Projet cofinancé par le Fonds Européen de Développement Régional (FEDER)
Project cofinanced by the European Regional Development Fund (ERDF)

Green Partnerships

Solar Energy

Expert Working Group

www.greenpartnerships.eu

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INTRODUCTION

GREEN PARTNERSHIPS project (GPs) aims to strengthen the implementation of local public policies and strategies related to energy efficiency for sustainable local and regional development of the MED cities and local communities by:

- developing a joint innovative approach including the development, promotion and testing of operational recommendations for overcoming the existing difficulties faced by local public authorities and
- enhancing the local capacity and human resources competence
- boosting cooperation of stakeholders in implementing energy efficiency measures by establishing local partnerships.

For this scope, the Green Partnership consortium has formed Expert Working Groups to support local communities by knowledge and best practise transferring. Capacity building workshops are organised to lead to long-term behaviour improvement, increased technical and organisational knowledge, competence to plan and implement energy efficiency projects and new investments.

Within this frame, the Solar EWGs has developed training material to provide the local authorities staff with the basic knowledge in Active Solar Energy Technologies, to motivate them presenting existing good practices and to provide them useful links for further information. Further guides and training materials on a number of knowledge topics, useful for Local Authorities implementing their energy strategies, may be found at the GreenPartnerships website (www.greenpartnerships.eu).

SOLAR ENERGY EXPERTS WORKING GROUP

Technical University of Crete -School of Environmental Engineering
Renewable and Sustainable Energy Systems Laboratory
www.resel.tuc.gr

Regional Energy and Environment Agency from North Alentejo - AREANATejo
www.areanatejo.pt

Institute for spatial planning of the Koprivnica- Krizevci County
www.prostorno-kkz.hr

Lakatamia Municipality
www.lakatamia.org.cy

Hydro – Engineering Institute Sarajevo
www.heis.com.ba

CONTENTS

1. ENERGY FROM THE SUN – BASICS

Drafted by TUC

The sun is a globally accessible renewable energy source, using it right and in combination with the evolving technology can bring a definitive solution to the problems of energy dependence.

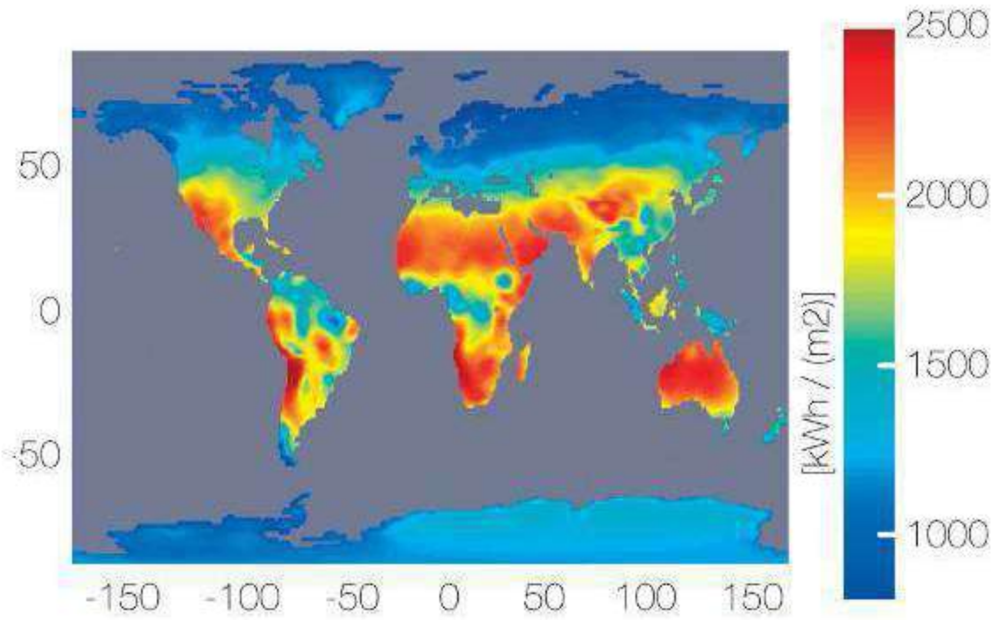


Figure 1: Solar irradiation around the world (source: Gregor Czisch, ISET, Kassel, Germany, 2007)[1]

The total solar radiation that reaches a flat surface can be divided in direct, diffuse and albedo radiation. **Direct radiation** is the amount of radiation that reaches a surface in a straight line from the position of the sun. **Diffuse radiation** is the amount of radiation that has been scattered by molecules and particles in the atmosphere or reflected by the ground and arrives from all directions. **Albedo** is direct or diffused radiation reflected from the soil or nearby surfaces.[1,2]

The solar path and its position are identified with use of the solar elevation and solar azimuth. The solar elevation is the angular height of the sun in the sky measured from the horizontal, whereas the azimuth is the compass direction from which the sunlight is coming. The elevation and azimuth angle varies throughout the day. It also depends on the latitude of a particular location and the day of the year.

