with: ("n.a.").
- The sections to assess material demand are probably the most difficult and most controversial parts of the survey. They are required to calculate the embodied energy. According to the workplan, the survey also covers "the ecological impact of the used material". It will be impossible to assess this at a high degree of accuracy, but e.g. for some unusual combisystems (like the French 'direct solar floor' or the Norwegian combisystems), we are likely to recognise some marked differences.
- The NEGST national lead institutions: SPF, INETI, ITW, SERC, AEE, DTU, Ecofys, ENEA, NCSR, INTA, Oslo are asked to contribute one national survey by filling in the following form until November 30, 2004.
- There is already a sufficient number of pure market surveys. This is a survey of the system **technology**. It is the objective of this work to identify and point out differences in technology which are relevant in the different countries today or which may be important tomorrow. Therefore please put emphasis on the paragraphs or sections labelled "trends" and "new or interesting concepts".

B Country information

Country	**(mandatory)**		
Name of responsible and Institution	**(mandatory)**		
		Unit, year (m)	remarks, source
Number of inhabitants	(mandatory, (m))	(m)	
Number of m^2 glazed solar collectors in operation	(m)	m^2, 2004 (m)	
Annual collector area [m^2] installed glazed collectors only, total of all heating applications	(m)	m^2, (m)	
Trend: Average annual increase in number of m^2 of glazed solar collectors installed annually over past 5 years	(m)	% p.a. (per year)	
Average heat demand for domestic hot water heating in single family homes, including hot water circulation if applicable.	(m)	kWh/a, per house	

C Climate information. If several relevant climates (relevant means: more than ca. 35% of the countries inhabitants live in that climate) multiply and number this paragraph you may designate the various climates.

Designation (if any):		unit, choice	remarks, source
Average annual irradiation on the horizontal plane	(m)	kWh/m^2	
Average annual temperature	(m)	°C	
Typical space heating demand of an average existing single family house (heat, not final energy, without DHW)	(m)	kWh/a (annual heat, not annual final energy)	
Related climates			

D1 Application; collector area; all solar systems for DHW preparation and space heating; solar domestic hot water systems (SDHW-systems) / solar combisystems (DHW and space heating)

	SDHW	Combi	remarks, source
Annual collector area [m^2/a] installed, glazed collectors only, total of all heating applications	(m)	(m)	m^2 per year
Annual collector area [m^2/a] installed glazed collectors only, small systems only (single	(m)	(m)	m^2 /a

family houses, etc.)			
Annual collector area [m²/a] installed glazed collectors only, multi family houses only	(m)	(m)	m^2 /a
Annual collector area [m²/a] installed glazed collectors only, public buildings only			m^2 /a
Annual collector area [m²/a] installed glazed collectors only used for other applications (industry, etc., specify below in this field). Mention if some of it is not used for pure heating purposes (solar cooling, solar desiccation, solar process heat, or other (specify in remarks)): businesses: office buildings and industry			m^2 /a
Other applications [m²/a] (specify):			
Trend (if any)			

D2 Application; small systems only, number of systems; solar domestic hot water systems (SDHW-systems) / solar combisystems (DHW and space heating)

	SDHW (single family application only)	combisystems (single family application only)	remarks, source
Annual **number of systems** installed	(m)	(m)	year with most recent data:
Trend (if any)			

E SDHW-systems (solar domestic hot water systems)

E1 System types for solar domestic hot water heating (SDHW-systems)

			remarks, source
Share of pumped systems	(m)	%	
Share of thermosyphon systems	(m)	%	
Share of integrated collector storage	(m)	%	

E2 Most popular SDHW-systems types. **Generic systems, not systems specific to a distinct manufacturer, unless a manufacturer dominates the market with that system type. Enter typical or average values. If there are several distinct popular systems, copy the following paragraph as many times as required and number the paragraph (table) E2-1, E2-2, etc.**

