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INTEGRATING SOLAR THERMAL IN BUILDINGS – A QUICK GUIDE FOR ARCHITECTS AND BUILDERS

United Nations Environment Programme

ACKNOWLEDGEMENTS

SUPERVISION AND COORDINATION

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EXECUTIVE SUMMARY

"Integrating Solar Thermal in Buildings – A quick guide for Architects and Builders" aims at promoting solar water heating (SWH) systems to architects and builders from developing countries and help them consider integrating SWH applications in their designs.
Intending to be a useful handbook, this "Quick Guide" provides a compact overview of the technology and its main characteristics; as well as the main requirements to be considered for its application in different types of projects and in different geographical locations.

It was elaborated in order to increase awareness about SWH among important stakeholders, such as architects and builders; and encourage the use of this type of solar systems. Hence, it gives a synopsis of the technology and general requirements for integration in buildings. It also provides a quick reference guide to the practicing architects and builders, helping them to quickly identify relevant sources of additional information.

"Integrating Solar Thermal in Buildings – A quick guide for Architects and Builders" was developed as part of the Global Solar Water Heating (GSWH) Market Transformation and Strengthening Initiative (GSWH Project), and as a result of a joint effort between The European Solar Thermal Industry Federation (ESTIF) and the United Nations Environment Programme (UNEP) through its Division of Technology, Industry and Economics (DTIE) and the Global Environment Fund (GEF).

Funded by the Global Environment Fund (GEF), the GSWH project's main goal is to accelerate the global commercialization and sustainable market transformation of SWH, thereby reducing the current use of electricity and fossil fuels for hot water preparation.
It will build on the encouraging market development rates already achieved in some GEF programme countries and seek to further expand the market in others where the potential and necessary prerequisites for market uptake seem to exist.

The GSWH project consists of two components as follows:

- Component 1 - Global Knowledge Management (KM) and Networking: Effective initiation and co-ordination of the country specific support needs and improved access of national experts to state of the art information, technical backstopping, training and international experiences and lessons learnt.
- Component 2 - UNDP Country Programmes: Work in the country programmes revolves around addressing the most common barriers to solar water heating development: policy and regulations, finance, business skills, information, and technology.

ESTIF, as one of the project's regional partners, is committed to the development of knowledge products and services. And to this end, ESTIF has been entrusted with the task of elaborating this "Quick guide for solar thermal in Buildings for Architects and Builders".

STRUCTURE AND METHODOLOGY

The proposed guide aims to promote solar water heating (SWH) systems among architects and builders from developing countries and help them consider integrating SWH applications in their designs. This quick guide will provide a compact overview of the technology, assisting the reader to understand its main characteristics and requirements for application in different types of projects, from single family houses to apartments or office buildings and even (public) swimming pools.

Specifically, the handbook seeks to meet the following objectives:

- Provide a quick reference guide to the practicing architects to answer questions about solar water heating systems;
- Increase awareness about SWH among architects and builders in developing countries and encourage its use;
- Present a step-by-step methodology for integrating SWH applications/systems in designs and projects;
- Facilitate the integration of efficient and lasting SWH systems by providing adequate information, tools and references related to design, installation and maintenance.

This quick guide is devised so as to provide information about solar water heaters for various levels of knowledge and background. The two relevant levels are:

Novice:
reader with no previous background or experience on solar water heaters.

Intermediate:
reader who is aware of SWH and might have used it before in simple applications and a limited number of projects.

More advanced users have already completed several projects with solar thermal and have worked with solar thermal professionals, who can answer any other question they may have. Therefore, this guide does not specifically target this group.

Each chapter is identified with the symbols related to each kind of expertise.

Considering that this guide intends to be compact and focused, making it easy and practical to read, it cannot explore some topics with the required level of technical detail, i.e. many factors depend on the type of building, its characteristics and geographical location. Therefore, at the end of each chapter, suggestions for further readings and literature are provided, to allow the reader to easily identify where to find additional information.

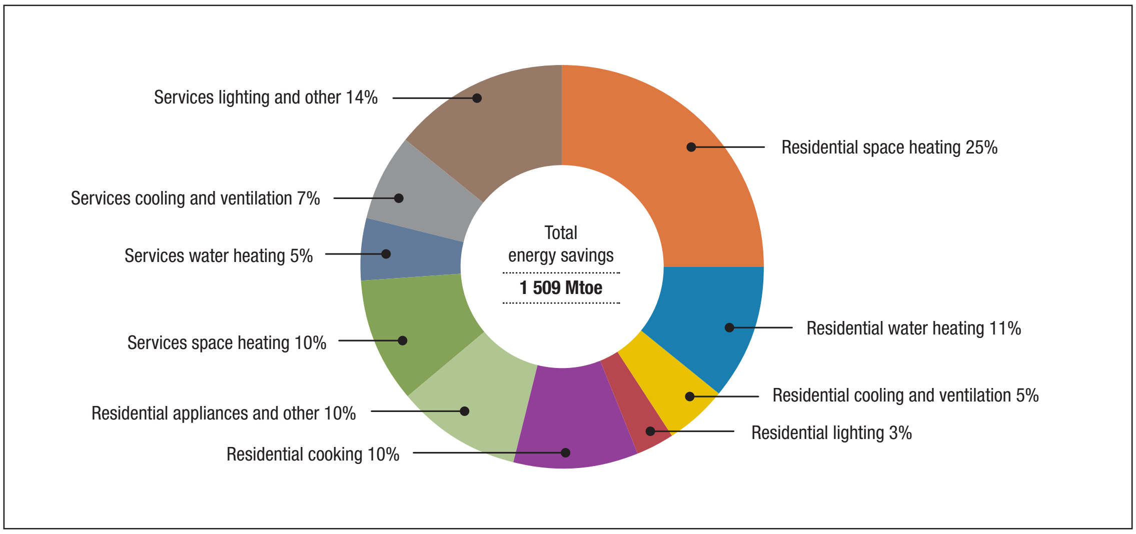
CONTENTS

INTRODUCTION

The building sector is responsible for about a third of the total energy consumption. Beside combined heat and power, heat pumps and thermal energy storage, solar heat (solar thermal) is defined as one of the key technologies to meet future carbon dioxide reduction goals in buildings.

Additionally, the use of solar energy in buildings is becoming of critical importance if we are to prepare for fossil fuel energy shortages, and reduce our exposure to global warming impacts and associated environmental costs. In this regard, there is a pressing need for architects to acquire competencies in this field. This guide is intended for architects, contractors and any person and/or organisation responsible for the conception, design or construction of buildings.

Figure 1: Building sector energy savings by sector and end-use [IEA 2011]



For the purpose of this guide, we shall assume that, beside project management, readers have a thorough understanding of architecture, building design and construction engineering. They may not have any knowledge about solar thermal or only have basic knowledge about the technology. This guide should enable its target audience to assess the potential benefit of the integration of solar thermal in building projects, to assess the feasibility of this integration, to guide in the selection and management of a supplier and provider of solar thermal technologies.

To this effect the quick guide is divided into three sections:

1	2	3
WHY CONSIDER SOLAR THERMAL FOR YOUR BUILDING?	**HOW TO INTEGRATE SOLAR THERMAL INTO YOUR BUILDING?**	**SOLAR THERMAL: CONTRACTING AND MAINTENANCE**

Each of these sections will direct to other sources, publications and tools allowing in-depth assessment and project (preparation) development.

A guide for emerging markets and developing countries

As was already the case for other Guides and handbooks designed in the framework of the GSWH programme, this publication aims primarily at the promotion of solar thermal in countries, and regions, where the market for this technology is less developed and therefore, where there are less resources and support available. At this stage, we would like to refer to the typology of solar thermal market development elaborated in the *"Guidelines for policy and framework conditions"*.

Architecture, construction and building project management

Architecture and building projects, whether relating to solar thermal or not, usually make use of project management tools and methodologies. In this guide we shall use a seven-step approach:

- **Step 1**: Develop the scope of work
- **Step 2**: Design and documentation
- **Step 3**: Identifying and working with a SWH supplier/ contractor
- **Step 4**: Infrastructure installation (collector field, piping, storage tank and ancillary equipment)
- **Step 5**: Interface with other construction processes
- **Step 6**: Product selection and installation
- **Step 7**: Commissioning, Monitoring and Training

In the following paragraphs, each step is outlined with a number of questions, which need to be asked and addressed. Answers or tools for how to approach them are then provided in subsequent sections.

Step 1: Develop the scope of work

When starting a new project, the scope of work is an effective planning tool. A clear, well thought-out scope of work can make plans easily accessible to outsiders; others can then see exactly what you intend to do and how you will proceed. These questions will enable you prepare your scope of work and make it work smoothly:

- What kind of building/site is to be developed/worked on?
- What type of heating application is required (sanitary hot water, swimming pool heating, space heating etc.)?
- If the building/site exists already: What is currently used for this/these applications?
- What is the motivation to consider solar thermal (kWh cost, cost predictability, no/reduced dependence on other fuels, unavailability of other fuels at the location, "green" marketing)?
- What is the expectation of the client concerning the solar thermal system (e.g. high solar fraction meaning most or all of the energy for an application to be covered by solar, or high utilisation of solar thermal system leading to low kWh cost of solar heat, or outstanding aesthetics)?
- Should the solar thermal system be included from the beginning or should the planning just ensure that the building/site is "solar ready" so that a SHW system can be easily added later?

In order to fully address these issues, it is advisable to read the following chapters in the suggested order:

- Which Applications for Solar Thermal? *(page 11)*
- Benefits of Solar Thermal *(page 12)*
- Site Assessment *(page 31)*
- Financial and Economic Aspects *(page 16)*

Step 2: Design and documentation

Good quality design and documentation are essential to ensure an efficient construction process, thus avoiding delays and increased project costs and time. It is important that the documentation provided is as complete as possible and accurately reflects the design concept. These are useful pointers:

- Choosing the collectors location: needed area, building integration, roofing or façade requirements (system size and weight, orientation, piping).
- Choosing the storage location: synergies with HVAC (heating, ventilation and air conditioning), storage integration into building elements, interface with other amenities (e.g. gas, water counters).
- Define requirements for the equipment: applicable standards and required/desired certificates (e.g. quality labels).
- Identify installation requirements: construction stage, required equipment (e.g. cranes).

In order to fully address these issues, it is advisable to read the following chapters in the suggested order:

- Basics of Solar Thermal *(page 23)*
- Choosing a Subcontractor *(page 38)*
- Codes, Standards and Certification *(page 32)*
- Design Implications *(page 34)*
- Guide to Tendering and System Specification *(page 36)*

Step 3: Identifying and working with a SWH supplier/ contractor

Finding the right partner is crucial. Architects usually work with specialised solar thermal planners/installers/developers and are not involved in the design, installation or operation of SHW systems. Answers to these questions should help towards selecting the right supplier/contractor:

- Who is capable of designing the SHW system for the given project?
- Will they also install the system? Or even operate it?
- What are the technical/non-technical requirements?
- What is needed to launch a request for tenders?
- How to choose the successful bidder, offer?

In order to fully address these issues, it is advisable to read the following chapters in the suggested order:

- Guide to Tendering and System Specification *(page 36)*
- Choosing a Subcontractor *(page 38)*
- Maintenance *(page 40)*

Step 4: Infrastructure installation (collector field, piping, storage tank and ancillary equipment)

Some issues must be identified and thoroughly considered to eliminate any potential gap between the design concept and its implementation:

- Is the building component, to which the collector field would be attached (roof, façade, balustrade etc.), strong enough to carry the weight of the collectors, mounting structures, fluids and wind loads (including negative wind loads, i.e. uplifts)?
- Would the collectors obstruct access to other parts of the roof/building?
- Is the distance from the collector field to the potential place of the storage tank short enough (normally, no more than 20m)
- Where can pipes from the collectors to the tank be located?
- Is the heating equipment room large enough to accommodate the storage tank?
- Is its floor strong enough to carry the weight of the tank and the fluid?
- How can the tank be transported to that room - are the paths, stairs and doors wide enough?