[1] PVTRIN Training course – Handbook for Solar installers
[2] T.Tsoutsos, I. Kanakis."Renewable energy sources, technology & environment", 2013

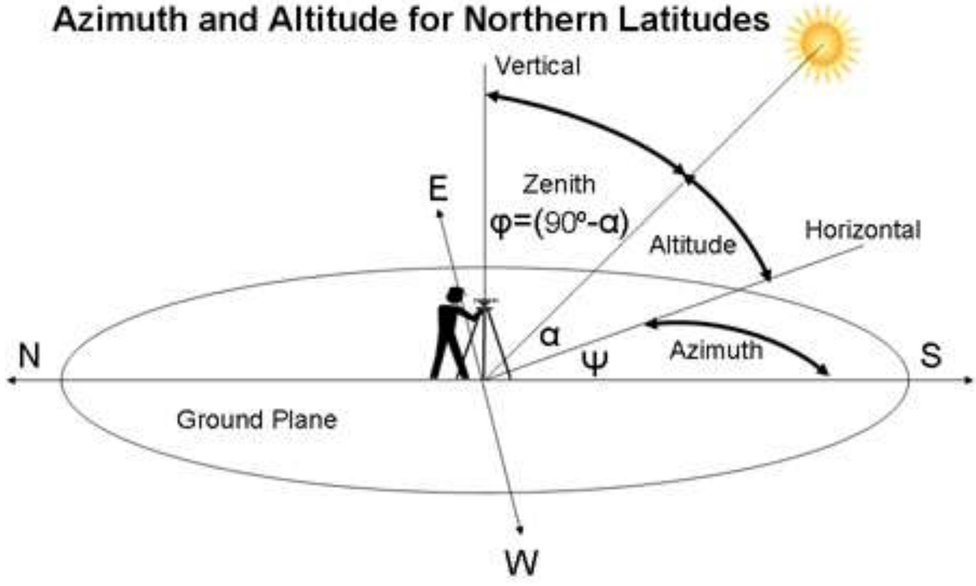


Figure 2: Solar azimuth and altitude (source: www.mpoweruk.com, 2011)[3]

[3] PVTRIN Training course – Handbook for Solar installers

2. SPACE HEATING/ COOLING, WATER HEATING – ACTIVE SOLAR THERMAL SYSTEMS

Drafted by AREANATejo

2.1. INTRODUCTION TO ACTIVE SOLAR THERMAL

The use of solar radiation as a thermal source is an ancient concept. Nowadays the concerns about the environmental impact of burning fossil fuels have made active solar thermal systems a very good solution to be used in several applications, like space heating, cooling and hot water production. How the solar energy is collected and used defines the difference between active and passive solar systems. Active solar systems collect the solar radiation with use of solar collectors and convert it in the form of heat to water, air or some other fluid. This is a relatively simple technology with low cost and many applications for low temperature systems.[4]

The main challenge is the interconnection of these systems in an intelligent and efficient way, in order to obtain an energetic and economic optimization. For that reason from the beginning of the design of such a system, an integrated planning between all the involved professionals should be done.

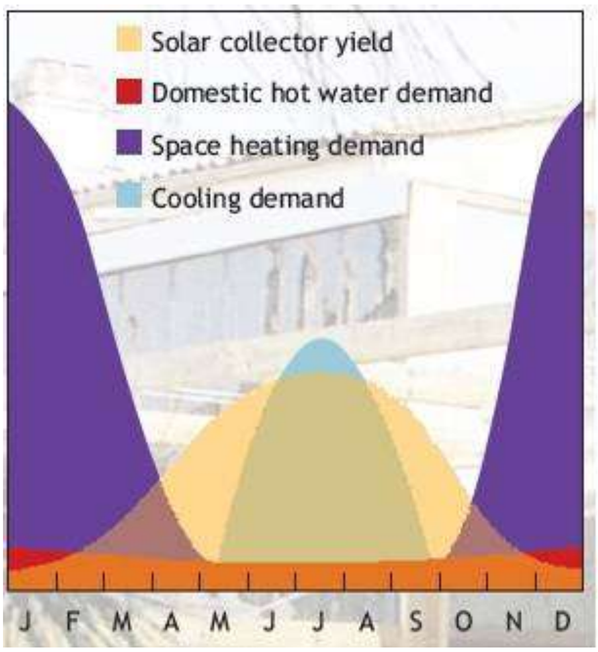


Figure 3: Solar energy, hot water production, space heating and cooling needs in Europe[5]