E2-1 SDHW-system type

		unit/select from	remarks, source
Share of this type of system design (number of systems per total number of SDHW-systems)	(m)	%	
Design type	(m)	select from: pumped, thermosyphon, ICS	
Solar fraction	(m)	%	
Collector area	(m)	m^2	
Tank volume	(m)	litres	
Type of auxiliary or emergency heat source	(m)	gas, oil, electricity, biomass, heat pump	
Design or position of auxiliary heater. State if the heater is rather an emergency heater in operation only exceptionally than an automatically activated heater.	(m)	Select what is appropriate. integrated in tank, separated from tank, automatic auxiliary, emergency heater, integrated heat exchanger	
Tank material	(m)	steel, stainless steel, other (specify), if fractions are specified this covers the overall share (share of all material of all systems of that type)	
Collector type	(m)	FP (flat plate), glazed, black paint; FP, glazed, selective; FP, unglazed; ETC CPC	

		others (specify)	
Collector mounting		select what is appropriate from: inclined roof integration (collectors replace tiles, etc.); on support structure (on supporting structure separate from building or on support placed on flat roof, or support placed on inclined roof); above inclined roof (parallel to roof, but above tiles, etc.)	
System cost (retail sales price, without installation cost)	(m)	Euro	
Installation cost	(m)	Euro	
Collector loop type and operation	(m)	select whatever is appropriate from: low-flow, high-flow, filled, drain-back, drain-down, direct, indirect, closed, open, pressurized, unpressurized.	
Material use in the **solar collectors** **per m^2 of gross collector area** without mounting material, in finished state, not including scrap material; average value of collectors of all systems of that type. **(m)**			
Copper		kg/m^2	
Steel		kg/m^2	
Stainless steel		kg/m^2	
Aluminium		kg/m^2	
Other metals (combined)		kg/m^2	
Glass		kg/m^2	
Plastics		kg/m^2	
Fibrous insulation (fibreglass and rockwool combined)		kg/m^2	
Material use in the solar collectors **mounting set per m^2 of gross collector area** without mounting material, in finished state, not including scrap material; average value of all systems of that type **(m)**			
Copper		kg/m^2	
Steel		kg/m^2	
Stainless steel		kg/m^2	
Aluminium		kg/m^2	
Concrete		kg/m^2	
Other metals (combined)		kg/m^2	

Plastics		kg/m²	
Material use in the **store for the size of store (tank volume) stated above** in finished state, not including scrap material; average value of store of all systems of that type (m). If the system intentionally uses the thermal mass of the building or a designated part of the building for heat storage purposes, that material should also be included. **(m)**			
Steel		kg/system	
Stainless steel		kg/system	
Aluminium		kg/system	
Other metals (combined)		kg/system	
Fibrous insulation (fibreglass and rockwool combined)		kg/system	
Material use in the **solar station (if any) (pump, valves, etc.)** in finished state, average value of all systems of that type. **(m)**			
Copper		kg per system	
Other metals (combined)		kg per system	
Material use in the **solar loop piping per m of pipe length of single pipe** including pipe mounting material, in finished state, not including scrap material; average value of piping used in all systems of that type. Single pipe means: if the pipe length of the supply line is 10 m and the length of the return line is 15 m, you should divide the total piping material by 25 m. This is the case even if the feed and return pipes are comprised in the same insulation and installed as one line. **(m)**			
average length of feed line		m	
average length of return line		m	
Copper		kg/m	
Steel		kg/m	
Stainless steel		kg/m	
Aluminium		kg/m	
Other metals (combined)		kg/m	
Plastics		kg/m	
Fibrous insulation (fibreglass and rockwool combined)		kg/m	
Remarks (keywords: embodied energy, ecological impact of material use, multi-use (combined pool heating and hot water heating, combined heating and cooling), integration of components and prefabrication, installation cost-trend, time required, building integration, market trends, related markets, related technology, auxiliary heater, etc.):			
Hydraulic scheme:			

E3 New or interesting concepts of SDHW-systems regardless of their market share (use as many sections E3-1, E3-2, E3-3, ... as there are interesting systems)

E3-1 Special SDHW

E3-2 Special SDHW

F Combisystems

F1 Description of the most popular solar combisystems.

Generic systems, not systems specific to a distinct manufacturer, unless a manufacturer dominates the market with that system type. Enter typical or average values. If there are several distinct popular systems, copy the following paragraph as many times as required and number the paragraph (table) F1-1, F1-2, etc.