- Or has the tank to be assembled onsite at its final destination or installed before that space is sealed during the construction process?

In order to fully address these issues, it is advisable to read the following chapters in the suggested order:

- Basics of Solar Thermal *(page 23)*
- Choosing a Subcontractor *(page 38)*
- Building Integration *(page 32)*
- Maintenance *(page 40)*

Step 5: Interface with other construction processes

It must be clearly defined from the outset, who does what and when. All the operations must be well organized, managed and planned. The following points should be considered:

- Who is in charge of the planning, the installation, the commissioning of the solar thermal system?
- What are the interfaces with the surrounding construction processes (e.g. roofing, conventional HVAC system installation)?
- Define project milestones, potential road blocks.
- Monitoring budget execution.

In order to fully address these issues, it is advisable to read the following chapters in the suggested order:

- How to integrate solar thermal? *(page 23)*
- Financial and Economic Aspects *(page 16)*

Step 6: Product selection and installation

The product selected can have a major impact on both the overall quality of the installation and satisfaction with the end result and system performance. Some factors are determinant, such as the quality of the products and how they are installed, and can be pinpointed with the help of the following questions:

- Does the client have specific requirements (technology, brands, costs, certification, aesthetics etc.)?
- What is the optimal product for the planned installation (e.g. limited availability of suitable roof space may favour vacuum tube collectors; low-temperatures may be reachable with low-cost unglazed absorbers etc.)?
- Apart from quality considerations: Is there a requirement to use only specifically tested and/ or certified products (e.g. to fulfil regulatory requirements, to make it eligible for financial support, to fulfil requirements of the building insurance)?

In order to fully address these issues, it is advisable to read the following chapters in the suggested order:

- Basics of solar thermal *(page 23)*
- Support policies and incentive schemes *(page 14)*
- Codes, Standards and Certification *(page 32)*

Step 7: Commissioning, monitoring and training

On completion, all the various equipment and systems must be fully tested to ascertain that they operate according to the expectations of the building owners and designers, as this process can affect the performance of the solar thermal system over time and even its lifespan. The following points should be tackled:

- Who is responsible for the handover (the planner, the installer, the developer)?
- What documentation regarding the system and the commissioning must be included at the handover?
- What parameters can and may the building owner or user influence, which ones need to be set and adjusted by the external expert?
- If the system is large/more complex, the handover may need to be accompanied by training of those in charge of operating the system.
- At least larger systems (e.g. >50m2 of collector area) should be remotely monitored to check correct operation and for easier management.
- Remote monitoring can be confined to frequent readings of a few parameters like temperature in the collector field(s) and storage tank. But it can also include real-time bi-directional connection with the system controls, so that the system can be completely operated remotely.

In order to fully address these issues, it is advisable to read the following chapters in the suggested order:

- Performance Contracting and ESCO models for solar thermal *(page 37)*
- Maintenance *(page 40)*

Further Readings and References

- Technology Roadmap: Energy-efficient Buildings - Heating and Cooling Equipment [IEA 2011], page 5: Key Findings

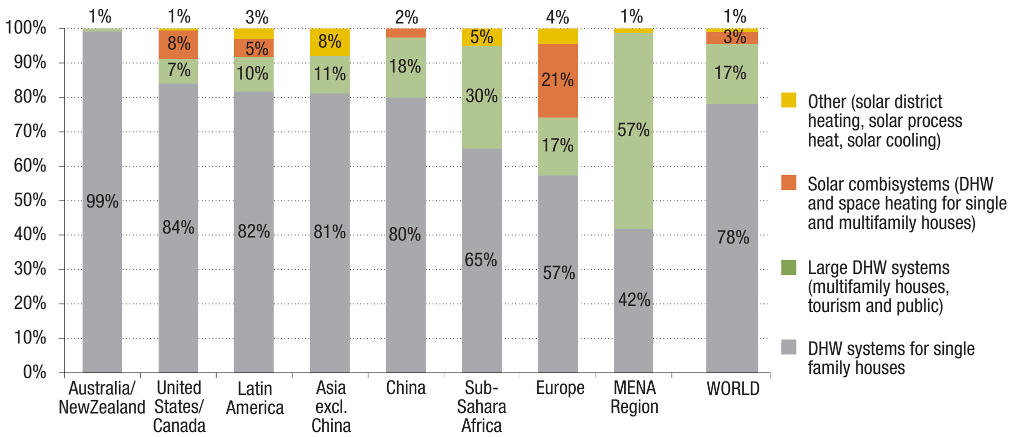
WHY CONSIDER SOLAR THERMAL?

NOVICE

Which Applications for Solar Thermal?

The main use of solar thermal applications is for (domestic) hot water: 95% of all installed glazed collector capacity is used for this purpose, with the vast majority being installed in small homes (85%). But the share of solar thermal collectors to supply hot water to larger residential and non-residential buildings is increasing. As we can observe in the following graph, in 2011 one sixth of the newly added solar thermal capacity was in this segment. 3-4% of the collector capacity is used also for space heating and only 1% is for other purposes such as district heating, industrial process heat and solar cooling.

Figure 2: Distribution of solar thermal systems by application for the newly installed glazed water collector capacity in 2011 by economic region [IEASHC 2013]



Asia excluding China: India, Japan, Taiwan

Latin America: Brazil, Mexico

Europe: EU18, Albania, Norway, Switzerland, Turkey

MENA Region: Israel, Jordan, Lebanon, Tunisia

It is in Europe that we find a larger percentage of alternative applications. Large installations for industrial process heat, district heating or solar cooling are growing in relevance, but still represent a small percentage of the market (4%). In all the other regions, over 90% of the new installations were dedicated to domestic hot water preparation. In the MENA (Middle East and North Africa) region we can find the highest percentage of large DHW. These are mainly for multi-family houses but also for services (such as hotels) or public buildings (e.g. schools).

This higher percentage can be attributed to solar obligations such as those in place in Israel. In force since 1980, this legislation requires the use of solar thermal in all new buildings, except buildings used for industrial or trade purposes, hospitals and buildings higher than 27 metres.[1]

The data provided above refers only to glazed collectors, as these are used in the vast majority of installations worldwide.

Cheaper unglazed water collectors can be used to produce lower temperature heat, mostly for swimming pool heating. On a worldwide scale, this application is small (ca. 3%) but shows strong regional variations. In Australia, New Zealand, North America and Brazil unglazed collectors account for well over 50% of the total solar thermal capacity.

Air collectors have been widely used for agricultural applications (crop drying), and are also used for space heating in commercial and residential buildings. However, they are not within the scope of this guide. For more information on this technology, see the SAHWIA website (Solar Air Heating World Industries Association, http://sahwia.org/).

Further Readings and References

- Technology Roadmap: Energy-efficient Buildings - Heating and Cooling Equipment [IEA 2011], pages 16-19: Solar heating and cooling applications
- Solar heat worldwide: Markets and Contribution to the Energy supply 2011 [IEASHC 2013], pages 38-40

Benefits of Solar Thermal

Beyond the more obvious benefits at macro level (shaving off peak electricity demand, avoiding CO_2-emissions, decreasing fuel import dependence) solar thermal offers compelling benefits to building owners and/or tenants.

- No, or reduced, dependence on fuels that need to be transported to the site: As an on-site renewable energy technology, solar thermal can replace other fuels normally used for heating purposes, such as oil, natural gas, LPG, coal, biomass and electricity. This can be of special importance, where transportation of fuel is cumbersome and/or costly.
- Applicable everywhere: Thermosiphon systems using natural convection can be deployed even without access to electricity. This makes them especially interesting in off-grid (e.g. rural) regions and where power outages occur frequently. The storage tank of these systems also brings security of water supply at locations with poor water supply.
- Healthier environment: Local air pollutants from (water) heating systems are a major hazard to health in many countries. By avoiding or reducing the need to burn (fossil) fuels, solar thermal can help create a healthier environment.
- Public support: In many countries, governments support the installation of solar thermal systems with financial incentives (direct grants, cheap loans, tax incentives etc.). Home owners and developers can benefit from financial support by installing a solar thermal system.

1 http://solarthermalworld.org/content/israel-worlds-first-solar-thermal-legislation

- Cost/benefit: Already without financial incentives, solar thermal energy is often cost competitive with other (water) heating technologies.
- Cost stability: Whereas cost of oil, gas or electricity can change dramatically, the cost of solar thermal energy remains constant for a long time. Once purchased and installed, a solar thermal system generates free energy for many years to come.
- "Green" image: Especially for many commercial companies, a solar thermal system can be a very visible statement of their interest in a more sustainable trade. And many governments require the use of renewable energies in their own buildings.
- Added value to real estate: Solar thermal often raises the value of the building. This increase in value is a consequence of the estimated savings provided by the system, having a similar effect as energy efficiency measures, such as double-glazing. In countries with energy performance certificates, solar thermal contributes to a higher rating.

Further Readings and References

- Solar Heating and Cooling for a Sustainable Energy Future in Europe. Vision, Potential, Deployment Roadmap, Strategic Research Agenda [ESTTP 2008], pages 14-15: The unique benefits of Solar Thermal
- Technology Roadmap: Energy-efficient Buildings - Heating and Cooling Equipment [IEA 2011], pages 7 and following: Benefits

Issues and Barriers

Throughout the world, modern solar thermal systems have been successfully installed for decades. They can be used under most climatic conditions, even where temperatures are rather low or where the availability of (direct) sunlight is limited. Market success, in countries as diverse as China and Germany, show that suitable solar thermal solutions are available for different regions and markets.

Nevertheless, solar thermal faces a number of barriers – informational/know-how, economic and technical. A detailed analysis of current barriers can be found in the IEA Technology Roadmap: Solar Heating and Cooling [IEA 2012].

From the point of view of architects, the most important barriers are[2]

- Lack of knowledge by client/developer
- Lack of interest by client
- Lack of suitable products

Amongst several hundred professionals, who participated in a survey by the IEA SHC (International Energy Agency Solar Heating and Cooling Programme) project "Solar Energy and Architecture (Task 41)", economic issues were regarded less of a barrier than these three issues.

This means, that architects and other building professionals can have an important role in showing to their clients the opportunities and possibilities of solar thermal.

2 According to survey by IEA SHC Task 41, see IEASHC 2012, p. 21.

For owners of small homes and for architects in this field, the availability of trained and motivated installers is another important barrier. Even though solar thermal is a relatively simple technology, installers often refrain from using solar products with which they are not familiar. Instead they recommend and install the relatively standard solution, most often based on fossil fuels or electricity.

For architects it can be important to establish good relations with planners/installers with experience in solar (water) heating systems or at least those who are willing and interested in working with these products. They can assist early-on with the design of the heating system, including the dimensioning and layout.

Where the cost of solar thermal installations is a major concern, it is important to distinguish between economic barriers (a certain system being not cost competitive with non-solar solutions) and financial barriers (the solar thermal system would be economic, but financing for the initial investment is not sufficiently available). In both cases, financial incentives can become decisive, which are often offered by public or private bodies (e.g. energy utilities).

Further Readings and References

- Solar Thermal Action Plan for Europe/ Heating & cooling from the sun [ESTIF 2007]
- International Energy Agency (IEA): Technology Roadmap - Energy-efficient Buildings: Heating and Cooling Equipment [IEA 2011], pages 6, 35: Issues and Barriers

Support policies and incentive schemes

Around the world, support for renewable energy and, in particular, solar water heating has been increasing. There is a variety of different schemes in place to promote the uptake of SWH applications.