2.2. SOLAR COLLECTORS

Solar energy collectors are heat exchangers that transform solar radiation energy to internal energy of the transport medium. The major component of any solar system is the solar collector. This is a device which absorbs the incoming solar radiation, converts it into heat,

[4] www.cres.gr/kape/energeia_politis/energeia_politis_active_solar_uk.htm
[5] www.iea.org/publications/freepublications/publication/Solar_heating_cooling.pdf

and transfers this heat to a fluid (usually air, water, or oil) flowing through the collector. The solar energy thus collected is carried from the circulating fluid either directly to the hot water or space conditioning equipment or to a thermal energy storage tank from which can be drawn for use at night and/or cloudy days.[6]

To describe the geometry of the collectors the following areas should be considered:

- The total size (floor surface) of the collector which corresponds to the external dimensions and define, for example, the minimum amount of surface area needed for the roof installation;
- The surface area of opening that corresponds to the area through which the radiation passes to the collector;
- The gathering area which corresponds to the surface area of the absorber.

Currently there are several types of solar collectors, namely:

1. Unglazed collectors – These collectors consist merely of absorber. Can be found in various applications, mainly as an absorber of plastic for water heating;
2. Flat plate collectors – Flat collectors have thermal insulation in the bottom and sides. At the top there is a transparent cover. Two pipes connected to supply and return the heat transfer fluid are arranged on the side of the collector.
3. Composite parabolic collectors – In order to reduce heat loss existing in the flat collectors, a new technology was developed, which is based on reduction of the absorption as compared with the catchment area of solar radiation. Thus it reduces the thermal losses, taking into account that the absorber is proportional to the area in opposition to the opening area.
4. Vacuum collectors – To reduce heat loss in collector glass tubes (with internal absorbers) are subjected to vacuum. Thus, heat losses to the atmosphere are significantly reduced.

The choice of the best solution will depend on the application of the solar system to be considered and also the thermal characteristics of the area.[7]

Solar collectors for space heating can be classified into three different types of construction. This classification depends on how the heat transfer mean ("air") is placed in contact with the absorber.

We can distinguish between:

- Higher flow collectors;
- Under flow collectors;
- Upper and lower flow collectors flow.

The design is the same for the three a.m. types of collectors. On the back of the collector there is thermal insulation in order to minimize heat losses to the surroundings. The box is closed on top by a transparent cover (“glass”).

Based on these three basic types, there are many variants and developments of solar collectors for space heating. The optimization of heat transfer is generally the main focus.

[6] Kalogirou, Soteris A., Solar thermal collectors and applications, Department of Mechanical Engineering, Higher Technical Institute, P.O. Box 20423, Nicosia 2152, Cyprus, February 2004

[7] Energia Solar Térmica, Manual sobre tecnologias, projecto e instalação, Instituto Superior Técnico, Janeiro 2004

However, when assessing these developments, it is necessary to consider that pressure losses must be minimized. In the end, these developments aim to optimize the system with two contrasting goals: to improve heat transfer and to minimize pressure losses. Some examples of standard solar collectors are outlined below.

Figure 4: Standard flat plate collector[8]

Figure 5: Example of a facade collector

[8] Intelligent Energy Europe, Solar Cooling – Overview and recommendations

Figure 6: Example of Solar Wall System[9]

2.3. SOLAR THERMAL APPLICATIONS

2.3.1. Water heating

DOMESTIC HOT WATER

The main systems for hot water production could be grouped as following:

- Thermosiphon systems that do not require pumps, since the transport of heat transfer fluid is made by gravity and forced circulation systems, which work with the installation of circulation pumps; this second type of systems is widely used in Europe;

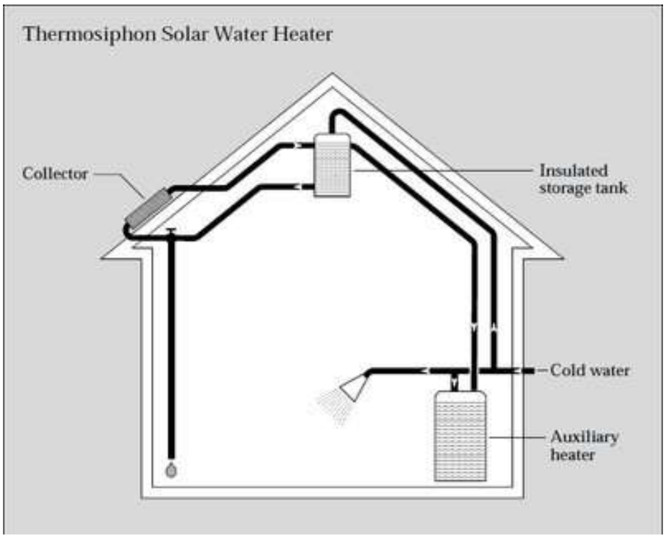


Figure 7: Example of a thermosiphon system[10]