F1-1 combisystem type

		unit/select from	remarks, source
Share of this type of system design (number of systems per total number of Combi-systems)	(m)	%	
Design type	(m)	Pumped, thermosyphon, ICS	
Solar fraction (space heating and hot water combined, typical value)	(m)	%	
Collector area	(m)	m^2	
Tank volume	(m)	Litres	
Type of auxiliary or complementary heat source		gas, oil, electricity, biomass, heat pump	
Design or position of auxiliary heater		integrated in tank, separated from tank	
Tank material	(m)	steel, stainless steel, other (specify), if fractions are specified this covers the overall share (share of all material of all systems of that type)	
Collector type	(m)	FP (flat plate), glazed, black paint; FP, glazed, selective; FP, unglazed; ETC CPC others (specify)	
Collector mounting	(m)	select what is appropriate from: inclined roof integration (collectors replace tiles, etc.); on support structure (on supporting structure separate from building or on support placed on flat roof, or support placed on inclined roof); above	

		inclined roof (parallel to roof, but above tiles, etc.)	
System cost (retail sales price, without installation cost) including the auxiliary heater	(m)	Euro	
Installation cost	(m)	Euro	
Collector loop type and operation		select whatever is appropriate from: low-flow, high-flow, filled, drain-back, drain-down, direct, indirect, closed, open, pressurized, unpressurized.	
Material use in the **solar collectors per m² of gross collector area** without mounting material, in finished state, not including scrap material; average value of collectors of all systems of that type. **General remark for this materials section of combisystems: If the collectors used in combisystems are identical to one of the collector types documented in the DHW-systems, refer to that section, instead of filling in the same numbers again.** (m)			
Copper		kg/m²	
Steel		kg/m²	
Stainless steel		kg/m²	
Aluminium		kg/m²	
Other metals (combined)		kg/m²	
Glass		kg/m²	
Plastics		kg/m²	
Fibrous insulation (fibreglass and rockwool combined)		kg/m²	
Material use in the solar collectors **mounting set per m² of gross collector area** without mounting material, in finished state, not including scrap material; average value of all systems of that type (m)			
Copper		kg/m²	
Steel		kg/m²	
Stainless steel		kg/m²	
Aluminium		kg/m²	
Concrete		kg/m²	
Other metals (combined)		kg/m²	
Plastics		kg/m²	
Material use in the **store for the size of store (tank volume) stated above** in finished state, not including scrap material; average value of store of all systems of that type (m). If the system intentionally uses the thermal mass of the building or a designated part of the building for heat storage purposes, that material should also be included.			
Steel		kg per system	

Stainless steel		kg/system	
Aluminium		kg/system	
Other metals (combined)		kg/system	
Concrete		kg/system	
Fibrous insulation (fibreglass and rockwool combined)		kg/system	
Material use in the **solar station (if any) (pump, valves, etc.)** in finished state, average value of all systems of that type. (m)			
Copper		kg per system	
Other metals (combined)		kg/system	
Material use in the **solar loop piping** **per m of pipe length of single pipe** including pipe mounting material, in finished state, not including scrap material; average value of piping used in all systems of that type. Single pipe means: if the pipe length of the supply line is 10 m and the length of the return line is 15 m, you should divide the total piping material by 25 m. . This is the case even if the feed and return pipes are comprised in the same insulation and installed as one line. (m)			
average length of feed line	(m)	m	
average length of return line	(m)	m	
Copper		kg/m	
Steel		kg/m	
Stainless steel		kg/m	
Aluminium		kg/m	
Other metals (combined)		kg/m	
Plastics		kg/m	
Fibrous insulation (fibreglass and rockwool combined)		kg/m	
Remarks (keywords: embodied energy, ecological impact of material use, multi-use (combined pool heating and hot water heating, combined heating and cooling), integration of components and prefabrication, installation cost-trend, time required, building integration, market trends, related markets, related technology, auxiliary heater):			
Hydraulic scheme:			

F2 New or interesting concepts of combisystems regardless of their market share (multiply the next paragraph as often as useful, use as many sections F2-1, F2-2, F2-3, ... as there are interesting system concepts)

F2-1 Special combisystems

F2-2 Special combisystems