These can be divided into two main types: financial or non-financial.

Financial incentives

Financial incentive schemes involve a financial contribution put in place by public authorities to users acquiring solar thermal systems. These can take the form of direct grants, solar heat tariff, tax reductions and loans at reduced rates or energy certificates. These incentives have a direct impact on the financial and economic aspects related to the installation, i.e. in the payback period and the return on investment. Some information about incentive schemes worldwide can be found at solarthermalworld.org/incentive. Nevertheless, information about such incentives should always be collected locally, as these differ from country to country (or even between regions or cities) and can also change within a short time frame.

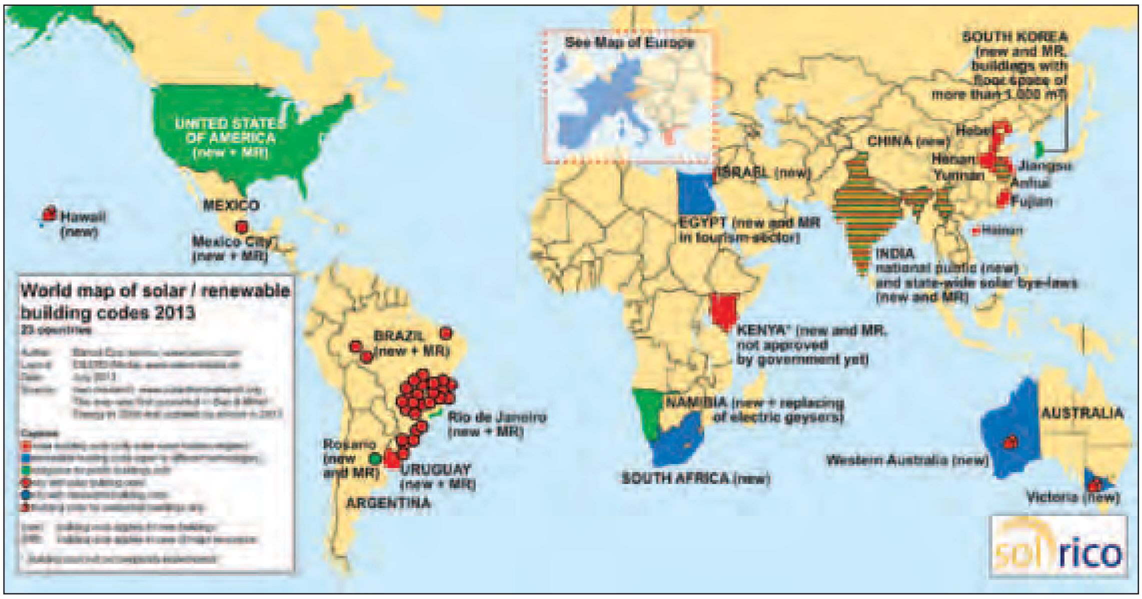
Non-Financial Incentives

This type of incentives includes public policies supporting the uptake of solar thermal; such as support to research and innovation, quality assurance measures, awareness raising initiatives or solar obligations in connection with building codes.

For the users of this guide the most relevant are solar obligations. These constitute legal provisions making mandatory the installation of solar thermal systems in buildings, applying mainly to new buildings and those undergoing major refurbishment. Most of the existing solar obligations are related to national or regional energy regulations and implemented through the municipal building codes.

The following map provides an overview of solar thermal obligations worldwide. Further information can be found at: solarthermalworld.org/content/database-building-codes-24-individual-regulations

Figure 3: World map of solar/renewable building codes 2013 Source: solrico



Requirements

The requirements vary according to the type of incentive and where and how it applies. However, the most common requirements include:

Collector area: normally the requirement is based on the square meters of collector area, sometimes varying according to certain size brackets, applications or technologies.

Energy yield: this requirement is not as common but has been increasingly used in relation to requirements related to energy performance of buildings in Europe, or support schemes providing a payment on the energy produced rather than on the installed capacity.

Quality assurance: it is usual that requirements related to quality assurance are also in place. These may be connected to the conformity of the products and/or the installation with particular technical standards. It is also possible to find requirements for product or installers certification.

Further Readings and References

- Guide on Standardisation and Quality Assurance for Solar Thermal [ESTIF 2012a]
- Technology Roadmap: Energy-efficient Buildings - Heating and Cooling Equipment [IEA 2011], pages 40-44
- Technology Roadmap: Solar Heating and Cooling [IEA 2012], page 34-35
- solarthermalworld.org/incentive
- solarthermalworld.org/content/database-building-codes-24-individual-regulations

Financial and Economic Aspects

Introduction

As mentioned above, financial and economic aspects do play a role in the process of deciding for or against a certain water heating product. Therefore, it is important to understand the key differences between conventional heating systems, using exclusively fossil fuels and/or electricity, and solar thermal heating systems.

Typically, conventional water heating systems have a lower initial investment cost than solar water heating systems. The reason behind this is that, in most cases, to lower the cost of conventional energy use, the solar thermal system complements a conventional heating system which remains 100% available even after several days of little sunshine. Thus there is the cost of a conventional heating system plus additional investment costs for the solar thermal part.

Table 1: Solar thermal system characteristics and costs for single-family dwellings, 2007 [IEA 2012]

	Single-family dwelling		
	OECD Europe	OECD North America	OECD Pacific
Typical size: water heating (kW_{th})	2.8 - 4.2	2.6 - 4.2	2.1 - 4.2
Typical size: combi systems (kW_{th})	8.4 - 10.5	8.4 - 10.5	7 - 10
Useful energy: water heating (GJ/system/year)	4.8 - 8	9.7 - 12.4	6.5 - 10.3
Useful energy: space and water heating (GJ/system/year)	16.1 - 18.5	19.8 - 29.2	17.2 - 24.5
Installed cost: new build (USD/kW_{th})	1 140 - 1 340	1 200 - 2 100	1 100 - 2 140
Installed cost: retrofit (USD/kW_{th})	1 530 - 1 730	1 530 - 2 100	1 300 - 2 200

Table 2: Solar thermal system characteristics and costs for multi-family dwellings, 2007 [IEA 2012]

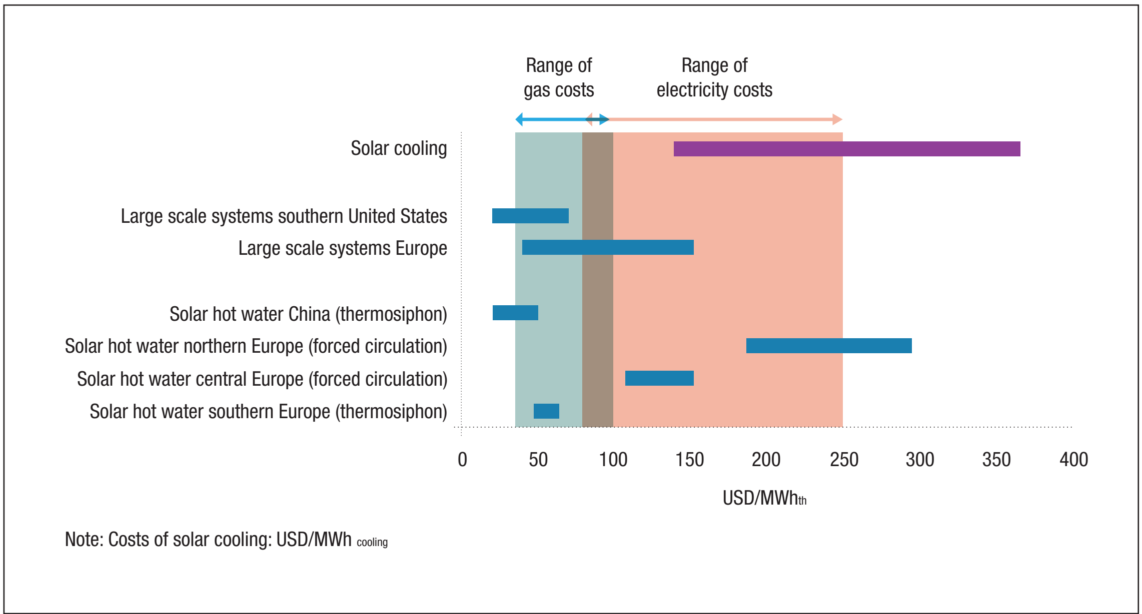
	Multi-family dwelling		
	OECD Europe	OECD North America	OECD Pacific
Typical size: water heating (kW_{th})	35	35	35
Typical size: combi systems (kW_{th})	70 - 130	70 - 105	70
Useful energy: water heating (GJ/system/year)	60 - 77	82 - 122	86
Useful energy: space and water heating (GJ/system/year)	134 - 230	165 - 365	172
Installed cost: new build (USD/kW_{th})	950 - 1 050	950 - 1 050	1 100 - 1 850
Installed cost: retrofit (USD/kW_{th})	1 140 - 1 340	1 140 - 1 340	1 850 - 2 050

The IEA Technology roadmap: Energy-efficient Buildings: Heating and Cooling Equipment

But where solar thermal is initially more expensive, its operation and maintenance costs are very low, and sometimes close to zero. Conventional heating systems, on the other hand, require fossil fuels and/or electricity throughout the whole lifetime of the system, thus generating relatively high costs.

Solar water heaters have a normal lifetime of between 10 and 30 years, depending on the specific technology and circumstances. Thus the higher initial investment costs may not be very high when spread over the total lifetime of the system.

Figure 4: Costs of solar heating and cooling (USD/MWhth) [IEA 2012]



	Conventional heating system	Solar heating system
Initial investment		
• Cost of system	Medium	higher (additional solar components)
• Other	None	possibly savings (when solar collectors replace other building components, such as roof tiles)
Running costs		
• fuel costs	High	low (electricity for pumps/controllers in a forced circulation system) to zero (simple natural circulation systems)
• maintenance	Medium	(somewhat) higher, depending on the specific system

Cost Benefit Analysis

The idea behind the Cost Benefit Analysis (CBA, sometimes also called Benefit Cost Analysis, BCA) is simple: All known or expected costs of the project are added and compared with all known or expected benefits – using monetary units in each case.

In order to take the time factor into account, future costs and benefits should be discounted to present values. Because of inflation, future costs and benefits will be reduced in real terms. Therefore, a fair comparison would actually be between the net present value of all costs and the net present value of all benefits.

So, apart from the actual investment costs, the main influencing factors are:

- Cost of money (interest rate to be paid on a loan or interest not received on money in the bank)
- Inflation rate
- Expected price development of conventional fuels

$$
\begin{aligned}
NPV_{costs} = {} & \text{Initial investment costs} \\
& + \frac{\text{Maintenance cost in year 1} + \text{Energy cost in year 1} + \text{Cost of loan in year 1}}{1 + \text{inflation rate}} \\
& + \frac{\text{Maintenance cost in year 2} + \text{Energy cost in year 2} + \text{Cost of loan in year 2}}{(1 + \text{inflation rate})^2} \\
& + \ldots \\
& + \frac{\text{Maintenance costs in year n} + \text{Energy costs in year n} + \text{Costs of loan in year n}}{(1 + \text{inflation rate})^n}
\end{aligned}
$$

$$
\begin{aligned}
NPV_{benefits} = {} & \frac{\text{Saved energy costs in year 1}}{1 + \text{inflation rate}} \\
& + \frac{\text{Saved energy costs in year 2}}{(1 + \text{inflation rate})^2} \\
& + \ldots \\
& + \frac{\text{Saved energy costs in year n}}{(1 + \text{inflation rate})^n}
\end{aligned}
$$

Below we have a practical example based on an initial investment of 10 000 cu (currency units). The operating costs, on a yearly basis, will be related to the maintenance (1.5% of the initial investment) and energy costs (electricity used by both pump and controller). The loan annuity (including capital repayment and interests) is calculated at a 10% interest rate for the loan and a repayment over 10 years.