[9] www.lneg.pt/download/4078/BrochuraSolarXXI_Dezembro2005.pdf
[10] www.your-solar-energy-home.com/thermosyphon.html

- Open and closed systems. The open circuits have a free surface container at the highest point of the solar circuit, which allows the absorption of the volumetric expansion of the liquid caused by an increase in temperature. The pressure in open systems corresponds to the maximum static pressure of the liquid column. On the other hand, closed systems operate with high pressure (1,5 to 10 bar), that influences the physical properties of the heat transfer fluid (such as the evaporation temperature). In the case of closed systems, special safety devices are required;
- (alternatively to the above) Simple circuit systems and twin circuit systems. In the first case, the sanitary water circulates from the storage tank to the collector and then goes back to the starting location. In the second case, the system is separated into two circuits: a solar one and a sanitary water one. The first one includes collectors, pipelines, a solar pump with safety equipment and a heat exchanger. A mix of water and glycol is used as heat transfer fluid. The sanitary water circuit includes a storage container as well as the cold water and hot water facilities.[11]

Internal solar heat exchanger

The heat exchanger is usually designed as a finned pipe or a serpentine flat tube installed in the bottom area of the storage tank. The heat transfer to the sanitary water is made through heat conduction and, as a result, convection takes place (i.e. heated water rises as a result of its low density).

Internal solar heat exchanger with a by-pass circuit

This is a variant of the previous system, but designed for larger systems. A radiation sensor measures the radiation. To a limit value of 200 W/m^2 (e.g.) the controller switches the solar pump and, initially, the three-way valve does the bypass to the heat exchanger. The solar circuit starts to heat and when the set difference of temperature between the collectors and the storage tank is reached in the sensor, the controller gives a command to the valve, in order to get through the fluid in the storage tank, which is loaded with heat.

Because of the daily and seasonal variation of the solar radiation active solar systems for hot water production are combined with auxiliary electric, gas or oil heating systems that can produce hot water by demand when there is no sun.

LARGE SCALE SYSTEMS

Possible application areas

Large solar systems for water heating can be used in a wide variety of public buildings, which have a corresponding need for hot water or a heating need throughout the year, including swimming pools, sports facilities and hospitals.

[11] Energia Solar Térmica, Manual sobre tecnologias, projecto e instalação, Instituto Superior Técnico, Janeiro 2004

Figure 8: Example of water heating systems in a swimming pool[12]

In order to size a solar energy system, and due to the variation in supply of solar energy, it is necessary to know the consumption pattern and profile as well as the desired hot water temperature. These data is then used in project's sizing.

The temperature required for hot water application is significant for the subsequent energy yield of the solar system. It is also important to highlight the following ranges: low temperatures (<60ºC), medium temperatures (60ºC – 150ºC) and medium-high temperatures (150ºC – 250ºC). The lower level of temperature required to heat the water in swimming pools is 25ºC to 35ºC. For sanitary hot water 45ºC temperature is usually enough. Larger buildings, generally, require 60ºC temperature outside the storage tank, in order to restrict the hot water tank's volume or to fulfill the requirements of technical regulations. In turn, the industry needs for hot water are around 50% in temperatures below 250ºC. Whenever is reasonable, water heating shall be limited to the level of temperature needed to save energy.[13]

2.3.2. Space heating

In the same principle that solar radiation can provide a large part of hot water production, with some more initial investment a substantial share of the space heating needs can also be covered. For that reason natural flow system – without pumps or control stations - and forced circulation systems can both be used. The natural flow systems are more commonly used in Southern Europe, while the forced circulation systems in Central and Northern Europe.[14]

In Central and Northern Europe the installation of solar thermal systems that provide both space heating and hot water production is common. These kinds of systems are named

[12] www.areanatejo.pt
[13] Energia Solar Térmica, Manual sobre tecnologias, projecto e instalação, Instituto Superior Técnico, Janeiro 2004
[14] www.erec.org/renewable-energy/solar-thermal.html

combisystems. Typically they have a collector of 7-20m^2 and a tank of 300-2.000 liters. Combisystems are more complex than systems providing only hot water, thus the system design must be adapted to the requirements of each building specifically. In Southern Europe the use of combisystems is not yet well established although there is a big potential for systems generating space heating in winter, air-conditioning in summer and hot water production all year long.[15]