The saved energy costs is estimated at 1 500 cu a year. The evolution of costs and benefits is also adjusted in function of the expected annual increase of energy costs (8% in the example) and a discount rate of 5%, which could be, for instance, the expected inflation rate.

		Year				
		1	**2**	**3**	**4-9**	**10**
Annual costs for an investment of 10 000 currency units (CU)						
Maintenance costs (1.5% of initial investment on a yearly basys)	150 CU	150	158	165	...	233
Energy costs (electricty for controller, pump)	100 CU	100	108	117	...	200
Loan annuity (10% interest rate for a 10 year period)	1627.45	1627	1627	1627	...	1627
Sum (Absolute annual costs)	CU	1877	1893	1909	...	2060
Discounted annual costs	CU	**1877**	**1803**	**1732**	**...**	**1328**
NPV$_{costs}$						**15834**
Annual benefit for estimated yearly savings of 1 500 currency units (CU)						
Saved energy costs (gas, oil, electricity replaced by solar)	CU	1500	1620	1750	...	2999
Discounted annual benefits	CU	**1500**	**1543**	**1587**	**...**	**1933**
NPV$_{benefits}$						**17083**
Other parameters						
Discount factor (based on annual inflation of 5%)	5.00 %	1.00	1.05	1.10		1.55
Expected annual price increase	8.00 %					

However, while this looks rather simple, it is important to understand that little variations in, for example, the expected increase/decrease of energy costs may have a very strong effect on the discounted benefits. If fast rising costs for conventional fuels (gas, oil, electricity,...) are expected, then the benefit will be rather high. Vice versa, if stable or even decreasing energy costs are expected, the net present value of all future benefits will be low. Therefore, it is often advisable to make a sensitivity analysis, carrying out the calculations for several different developments of interest rate, inflation rate, and price developments of conventional energies.

Furthermore, it may sometimes be difficult to determine all cost and benefit components. For example: A SHW system may allow the owner to completely switch off conventional heating during the warmer seasons. Thus, the energy savings are even higher (consumption of conventional fuel due to standby losses is reduced). And, as the conventional boiler is switched off for several months per year, the lifetime of the hardware is extended, thus reducing the expected costs of hardware replacement.

Unfortunately, it is often difficult to attach monetary values to non-monetary items, e.g. if a company invests in a SHW system to improve its "green" image, there is likely to be a positive effect from the improved image (more consumers buying/using the company's products/services).

Lastly, that the resulting difference between (discounted) costs and benefits is an absolute value must be kept in mind. It should also be compared to the absolute amount of investment. For example: If a SWH system generates 1000 USD more in discounted benefits than in discounted costs, this may seem high when looking at a small domestic hot water system. But it could be negligible if the initial investment was 100,000 USD for a large collective system, providing hot water to many households.

Payback Analysis

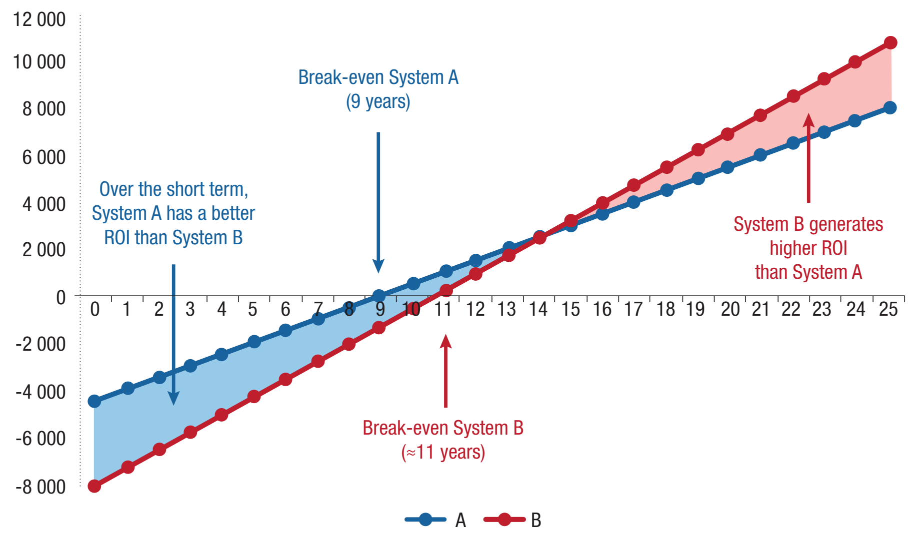
Commercial clients, in particular, often evaluate solar thermal systems based on their payback time, i.e., the time it takes for the cumulated running costs saved by the solar thermal system to equal the additional initial investment.

An important factor for them is to remain financially flexible and not to lock their capital in fixed assets for long periods. This is where offerings such as leasing or energy services (paying not for the system but for the energy produced) can overcome initial objections by the client. Public loans at preferential conditions can also serve as an incentive to overcome longer payback times.

The focus on payback times is important but should be assessed together with other aspects, such as return-on-investment. An isolated analysis of the payback period may be misleading, as it can result in decisions in favour of cheaper and often less performing or less durable solar thermal systems, which, over the lifetime of the system, save less conventional energy and generate lower net benefits.

The following diagram shows the initial investment and cumulated net benefit of two different systems, A and B. A costs 4 500 currency units and breaks even after 9 years. B costs 8 000 currency units and breaks even only after 11 years. However, B has a higher rate of return, and after 14 years, the cumulated net benefit of B is higher. After 20 years it is already 1500 units and at 25 years the ROI is 2750 currency units higher than that of system A.

Figure 5: Exemplary economic analysis of two different solar thermal systems A and B



	System A	System B
Initial investment	4 500	8 000
Annual net benefit	500	750
Expected life time	20-25 years	20-25 years

Internal Rate of Return Analysis for larger projects

For commercial investors and financial institutions, the Internal Rate of Return (IRR) is a key indicator when assessing the financial viability of a project. When all other criteria are fulfilled, an investment is made when the IRR is higher than the cost of capital. However, like the payback time, the IRR does not give any information about the total net benefit for the investor. A lower IRR but higher initial investment may actually yield a higher net benefit over the lifetime of the system than another project with a higher IRR but a lower initial investment. Likewise, the IRR should not be used to compare, for example, different heating system with assumed different lifetimes: a system with a lower IRR but longer lifetime may actually bring a better return on your money than the investment with a higher IRR but shorter lifetime.

Solar Water Heating Techscope Market Readiness Assessment

The Global Solar Water Heating (GSWH) Market Transformation and Strengthening Initiative published a report presenting a replicable and public methodology to evaluate the solar water heating (SWH) policy, finance and investment, business, and quality control infrastructure across countries: the SWH TechScope Market Readiness Assessment methodology. This report is intended to be used in conjunction with an Excel-based evaluation tool, the SWH TechScope Market Readiness Analysis Tool, which can be used as a benchmark to evaluate different SWH markets.

Users of this guide may refer to the guide for additional information on solar thermal competitiveness in the following countries: Albania, Chile, India, Lebanon or Mexico.

Expert users and public authorities may refer to this publication in order to assess their own market using the proposed methodology.

Further Readings and References

- Strategic Research Priorities for Solar Thermal Technology [RHCTP 2013], Appendix 3, pages 62-63: Levelized costs of heat
- Technology Roadmap: Solar Heating and Cooling [IEA 2012], pages 20-21: Economics today
- Solar water heating techscope market readiness assessment [UNEP 2014]

Figure 6: Pool heating with unglazed collectors in Ecuador
Source: Magen Eco-energy

Figure 7: Thermosiphon installation in Galapagos Islands, installation done by Ing. Francisco Beckmann Source: Chromagen

HOW TO INTEGRATE SOLAR THERMAL?

Basics of Solar Thermal

The following descriptions cover the most common product types. There are many more variations available, using different materials, principles, designs etc.

Solar thermal systems are based on a simple principle known for centuries: the sun heats up water contained in a dark vessel. Today, most solar thermal systems are a little more complex and comprise at least a dedicated solar collector, pipes and a storage tank. Water is used to transfer and store the collected heat. Depending on the specific system type, additional components are added:

- controller
- pumps
- heat exchangers
- valves

The collector converts the heat from the solar irradiation and transfers it to a heat carrier fluid like water or a water glycol mixture. The storage tank accumulates the heat in order to have sufficient volumes available, even when direct sunlight is or was limited. From the tank the heated water can then be used for various purposes, such as domestic hot water, space heating, district heating, and agricultural and industrial processes.

System types: Thermosiphon (natural convection) and forced-circulation

Many small domestic solar hot water systems are gravity systems such as thermosiphon systems or integrated collector storage systems. They make use of the fact that warm water is lighter than colder water and thus of the natural convection in the collector when it is not installed horizontally. In the case of thermosiphon systems, the tank is usually placed directly at the top of the collector or very close by and slightly above. The heated water enters the tank at the top and colder water at the bottom of the tank then flows back to the bottom of the collector. As it does not need controllers and pumps, it can operate very efficiently and completely without electricity. Small thermosiphon systems are the cheapest solar thermal systems available.

Figure 8: Solar thermal thermosiphon system for domestic hot water preparation Source: Strategic Research Priorities for Solar Thermal Technology, RHC-Platform

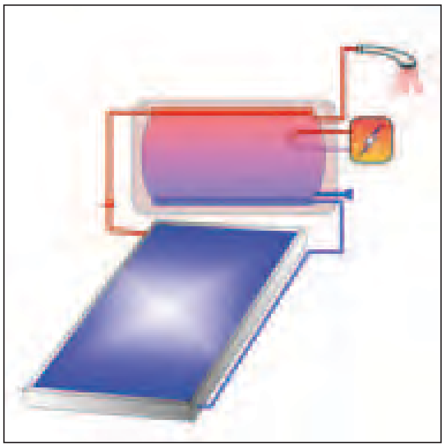
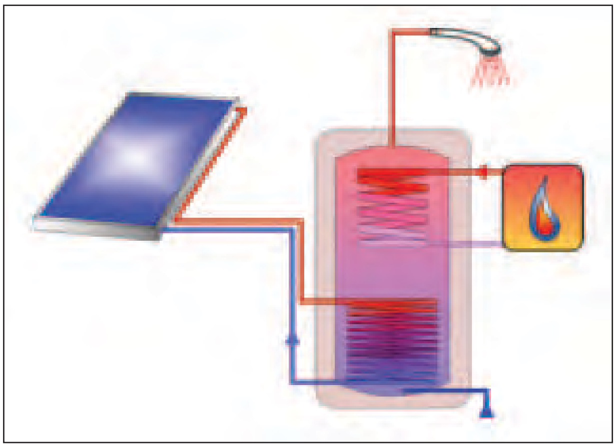


Figure 9: Solar thermal forced water circulation system for domestic hot water preparation Source: Strategic Research Priorities for Solar Thermal Technology, RHC-Platform



Forced circulation systems use sensors and a controller to determine if and when a pump is to circulate water through the collector. If the temperature in the collector is higher than that in the tank and if the temperature in the tank is still below boiling point, the pump is switched on to transport the heat from the collector to the tank. Forced circulation systems are more complex but allow for a much more flexible system design, e.g. where the tank is placed below and further away from the collectors.

Solar thermal collectors

By nature, the collectors are the most visible of all solar thermal components – they are typically mounted on the roof of a building, but can also be placed on the façade, on balconies or mounted on ground structures. All collector types have in common that solar irradiation is absorbed by a dark – often black or dark-blue – surface, which heats up and from which the heat is transferred directly or indirectly to water.

For lower temperatures (ca. up to 100°C) three different collector types are most common: Evacuated tube collectors, flat plate collectors and unglazed absorbers.

Figure 10: Exploded view of a flat plate collector Source: GREENoneTEC

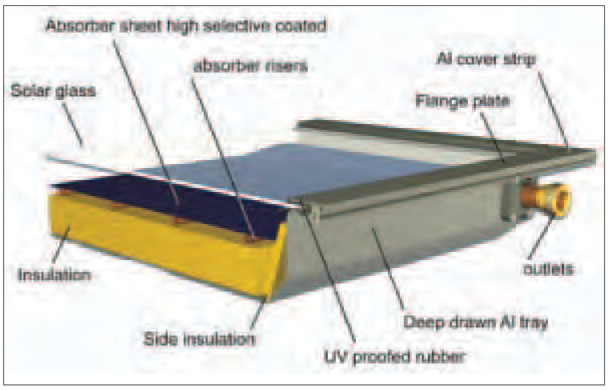
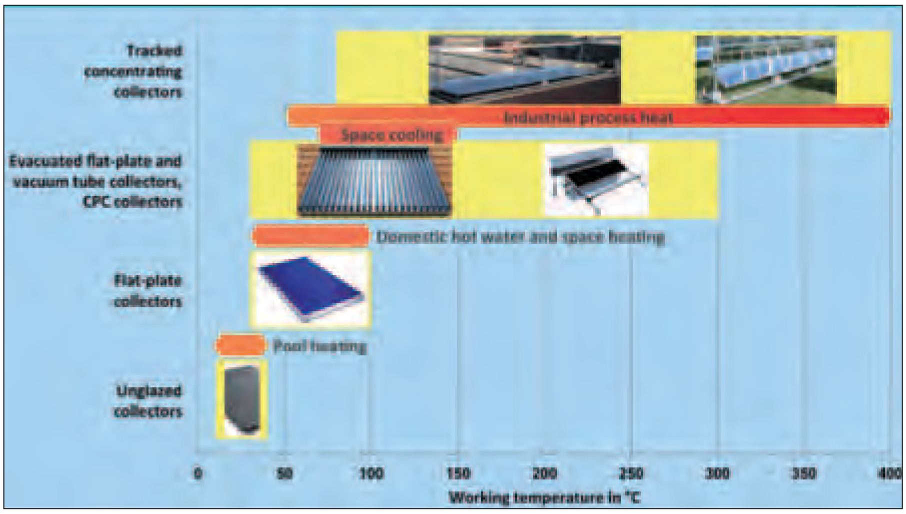


Figure 11: State of the Art European evacuated tube collector, using high temperature composites as a manifold fluid Source: Kingspan

Due to the temperature levels they can usually provide, the latter are used almost exclusively used for swimming pool heating, while the former are used for a wide variety of applications. Typical evacuated tube or flat plate collectors are rectangular, covering an area of 1.5-2.5m^2 but much larger sizes are available (12-15 m^2), sometimes even custom-built for individual projects. Their height is usually between 80-120mm for flat plate collectors and 120-200mm for vacuum tubes, depending on the manufacturer and model. Multiple collectors can be combined to form a collector array.

Figure 12: Working temperature of different types of solar thermal collectors [RHCTP 2013a]



Flat plate collectors consist of a casing from metal, wood or polymer with a transparent front cover (glass or polymers). The absorber is made of metal (mostly copper or aluminium) with pipes at the back through which water flows to transfer the heat to the storage tank. On sloping roofs flat plate collectors can be mounted onto or into the roof, depending on the model. On flat roofs they are typically mounted on tilted systems to better face the sun. Façade collectors are available, which can be mounted vertically.

Evacuated tube collectors consist of evacuated and sealed glass tubes connected to one another at one end by a manifold. The most common type is the Sydney tube, which uses the thermos flask principle (two layers of glass with vacuum in between). Another model, more popular in Europe, consists of single layered glass tubes where a metal absorber is placed within the vacuum.

Unglazed absorbers are usually used for (very) low temperatures and thus mostly for swimming pool heating. They come in many different forms and shapes, from bands of flexible rubber/polymer tubes to products similar to flat plate collectors.

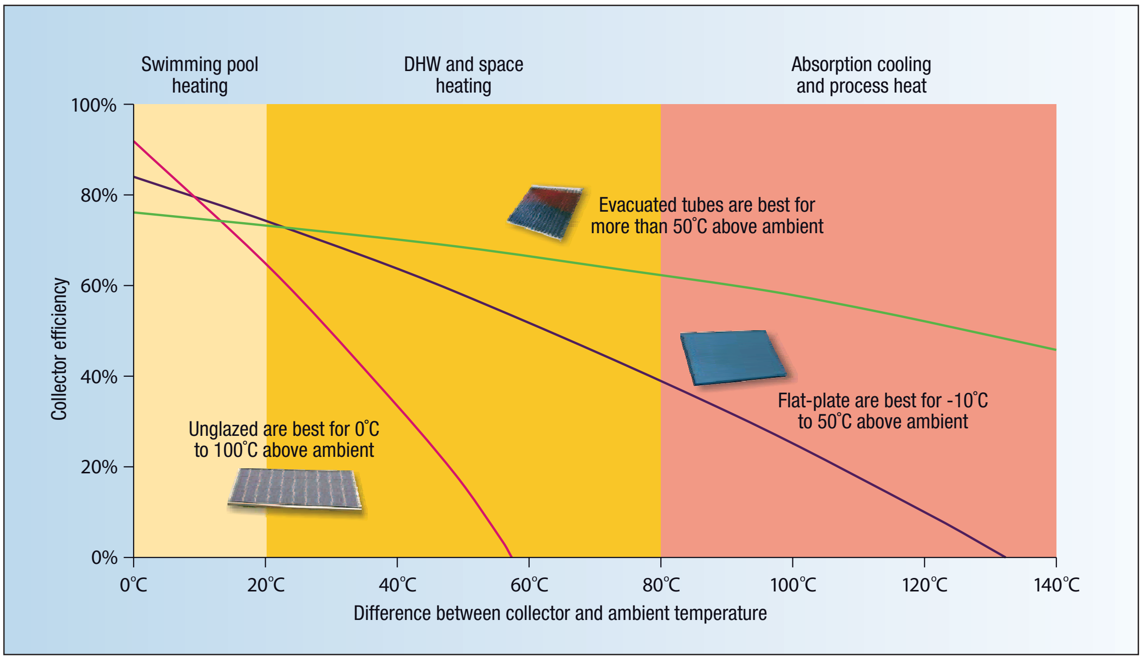
Typical characteristics of different collector types

	ETC	FPC	UA
Higher temperatures, e.g. 80-100°C	☺☺	☺	☹☹
Suited for cold climates	☺☺	☺	☹☹
Roof integration	☹	☺	☹
Vertical installation	☺☺	☺☺	☺☺
Horizontal installation	☺	☺	☺☺

Temperature needed by the application	Type of application	Collector technologies used
Low temperatire 20°C - 95°C	Swimming pools, domestic hot water heating, space heating, district heating, solar cooling and low temperature process heat	Unglazed, flat plate, evacuated tube and CPC concentrator collectors
Medium temperatire 95°C - 250°C	Process heat, desalination, water treatment, high efficiency solar cooling, district heating and cooling	High efficient vacuum insulated flat plate, evacuated tube, CPC and other low concentrating, linear Fresnel and parabolic trough collectors
High temperatire > 250°C	High temperature process heat and electric power via thermal cycles	Parabolic troughs and linear Fresnel collectors, solar dishes and solar towers

Source: RHCTP 2013, table 3.1, p.40

Figure 13: Collector efficiencies at different temperature levels [IEA2012]

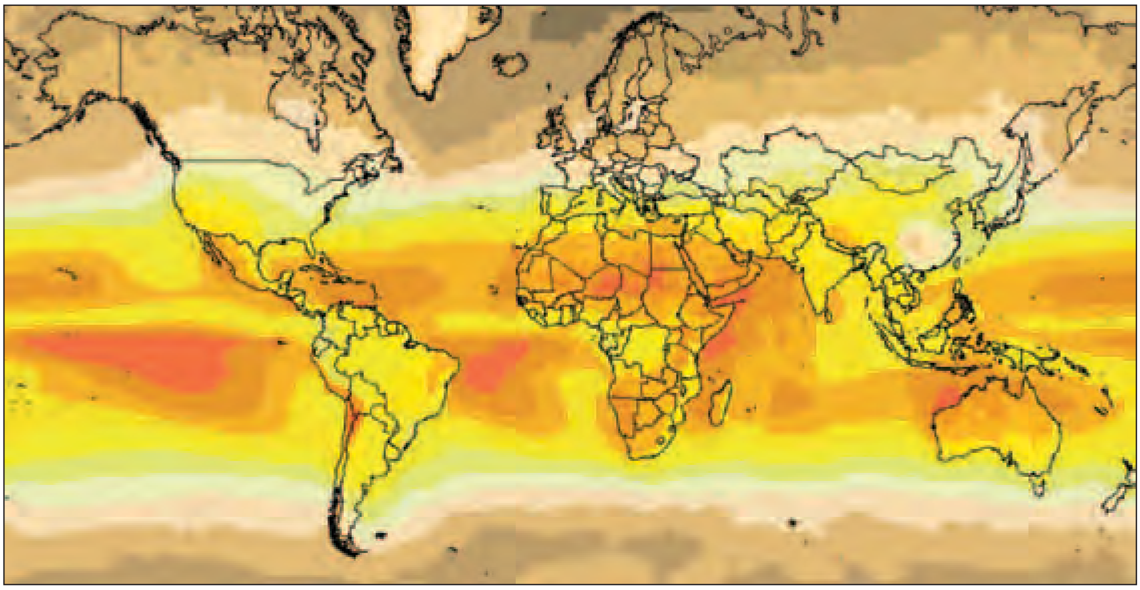


Apart from the required temperature level, other factors influence the choice of collector technology, e.g. in areas where hail is a regular occurrence, ETC should not be used as glass tubes are likely to break during a hail storm. Similarly, in areas where animals, such as monkeys or cats, are frequent visitors to the solar water heater installation area, glass tubes of ETC may break leading to system shutdown. Therefore, it is advisable not to use ETC based systems in these areas[3].

As the collector is placed outside the building envelope, the water it contains must be protected against freezing, where this can occur. This is usually achieved in one of two ways: The water in the collector loop is either treated with anti-freeze (glycol) or, the water is drained out of the collector and pipes when it gets too cold. The former requires that the water in the collector is separated from the drinking water with a heat exchanger. The latter is the so called “drain back” principle, which is popular mostly in the USA and in parts of Europe. If the storage tank contains a backup heater (e.g. direct electrical resistance heater) it should not be placed outside the building envelope in order to avoid additional heat losses.

3 User’s handbook on Solar Water Heaters [UNDP 2010]

Figure 14: Global Horizontal Irradiation Source: Clean Energy Solutions Center cleanenergysolutions.org



The exact orientation of the collectors – the cardinal direction and the tilt of the collector – has consequences for the solar energy yield. However, deviations from the optimum are not as bad as one might think.

Optimally, the collector faces toward the equator – in northern latitudes to the south and in southern latitudes to the north. However a 45° deviation to the east or west should never be a problem and even east or west-facing roofs can still be used to harness solar thermal energy.

As a rule of thumb, the optimal tilt of the collector is equal to the degree of latitude. However, specific situations may make a different tilt more beneficial (e.g. a steeper angle will absorb less than the maximum irradiation in summer, but allow for better solar gains in winter – which would be perfectly suitable for a solar thermal system to support space heating).