Solar space heating systems by air heating are comparable to solar systems whose heat transfer is made with a liquid medium. However, the air (as heat transfer medium) has different physical characteristics of the water, which leads to deep consequences, such as:

- **Heating speed:** the air warms and cools faster than water due to its lower heat capacity. This means that useful temperatures in solar collectors for space heating can be achieved even with low levels of solar irradiation;
- **Indirect storage:** storing energy in space heating systems is more expensive and can only be made indirectly, as the heat transfer mean (air) is, in itself, unsuitable for energy storage;
- **Low thermal conductivity:** the heat transfer from the absorber to the heat transfer fluid is worse in a solar collector for space heating using air when compared to a collector of identical size using liquid;
- **High mass and volumetric flows:** space heating systems require a careful design and installation in order to minimize the use of auxiliary power. [16]

Solar Ordinances

In a number of countries, regions and local authorities in Europe and beyond, solar ordinances are being adopted or discussed. Solar ordinances are regulations that oblige the use of a minimum share of solar energy for covering the heating and DHW demand in new buildings, major refurbishment or replacement of the heating system. In most cases this ordinances are part of national or regional energy laws implemented through local building codes at municipal level.[17] Solar obligations are an efficient tool of promoting the use of renewables in new buildings. To ensure that customers are not going to apply the cheapest possible solution, solar obligation must include appropriate quality assurance measures.[18]

TYPES OF SPACE HEATING SYSTEMS

Fresh air solar systems

This system represents the simplest solar system for space heating. The fresh air circulates inside the collectors, being then ventilated into the building divisions.

[15] www.estif.org/st_energy/technology/combisystems/
[16] Energia Solar Térmica, Manual sobre tecnologias, projecto e instalação, Instituto Superior Técnico, Janeiro 2004
[17] www.solarordinances.eu/SolarOrdinances/AboutSolarOrdinances/tabid/64/Default.aspx
[18] www.estif.org/policies/solar_ordinances/

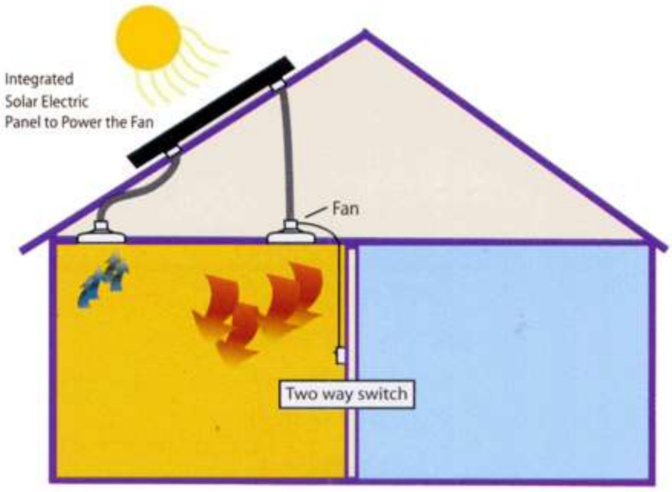


Figure 9: Example of fresh air solar systems[19]

There is no forced air exhausting system. If the air renewal (needed for hygiene and/or comfort requirements) is made to the building throughout solar collectors for inside environment heating, all degrees of temperature rise also imply energy savings.[20]

Air heating through solar system with storage

In order to use a solar heating system of a building in periods that do not coincide with the availability of solar radiation, the heat must be stored. In order to store the generated heat, it should be transferred to a suitable environment. For this purpose, gravel or stone containers can be used, but usually they are associated with high costs.

It is possible to have a relatively cheap method of intermediate storage of solar heat by using systems named "hypocausts", once the inside environment heating solar system is planned for a building at the design stage. In this case, the heat is transferred to the walls and floors of the building and, subsequently, to the adjacent rooms. The conventional needed heating may also be operated through this system, in order to be used optimally. [20]