Figure 15: Façade integrated flat plate collectors, Student residence in Kolpinghaus, Austria Source: AEE NTEC

Figure 16: Collector performance depending on orientation and mounting for France (mainland) [ENERPLAN 2011]

Storage Tank

The heated water is typically stored in an insulated cylinder. The water in the tank can be separated from either the water in the collector and/or the actual drinking water through heat exchangers, but very simple thermosiphon systems are of the open-loop type in which sanitary water from the mains flows through the collector and tank.

Tank size and collector area should match: Having one of them too small or too big reduces usable heat output and/or creates problems with overheating. Under the heading "sizing" you will find simple calculations to assess the required tank volumes and collector areas. This will help you assess whether the site is suitable for solar thermal and e.g. the roof area which should be covered by solar collectors.

Solar water heaters for swimming pools do not use a storage tank: The pool itself is "the tank".

Further Readings and References

- Copper Solar Thermal Systems [UKCB 2010], pages 3-8: Solar Thermal Collectors, Solar Thermal Systems
- Heat Your Water with the Sun. A Consumer's Guide [US DOE 2003], pages 2-12

Sizing and performance

Usually, the architect will not be designing and sizing the solar thermal system. Therefore, the following section does not cover the calculation in detail, but tries to give an overview of the parameters involved and some guidelines or rules of thumb, so that you get a rough idea of how large a collector field would be or how big the storage tank should be. Again, this section will focus on the most common products and systems – it does not try to cover less standard products/designs or other unconventional cases.

The given rule of thumb will give you estimations. They should not be used for the actual design of the system. More detailed data can be derived from system simulation using specialised software. Among the most widely used solar thermal simulation tools are Polysun by Vela Solaris and TSol by Valentin Software. Basic versions of both tools are available online, free of charge (for more details: see Annex I).

Domestic hot water

Normally, a solar hot water system is aimed at providing 90-100% of the hot water demand in summer and a somewhat lower share in winter. Over the year, the system may then reach a “solar fraction” of 60-80%, meaning that 20-40% of the hot water demand would need to be provided by the (conventional) backup-heater.

Steps in estimating the storage tank volume and collector area:

- **Hot water demand**
  Sometimes, this is well known/measured. But more often, it is not. For a first rough estimation, the following can be assumed: 30-60l per person and day (at 45-50°C)
- **Storage tank**
  The solar hot water tank should then be sized to provide enough hot water even on a cloudy day. As a rule of thumb: In warm and sunny regions a factor of around 1 may be used (the tank should store 1 day’s demand), in colder climates this factor should be increased to 2 or even 2.5. If the hot water store has a higher temperature (e.g. in some countries required by drinking water regulation), then the tank size can be smaller.
- **Collector area**
  The collector area should not be too large for the tank, otherwise problems with excess heat may occur. Usually, the collector area should then be no more than 1/50 – 1/80 [m^2/l] of the tank size in warm climates or 1/20 to 1/40 [m^2/l] in colder climates.

Example: A house with 4 persons, each using 40l (45°C) of hot water per day per person would use a tank of 160l in warm climates and 320-400l in colder climates. The collector area should then be roughly 2-3 m^2 in warm climates and 5-8m^2 in colder climates.

In larger residential buildings the collector area is often designed for greater use (and thus lowest specific cost). But this reduces the share of hot water provided with solar energy (the solar fraction).

In non-residential buildings, the specific use patterns may need to be taken into account too, e.g. in hotels at a beach resort may be used mostly during the sunnier season and much less, or not at all, during the less sunny times of the year. Vice versa, in a hotel at a ski resort will be used (almost) exclusively during the skiing season, when solar irradiation is less abundantly available.

Further Readings and References

- Measurement of Domestic Hot Water Consumption in Dwellings [EST 2008]
- Copper Solar Thermal Systems [UKCB 2010], pages 12-15

Open-air swimming pool heating

Solar thermal energy is particularly suited to heat open-air swimming pools:

- Solar radiation is usually abundantly available during open-air swimming season
- the low-temperature demand (typically between 18 and 28°C) results in small differences with outside air temperature, drastically reducing heat losses and allowing the use of unglazed absorbers
- There is no need to store heat except for the pool itself. Thus a specific storage tank is not needed.

For small private swimming pools, the following rules of thumb can be applied:

- Temperate climates: absorber surface area = 0.5-1.0 x pool surface area
- Subtropical climates: absorber surface area = 0.3-0.7 x the pool surface area.

For larger – e.g. public – swimming pools more detailed calculations should be carried out to determine the absorber area.

Further Readings and References

- Dimensioning and Design of Solar Thermal Systems [AEE 2010]
- Planning & Installing Solar Thermal Systems. A guide for installers, architects and engineers [DGS 2010], pages 77-89
- Technical Guide Solar Thermal Systems [Viessmann 2008], pages 106-131: Sizing

Site Assessment

Before a detailed analysis of the site is made, the following questions need to be asked – they are important for the whole project (design, economics, timing etc.):

- What is the motivation of the client?
- Do they own the building/site or are they renting? Is the owner involved, too?
- What is their planning scope – for how long do they plan to stay in the building / on the site?
- Does the client have a fixed budget for the (solar) water heating system?
- What is the possible timeframe for the project: When will the building be built? Or in the case of retrofitting: Is the solar thermal installation part of a larger renovation project?

When assessing, whether or not a building is well suited for solar thermal, the following should be taken into account ("Planning & Installing Solar Thermal Systems. Page 74):

- What is the cardinal orientation of the building area that could be used to install the collectors (roof, façade, balcony, ground)
- How large is the suitable area?
- Is the roof (or façade, balustrade) strong enough to carry the weight of the collector field, and in the case of thermosiphon DHW systems also the tank?
- Would the collectors be shaded by trees, parts of the building or surrounding buildings (partial shading is not a big problem – in contrast to photovoltaic panels, solar thermal collectors reduce their output almost proportionally to the shading. If 10% of a collector is shaded, the output at that time drops by ca. 10%).
- Would collectors be placed beneath aerials or similar equipment (possible problems with bird droppings)
- What is the accessibility of the collectors for future inspections/maintenance?
- Where could the storage tank be placed (space/volume and accessibility when installing the (large) tank)
- What is the shortest possible distance from the collectors to the storage tank? Can existing channels (e.g. chimney) be used for the piping?
- Does central hot water heating already exist?

Further Readings and References

- Best Practices Manual for Solar Hot Water [AO 2011]
- Active Solar Heating Systems Design Manual [ASHRAE 1988]
- Risk assessment of structural impacts on buildings of solar hot water collectors and photovoltaic tiles and panels [BSD 2010]
- Inspection Checklist Solar Water Heaters [Ecofys 2007]
- Solar Water Heating. Specification, Checklist and Guide [EPA 2011], pages 4-9
- A Really Simple Solar Domestic Hot Water Checklist [HPBM 2012]
- Solar Ready Buildings Planning Guide [NREL 2009]

Building Integration

Codes, Standards and Certification

In more and more countries, there exist minimum energy efficiency requirements at least for new buildings. And most of these recognise the on-site production of renewable energy (e.g. solar or biomass heating or electricity) as one way to reduce the (conventional) energy demand – thus increasing the energy efficiency of the building. When such regulations are introduced, builders and home owners typically try to first reap the "low-hanging fruits". In many cases that would be better insulation against cold (roof or façade insulation, double- or triple glazed windows etc.) or protection from heat (light coloured roofs, shading devices). But no matter how much the energy consumption for space heating or space cooling is reduced, there always remains a need for (domestic) hot water – for showers, for washing purposes etc. And this is why solar water heaters have become one of the most cost efficient solutions to reach the minimum energy efficiency requirements in new buildings. In fact, for the customer a solar water heater is equal to, for example, improved insulation: In both cases, the owner has to invest a certain sum of money in the beginning but then benefits from years of savings on the conventional energy bill (gas, electricity, oil etc.). Architects planning a building in an area with such energy efficiency requirements should compare costs and benefits of energy saving technologies and renewable energy producing technologies. And of course: they need to stay informed about specific regulations, and which technologies and products are assessed and how.

In most countries, solar thermal systems can be installed without an additional (planning) permit. However, (local) building and planning codes need to be observed. This may also include regulations on monument protection: While there are attractive examples of old and protected buildings which have been retrofitted with solar thermal, regulations often stipulate that modern additions such as satellite dishes etc. are not allowed. And this may also apply to solar thermal collectors.

Furthermore, certain products, materials or system types may not be compatible with local/national regulation. For example water heating systems, including those using solar energy, are sometimes subject to regulations concerning the growth of legionella bacteria, which can pose a threat to health. Certain countries have effectively banned specific water heating designs, which can also affect solar thermal.

Apart from this, there are sometimes special incentives to use specific products or product types, because they are eligible for financial incentives or because their characteristics are acknowledged (higher), for instance, in energy efficiency regulations for buildings, as mentioned above.

A typical example for such requirements is that collectors be third party tested and certified by specific certification bodies. Product testing standards exist for various solar thermal products, from flat plate collectors to complete systems[4].

Figure 17: World map of solar thermal quality labels and applicable standards (ESTIF 2012b]

4 A detailed list of Standards used in different countries is available on [ESTIF 2012b], pages 8 to 13.

Insurers too may have their own requirements regarding building components and/or their planning and installation.

In most cases this will not significantly affect the work of the architect. But if the architect wants to use a very specific technology or product she or he should discuss the viability of the plan, and possibly its eligibility for financial support, with a solar thermal professional and/or the relevant local authorities.

Further Readings and References

- Collector certification across the world - challenge or opportunity [FRITZSCHE 2012]
- Guide on Standardisation and Quality Assurance for Solar Thermal [ESTIF 2012b]
- IEA SHC: Solar Rating & Certification (Task 43) [IEASHC43]

Design Implications

Functional and constructive requirements for building components

A solar thermal system should not impede the correct operation of other building components. For example, a roof with collectors must still protect the building against wind, rain, cold, heat, animals etc. It must also not interfere with the structural strength and stability of the roof, façade or other building component.

Formal (aesthetical) aspects

Because they are placed to absorb solar irradiation, solar thermal collectors in and on buildings are usually very visible – often from street level, but also from surrounding buildings, hills or other elevated points. This characteristic is often seen as a drawback by many architects. They feel they “have to” somehow integrate solar collectors into their design. For them it often remains an ugly “add-on”. However, numerous examples from around the world prove that collectors on the roof, façade, integrated in balconies etc. can become an interesting feature of the building design. Or, alternatively, they can be blended into the building envelope so that casual passers-by would not even notice that the blue roof is in fact a large solar collector array. Collectors can even take over certain additional functions, e.g. by serving as a shading element for windows, car ports or other structures. In these cases, orientation of the collectors does not have to be optimal, as it can often be offset with larger collector areas.

When working out the design, it is also worth keeping in mind the motivation of the client: Sometimes it is explicitly expressed that the “sustainable” or “green” elements of the building should be very visible. The client can then use it to show his “green credentials” (e.g. “green” hotels, sports facilities, housing companies) for marketing purposes.

Figure 18: Different collector mounting typologies [ENERPLAN 2012]

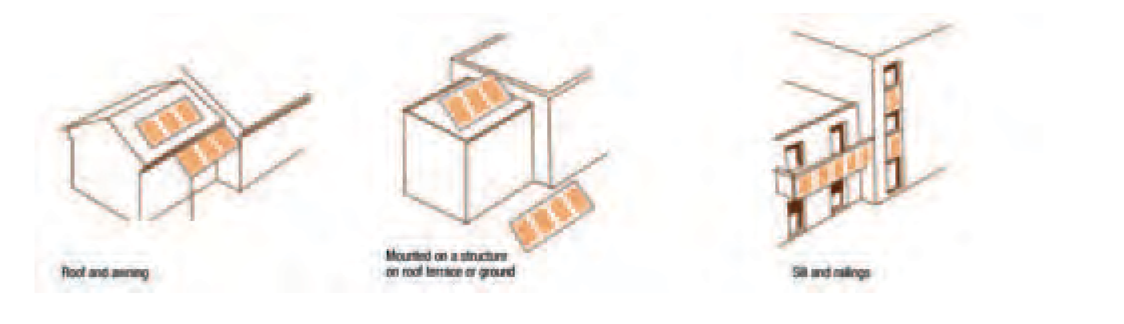
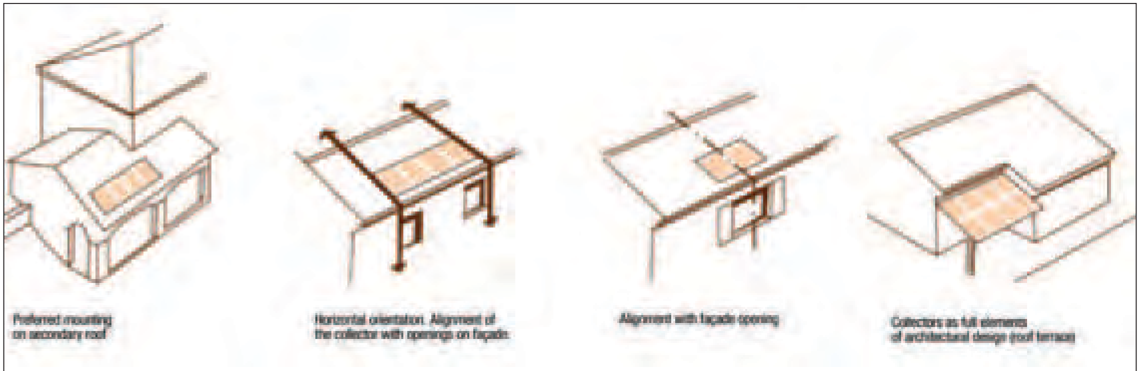


Figure 19: Types of architectural design [ENERPLAN 2012]



Further Readings and References

- State-of-the-Art of Digital Tools Used by Architects for Solar Design [IEASHC 2010]
- Building Integration of Solar Thermal and Photovoltaics – Barriers, Needs and Strategies [IEASHC 2012]
- Needs of architects regarding digital tools for solar building design [IEASHC 2012a]
- Energy Systems in Architecture - integration criteria and guidelines [IEASHC 2012c]
- IEA Solar Heating & Cooling Programme: Architectural integration of solar thermal energy systems (online database) [IEASHC39]
- Solar Ready Building Design Guidelines for the Twin Cities [MSP 2010]
- Architectural Integration and Design of Solar Thermal Systems [Munari Probst 2008]
- Solar Ready Buildings Planning Guide [NREL 2009]
- Solar Water Heating Project Analysis [NRCAN 2004]

SOLAR THERMAL CONTRACTING/ MAINTENANCE

Guide to Tendering and System Specification

Before you publish a Request for Tenders or Request for Proposals, you should have at least a basic idea of what you are looking for and what parameters are most important to you, so that you can later choose between different proposals. This also makes it easier for businesses to make a reasonable proposal and to participate in the tendering process.

Please note that many public (and private) organisations have formal requirements for tendering procedures, e.g. projects from a certain value upward may need to be published at least x weeks in advance on a certain website or in a public journal. Make sure that you know and follow exactly the relevant procedures; otherwise you may have to start the process all over again or – even worse – are held liable.

System Specification

Maybe you know exactly what you would like to have in your project. Then you should be as specific as possible. But maybe you want to remain open to very different proposals, offering potentially different technologies and solutions. Or certain parameters are not (yet) known to you and you leave it to the external experts to make reasonable proposals. Please see also the section Site Assessment *(page 31)* in this document.

Depending on your specific situation, the following pieces of information should be provided by you:

- For what type of building/site is a solar water heating solution sought (a detached house for one family, a multi-story apartment building, a hotel, a camp ground etc.)? Where is it situated? Maybe you can make maps/plans available to interested companies?
- If you can specify it: What does the hot water demand look like. When and how much heat is needed at what temperature. Is the demand similar for every day (e.g. typical in a hospital) or is the building occupied only on work days or weekends (e.g. an office building). What are the variations throughout the year? For example, will the building/site be used more or less during the warmer/ colder season?

- Is currently a water heater in place? Should the solar water heater complement the existing one, or should it replace it? Should the offer include the back-up heater and what type of fuel may it use (gas, electricity, fuel oil etc.).
- What should the proposal aim at: Low cost? Low carbon emissions?
- Where should/could solar thermal collectors be mounted? How large is the available area, what is their orientation?
- Do you have a preference or even need for a certain collector technology?
- Any other technical requirements or limitations, such as a certain minimum performance, use of certified products, maximum additional weight the roof can support etc.
- When is the installation to be carried out? When does the system have to be fully operational?
- Will the system be provided as a turn-key solution? Will ownership be transferred or will it be owned and operated by the proposing company?

Specification of other requirements

Apart from technical and economic specifications you may have requirements concerning the business, its experience and capabilities. At least you may want to ask for such information so that you can evaluate the different companies and offers

- How long has the company existed?
- How long have they been in the solar water heating business?
- What experience does the company have? How many people with relevant experience do they have?
- How to apply, what documents need to be provided?
- How will the best offer be selected? Will there be a short-list of proposals followed by a second round?

Performance Contracting and ESCO models for solar thermal

As pointed out above: Often it is not the economic competitiveness that decides the inclusion of solar thermal in a specific project but the availability of finances for the initial investment. Even where the system was cost competitive with conventional solutions it may not be selected because it requires additional money in the beginning.

Therefore, it can be interesting to look for more innovative business models offered by some solar thermal companies and or project developers – namely, contracting and ESCO models. But please note: These models are usually only attractive and available for large(r) projects (e.g. larger apartment buildings) – for small projects their overhead is usually too high in comparison with the total costs.

ESCO (Energy Service Companies) offer energy as a service, meaning that they install, own and operate the installation and that they charge for the (solar thermal) energy delivered to the customer. This approach has several advantages for the client, most importantly: The initial financing is taken over by the ESCO. And the company has a high interest in a well running system – after all, it receives money only for the energy it supplies to the customer. If the solar thermal system does not function well, more heat must be produced by using fossil fuels, increasing the costs for the ESCO. This is different from a company that sells the hardware and installation. As long as the customer does not complain, they often do not care how well the system actually works.

Contracting (especially Energy Performance Contracting) is another interesting option. Here, the contracting company guarantees a certain performance (e.g. energy or cost savings) and its remuneration is related to this performance, i.e. if the costs savings in one year are lower than expected, the contracting company receives less or even no money. Here, too, the contracting company typically remains the owner of the SHW system.

Further Readings and References

- Business models for renewable energy in the built environment [ECN 2012]

Choosing a Subcontractor

What to look for in a SWH planner/installer

Usually an architect works together with a solar water heater planner/installer to actually plan and install the system. If you have no experience with solar water heaters, we recommend that you ask at least three planners/installers for offers and evaluate not only the offer itself, but also the companies and how they interact with you.

The SWH planner/installer should:

- Have the necessary know-how for the task (e.g. to install a gas plus solar water heating system in an apartment building)
- Have experience with similar projects
- Where relevant: fulfil the necessary requirements to obtain financial support (e.g. have necessary certification or accreditation)
- Be generally a good business partner (e.g. fair conditions, friendly behaviour)

Know-how

- Ask for training background, certificates
- Ask and possibly check membership in relevant trade organisations (e.g. a solar thermal association)
- Ask the planner/installer for estimations for the energy production / energy usage of the planned system, to explain her/his calculations, choice of products/systems, how to operate and maintain the system

Experience

- How long have they been in business of planning/installing solar water heaters?
- Ask for references of their work, especially in similar projects
- Ask colleagues, neighbours or clients for their experience with the planner/installer – would they chose her/him again?

Furthermore

- Ask for and read the general terms and conditions of her/his service.
- Ask and check what is covered by her/his offer:
  - Does the offer include everything needed to have a fully working system in place – or are additional works/components needed before or afterwards? Is the removal of existing equipment also included, e.g. a previously existing water heater?
  - What are the warranties – on the work and on the hardware?
  - What after-installation services are included? Or offered at what additional cost?
- Get the offer in writing, so that you can better compare offers and hold the planner/installer accountable, later.
- Where applicable: Get confirmation from the planner/installer that the proposed system will be eligible for financial support or other benefits.
- Products/brands offered: While most installers prefer to work with one or a few brands you should try to ensure that they offer you a good solution for your specific project and not just the standard system from their preferred supplier.
- Depending on the project you are working on: Look rather for a local planner/installer who has done similar projects in the same region – under same regulations, climatic conditions etc. and who can quickly support you or the building owner even after completion of the project.
- Rapport: A good SWH installer has an informative and helpful attitude, and is never patronizing. Especially if you are not yet too familiar with SWH technologies: You need an installer who is eager to explain the multitude of possibilities and guide everyone through the process.
- Project management: A SWH installer should work alongside other contractors to help them understand the requirements of the piping infrastructure. Meticulous product management is essential to ensure the project runs smoothly.
- Adequate staff and resources: Make sure the installer has adequate design, documentation, project management, systems programming and installation staff and resources to ensure the project is carried out on time and to budget.

Further Readings and References

- Finding an Installer [EST FIND]
- Planning permission, finding an installer, and making the most of your system [EST PLAN]

Commissioning report

After the installation, the system needs to be commissioned. Frequently, it is the installation company that does this, but sometimes the hardware manufacturer takes over the commissioning, or even a third party. Sometimes specific reports are required, for example, to make the system eligible for financial incentives.

The commissioning must ensure that everything works as planned – this includes removal of protective covers from collectors, opening or closing of valves, filling the primary circuit with fluid (possibly including anti-freeze), checking that sensors report sensible information, that controller and pumps communicate correctly with each other etc.

For large(r) projects a 3-phase model is considered best practice, today:

1. Putting into operation of the system including pre-commissioning
2. Testing phase (e.g. 3 months) including reworks, readjustments, troubleshooting
3. Final commissioning/final approval

Check-lists have been developed by companies, associations and governments, covering different system types, countries, brands etc. Please find here a short overview of suitable checklists – please feel free to search and use others, where appropriate:

- CSI-Thermal Program Installation Inspection Checklist [CSI]
- Solar Thermal Handover Pack Information [MCS 2012]

INTERMEDIATE

Maintenance

Problems with solar thermal systems are most often due to faulty planning and/or installation of the system. And usually, these problems show up rather earlier than later. (Remote) system monitoring can help identify problems, it is already common in large(r) solar thermal plants (e.g. >50m^2 of collector area).

However, like any other technical device, solar thermal systems are subject to wear and tear and – especially larger, more complex – solar thermal systems should be inspected and maintained at regular intervals.

Already today, it is very common to remotely monitor larger systems. Then, an external company (e.g. the installing company) can view important parameters of the system, such as temperatures in the tank, in the collector field(s) the flow of the solar fluid in the primary circuit (connecting collectors with the tank) etc. Many common problems can be identified through this remote monitoring (e.g. a broken sensor, the non-functioning of the pump).

However, even with remote monitoring in place, some physical checks should be carried out on-site in order to spot or avoid problems.