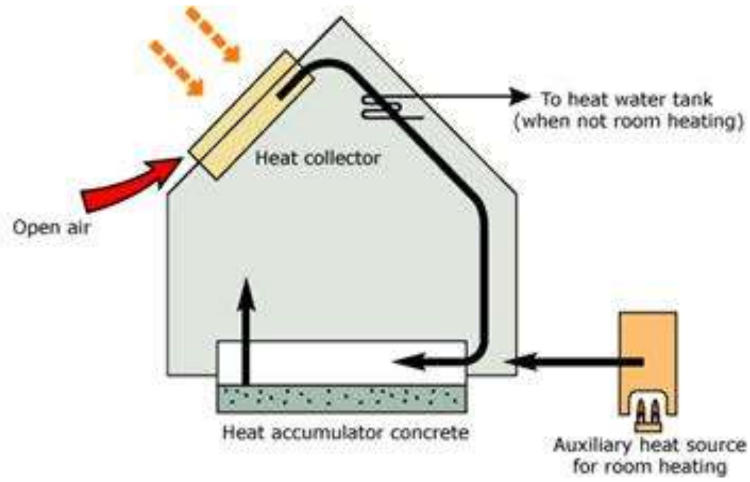


Figure 10: Example of domestic ventilation system[21]

[19] www.metaldynamics.com.au/watertanks_3.htm
[20] Energia Solar Térmica, Manual sobre tecnologias, projecto e instalação, Instituto Superior Técnico, Janeiro 2004

In rooms equipped with a system like this, the surface area of the collector is often subdivided. A part of the system supplies the hypocaust system, while the other supplies a controlled direct heating system.

Note: *A common solar thermal application, which is more often regarded as a passive solar thermal system, is the Trombe wall. A typical Trombe wall consists from a thick, south facing masonry wall with a dark, heat-absorbing exterior surface and a single or double layer of glass. Its function is to absorb sunlight passing through the glass onto the dark surface and store it in the wall. From there the heat is slowly delivered into the room.*[22]

2.3.3. Solar Cooling

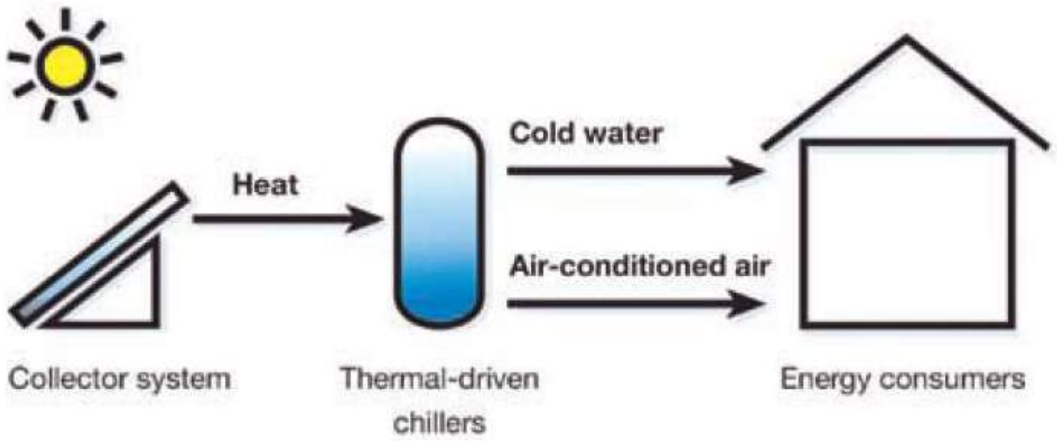


Figure 11: Solar cooling system[23]

In the past few years, the increasing demand for higher levels of thermal comfort has led, generally, to the increase in the number of buildings equipped with air-condition. This trend has been observed in Europe, with special emphasis on the Southern countries.

Since the energy consumption associated to air conditioning systems is relatively high and since the default refrigeration compression systems use electricity, the possible solution for a sustainable energy supply go through the energy systems, by using renewable energy sources.

The production of cold air throughout the use of solar energy may, at first sight, consist of a paradox, since the sun is viewed as a heat source, generally.

However, there are thermal processes for cold production, wherein water or air conditioned are cooled throughout a direct heat input. Generally, these processes are suitable for the use of the heat from solar thermal collectors, thus functioning as primary energy source. We must highlight that solar radiation can be converted into "solar electricity" by photovoltaic systems, thus leading to conventional compression refrigeration systems.

[21] www.pages.drexel.edu/~act27/AE390/A6/index_files/Page890.htm
[22] T.Tsoutsos, I. Kanakis."Renewable energy sources, technology & environment", 2013
[23] Intelligent Energy Europe, Solar Cooling – Overview and recommendations.