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ANNEX I

Solar thermal simulation tools

Software

One of the software tools available for free to calculate/simulate solar thermal systems is the RETScreen 4 software. This software, , developed with the support of several entities, including UNEP and the Green Energy Fund, can be found at www.retscreen.net

Other free tools can be found at http://photovoltaic-software.com/solar-thermal-free.php

The most widely used commercial products are

- **Polysun by Vela Solaris**
  From the product website [retrieved June 2014]: *Polysun simulation software is the ideal sales and design tool. You will get optimal support in the design of solar thermal, heat pump and photovoltaic systems as well as combined systems*

  See: www.velasolaris.com/english/product/overview.html

  A free online version of Polysun is available at:
  www.velasolaris.com/english/product/online-calculator.html

- **TSol by Valentin Software**
  From the product website [retrieved June 2014]: *T*SOL® is the simulation program that allows you to accurately calculate the yield of a solar thermal system dynamically over the annual cycle.*

  *With T*SOL® you can optimally design solar thermal systems, dimension collector arrays and storage tanks, and calculate the economic efficiency.*

  See: www.valentin-software.com/en/products/solar-thermal/14/tsol

  A free online tool, based on TSol is available at:
  http://valentin.de/calculation/thermal/start/en

ANNEX II

Project development checklist

This form can be downloaded from:
www.estif.org/fileadmin/estif/content/publications/downloads/Annex_II-Project_Development_Checklist.docx

Project Development Checklist

Integrating Solar Thermal in Buildings
A quick guide for Architects and Builders

Project Summary

Project: [project name]

Description: [short description]
Location: [short description]
[...]

Responsible: [name]

Contacts: E-mail: [email@domain.cy] Tel: [phone number]
Start: dd/mm/yyyy **End:** dd/mm/yyyy

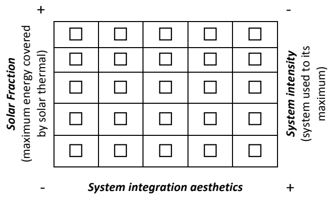
Budget (CUR): **Total:** [...]

Project Development Steps

- Step 1: Develop the scope of works
- Step 2: Design and documentation with a list of tasks and related skills.
- Step 3: Identifying and working with a SWH supplier/ contractor.
- Step 4: Piping infrastructure installation
- Step 5: Integrating the solar thermal installation with other construction processes
- Step 6: Product selection and installation.
- Step 7: Handover and tuition

Scope of works

- **What kind of building/site is to be developed/worked on?**
- **What type of heating application is required?** Choose an option
- **Is it a new or an existing building?** Choose an option
- **What is the existing/planned backup system?** Choose an option
- **What is the main reason to include solar thermal?** Choose an option
- **Should the building include a system or be "solar-ready"?** Choose an option
- **Expectation regarding the solar thermal system performance?**



Design and documentation

1

Project Development Checklist

Integrating Solar Thermal in Buildings
A quick guide for Architects and Builders

- **Characterisation of the system:**
  - Size: m² - Weight: Kgs - Orientation - Tilt
- **Preferred collector mounting?** Choose an option
- **Characterisation of HVAC:**
  - Equipment: - Location:
- **Location of amenities & meters:**
  - Water - Gas - Electricity - Other
- **Heat storage:**
  - Size: m³ - Dimensions: x - Location:
- **Standards & certification:**
  - *Applicable technical standards*
  - *Certification required: Products: Installation:*

Identifying and working with a SWH supplier/ contractor

- **Evaluation of the subcontractor:**

Item	Relevance of item (%) [a]	Evaluation 1 (low) – 5 (high) [b]	Ponderation [a] x [b]
Necessary know-how for the task	%	1	
Experience with similar projects	%	1	
Possesses accreditation/certification	%	1	
Availability of work references	%	1	
Clear and thorough proposal	%	1	
Capacity to assist with regulatory requirements	%	1	
Clear estimation of system performance and energy costs	%	1	
(other important requirements)	%	1	
Total score			

Note: recommended to evaluate at least three options

Piping infrastructure installation

- **Assessment of requirements for piping infrastructure:**

	Yes	No	N/a
Building component strong enough to carry the weight of the collectors, mounting structures, fluids and wind loads (including negative wind loads, i.e uplifts)	☐	☐	☐
Collectors does not obstruct access to other parts of the roof/building	☐	☐	☐
Distance from the collector field to the potential place of the storage tank short enough (normally, no more than 20m)	☐	☐	☐
Piping installation is not obstructed by physical/design constraints	☐	☐	☐
Heating equipment room large enough to accommodate the storage tank	☐	☐	☐
Floor strong enough to carry the weight of the tank and the fluid	☐	☐	☐
Water store installed at the end of the works (does not imply on room/wall finalization)	☐	☐	☐
Water store fits on accesses to the storage room without additional works	☐	☐	☐

Integrating the solar thermal installation with other construction processes

- **Requirements and interfaces of solar system installation with regard to:**

Roofing works	
HVAC installation	
Façade works	
Storage installation	
Finishing works	

- **Project milestones:**

•	Description	Comments	Reference Date
M1			dd/mm/yy
M2			dd/mm/yy
M3			dd/mm/yy
M4			dd/mm/yy
…			dd/mm/yy

Comments:

Project Development Checklist

Integrating Solar Thermal in Buildings
A quick guide for Architects and Builders

Product selection and installation

- **Product requirements:**
  - *Collector type:* *Choose an option*
  - *System type:* *Choose an option*
  - *Preferred brand:*
  - *Certification option:*
  - *Aesthetics requirements:*
  - *Constraints (space, exposure, etc.):*

Commissioning, monitoring and tuition

- **System handed over to building owner/user:**
  - *Responsible for the handover* *Choose an option*
  - *Documentation required regarding system and commissioning*
  - *System parameters adjusted by:*

Building owner/manager	*User*	*External expert*
-	-	-

ANNEX III

Solar Thermal Site Assessment

This form can be downloaded from:
www.estif.org/fileadmin/estif/content/publications/downloads/Annex_III-site_assessment.docx

Name of client
Click here to enter text.

Site address
Click here to enter text.

Type of site:
☐ small residential building
☐ large(r) residential building
☐ public building
☐ commercial building
☐ other, please specify: Click here to enter text.

Site visited
☐ yes, on Click here to enter a date. (date) ☐ no

What is the (main) motivation of the client?
☐ cost
☐ security of supply
☐ local environment (clean air)
☐ global environment (global warming)
☐ convenience
☐ other, please specify: Click here to enter text.

Is the client the owner of the building / site?
☐ yes ☐ no (please specify relation): Click here to enter text.

How long do they plan to stay in the building / on the site (planning horizon)?
Click here to enter text. years

Does the client have a (fixed) budget for the (solar) water heating system?
☐ yes Click here to enter a date. (currency unit) ☐ no

Would the system be installed in a new building or retrofitted to existing building?
☐ new ☐ retrofit

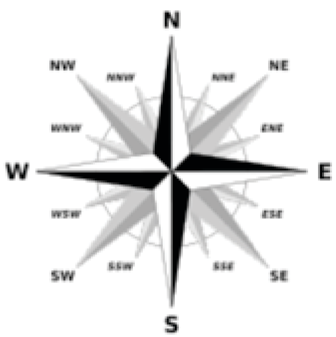
Time frame for the project
☐ not yet determined
☐ approximately in Click here to enter text. months
☐ the system must be completed by: Click here to enter a date.

Approximate hot water / heating demand of the building / site
Click here to enter text. ☐ litres ☐ gallons per day
at Click here to enter text.° ☐ Celsius (C) ☐ Fahrenheit (F)

Which building component could the collector field by installed upon?
☐ flat roof ☐ sloped/pitched roof ☐ façade ☐ balcony ☐ ground

Please describe further (type, material): Click here to enter text.

Cardinal orientation of the building area that could be used to install the collectors (roof, façade, balcony, ground)
Exact orientation in degree: Click here to enter text.°
Or approximate orientation (please mark on compass rose[i]):



What is the tilt of the suitable area?
Click here to enter text.°

How large is the suitable area?
Click here to enter text. ☐ square meter (m^2) ☐ square feet (sq ft)

Is the roof (or façade, balcony etc.) strong enough to carry the weight of the collector field and – in the case of a thermosiphon DHW system – also the tank?
☐ yes ☐ no ☐ to be determined

Shading of collector field
☐ (almost) none
☐ yes, approximately Click here to enter text.% of collector field shaded for Click here to enter text. hours per day (explain further, if necessary – e.g. if strong seasonal differences occur)

Would collectors be placed beneath aerials or similar equipment (possible problems with bird droppings):
☐ yes ☐ no

Accessibility of collectors for future inspections / maintenance
☐ (very) good
☐ somewhat cumbersome, please explain: Click here to enter text.

Possible placement of thermal storage tank
Please, describe possible locations: Click here to enter text.

Where could pipes be installed from collector to tank? Please, describe possible paths and lengths: Click here to enter text.
Does central water heating exist already at the site? ☐ no (explain, if necessary): Click here to enter text. ☐ yes, with main energy source ☐ natural gas ☐ heating oil ☐ LPG ☐ wood ☐ other, please specify: Click here to enter text.

[i] Compass rose: Copyright by Rosen

ANNEX IV

Periodic Inspection List

(Source: http://energy.gov/energysaver/articles/solar-water-heating-system-maintenance-and-repair)

Here are some suggested inspections of solar system components.
Also read your owner's manual for a suggested maintenance schedule.

Collector shading

Visually check for shading of the collectors during the day (mid-morning, noon, and mid-afternoon) on an annual basis. Shading can greatly affect the performance of solar collectors. Vegetation growth over time or new construction on your house or your neighbour's property may produce shading that wasn't there when the collectors were installed.

Collector soiling

Dusty or soiled collectors will perform poorly. Periodic cleaning may be necessary in dry, dusty climates.

Collector glazing and seals

Look for cracks in the collector glazing, and check to see if seals are in good condition. Plastic glazing, if excessively yellowed, may need to be replaced.

Plumbing, ductwork, and wiring connections

Look for fluid leaks at pipe connections. Check duct connections and seals.
Ducts should be sealed with a mastic compound. All wiring connections should be tight.

Piping, duct, and wiring insulation

Look for damage or degradation of insulation covering pipes, ducts, and wiring.

Support structures

Check all nuts and bolts attaching the collectors to any support structures for tightness.

Pressure relief valve (on liquid solar heating collectors)

Make sure the valve is not stuck open or closed.

Dampers (in solar air heating systems)

If possible, make sure the dampers open and close properly.

Pumps or blowers

Verify that distribution pumps or blowers (fans) are operating. Listen to see if they come on when the sun is shining on the collectors after mid-morning. If you can't hear a pump or blower operating, then either the controller has malfunctioned or the pump or blower has.

Heat transfer fluids

Antifreeze solutions in liquid (hydronic) solar heating collectors need to be replaced periodically. It's a task best left to a qualified technician. If water with a high mineral content (i.e., hard water) is circulated in the collectors, mineral buildup in the piping may need to be removed by adding a de-scaling or mild acidic solution to the water every few years.

Storage systems

Check storage tanks, etc., for cracks, leaks, rust, or other signs of corrosion.

NOTES

For more information,
see **www.unep.fr**

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UNEP

"Integrating Solar Thermal in Buildings – A quick guide for Architects and Builders" aims at promoting solar water heating (SWH) systems to architects and builders from developing countries and help them consider integrating SWH applications in their designs.

Intending to be a useful handbook, this "Quick Guide" provides a compact overview of the technology and its main characteristics, as well as the main requirements to be considered for its application in different types of projects and in different geographical locations.

This publication was elaborated in order to increase awareness about SWH among important stakeholders, such as architects and builders, and encourage the use of this type of solar systems. Hence it gives a synopsis of the technology and general requirements for integration in buildings. It also provides a quick reference guide to the practicing architects and builders, helping them to quickly identify relevant sources of additional information.

This "Quick Guide" was developed as part of the Global Solar Water Heating (GSWH) Market Transformation and Strengthening Initiative.