This chapter aims to provide a general overview of the solar cooling processes, thus highlighting the key challenges associated with the integration of collectors' installation and cooling technology.[24]

COOLING PROCESSES DRIVEN BY HEAT

Cooling by absorption

The absorption chiller is mainly composed by a vacuum tank divided into three chambers: i) evaporator (lower chamber), ii) collector and generator (medium chamber) and iii) condenser (upper chamber). The generator and the collector are connected by "flap" type valves and, as a result of pressure differences, they automatically open and close to the condenser above them and the evaporator below them. [25]

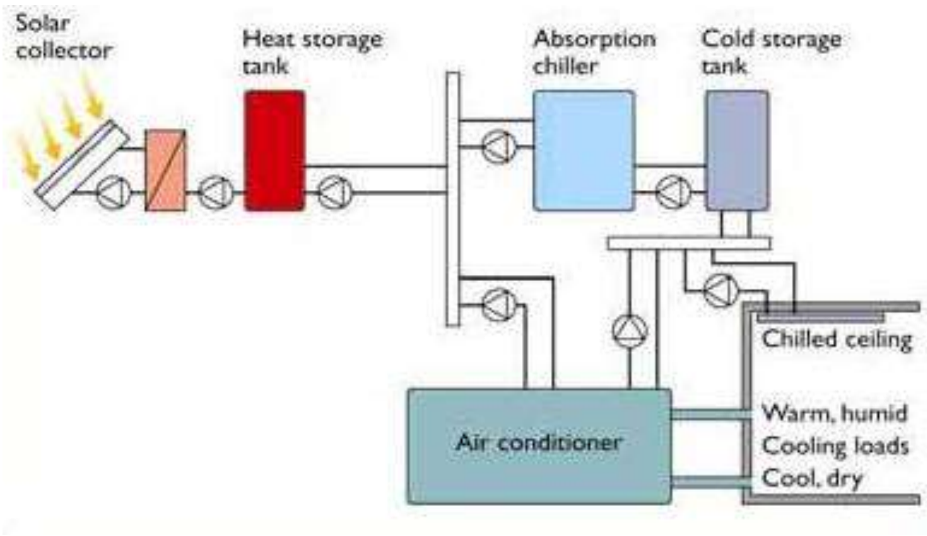


Figure 12: Example of a system with cooling by absorption[26]

A typical liquid solution H_2O/LiBr is continuously pumped into the generator, where regeneration is achieved with use of hot water. The refrigerant (water) leaving the generator condenses through the application of cooling water in the condenser and by means of an expansion valve circulates into the evaporator. The cooling effect is based on the evaporation of the refrigerant in the evaporator at a very low pressure.

Cooling by adsorption

The main components of an adsorption chiller are the two sorbent compartments, the evaporator and the condenser. The sorbent, which is usually silica gel, in the first compartment is regenerated using hot water from the solar collector, the sorbent in the second compartment adsorbs the water vapour from the evaporator. The useful cooling is

[24] Energia Solar Térmica, Manual sobre tecnologias, projecto e instalação, Instituto Superior Técnico, Janeiro 2004
[25] Energia Solar Térmica, Manual sobre tecnologias, projecto e instalação, Instituto Superior Técnico, Janeiro 2004
[26] eecm.eu/wp-content/uploads/2011/01/Gradivo_img_228.jpg

produced in the evaporator, where the water is transferred into the gas phase using heat from the external water circle.[27]

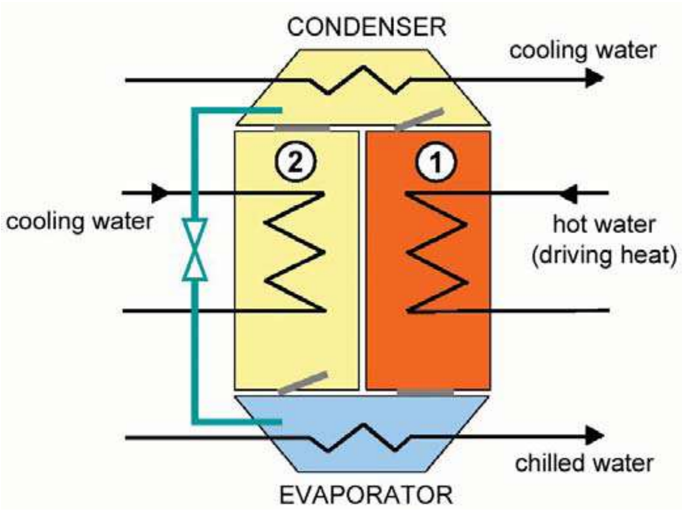


Figure 13: Schematic drawing of an adsorption chiller[28]

Table 1: Comparison of the main sorption technologies[29]

	+	-
Absorption	Only one moving part (pump) with possibly no moving part for a small system	Low COP
		It cannot achieve a very low evaporating temperature
	Low-temperature heat supply is possible	The system is quite complicated
Adsorption	No moving parts (except valve)	High weight and poor thermal conductivity of the absorbent
	Low operating temperature can be achieved	Low operating pressure requirement makes it difficult to achieve air-tightness
	Thermal Coefficient of Performance (COP) is quite high compared to other heat operating systems	Very sensitive to low temperatures especially the decreasing temperature during night-time
		It is an intermittent system

[27] M. Delorme, R. Six, D. Mugnier, J.Y. Quinette, N.Richler, F. Heunemann, E. Wiemken, H. Henning, Th. Tsoutsos, E.Korma, G. Dall'O, P. Fragnito, L. Piteru, P. Oliveira, J. Barroso, J.R. Lopez, S. Torre-Enciso, "Solar Air-conditioning Guide" (ALTENER, 2004)
[28] M. Delorme, R. Six, D. Mugnier, J.Y. Quinette, N.Richler, F. Heunemann, E. Wiemken, H. Henning, Th. Tsoutsos, E.Korma, G. Dall'O, P. Fragnito, L. Piteru, P. Oliveira, J. Barroso, J.R. Lopez, S. Torre-Enciso, "Solar Air-conditioning Guide" (ALTENER, 2004)
[29] raee.org/climatisationsolaire/gb/index_gb.htm

Cooling by drying

Unlike the absorption and adsorption processes, cooling systems by drying are classified as open procedures, once in these systems the air is conditioned by direct contact with the cooled means (in this case, the water), thus constituting a surplus for this type of systems. In addition, the sorbent (which may be solid or liquid) gets in direct contact with the air conditioner, thus allowing the necessary air dehumidification.

2.4. EFFICIENCY AND ECONOMICS OF ACTIVE SOLAR

One of the ways to evaluate, from the economic point of view, the benefits obtained with the acquisition of a solar system is the payback period of the investment, i.e., the ratio between the system cost (initial investment) and the annual expected savings. These are calculated taking into account that the conventional energy bill (electricity or gas) is annually reduced by an average value equivalent to the energy supplied by the solar system.

When designing a solar cooling system, we shall follow (in all the situations) the following steps[30]:

i. Load calculation for cooling/heating of the building.
ii. Optional: Calculation of the time series of cooling/heating loads for each hour of the year, based on a thermodynamic simulation of the building.
iii. Design of air conditioning and/or cooling technology. At this point, we have to verify what technology of air conditioning and/or cooling shall be used or adjusted to the building.
iv. Optional: in the case of completion of point ii), we must decide if the design of air conditioning technology and/or cooling shall be based on the peak load or if we shall accept deviations occurred during certain hours/days. We have to analyze the quantitative effect of the reduction potential of air conditioning and/or cooling in ventilation conditions, using a simulation that combines building and system.
v. Calculation of heat conduction capability of heat-driven cooling technology.
vi. Optional: Calculation of the time series of the heat process to each time of the year, based on a simulation of the building.
vii. Sizing of solar thermal system and, if necessary, of the heat storage tank in order to cover completely (or partially), the thermal conduction capacity. Drawing of the auxiliary heating system, if considered. At this point, we shall compare the several configurations of existing systems by using simulations, taking into account that this only makes sense if we carry out point vi). If we planned a solar facade system or one that partially overshadow the facade, it is possible that we have to recalculate new values regarding cooling/heating load, in accordance with point i).
viii. Calculation of all the necessary energy and water consumption of the entire system.
ix. Calculation of the solar system and the auxiliary heating system costs, according to point vi). It shall be taken into account both the selling price to the consumer and the unit price of electricity and heat.

[30] Energia Solar Térmica, Manual sobre tecnologias, projecto e instalação, Instituto Superior Técnico, Janeiro 2004

x. Calculation of costs associated with the entire system.

xi. If the calculated costs are not acceptable, it is recommended to repeat steps iii) to vii).

xii. In addition to this technical and economic approach, it is also important to take into account the primary energy savings achieved when designing the system.

In order to obtain a successful system, it is quite important to work together with professionals with experience acquired in this area. We'll obtain better results if we use simulation software that allows us to describe both the building and the technology associated with the system (including the solar thermal system)

2.4.1 Planning and sizing

When planning a system, it is important to have an accurate record of site conditions. Part of this record includes a clarification of all the details that are important for planning and installation, to data collection from the building and regarding hot water consumption and heat needed by the building. It is then important to draw a sketch with all the important details required for the preparation of the proposal.

When preparing a proposal, we shall take into account the following topics:

- Local restrictions
- To set the shadow effect in the collectors due to the trees, the building itself or other buildings, or to access the shadow effect in the collector's temperature sensor;
- To assure the best possibility of a favourable alignment of collector' surface;
- Set the shortest possible route between the collectors and the storage tank;
- Take into account the specific requirements of the building;
- To use and fulfill checklists;
- To access the need for safety measures (.e.g. security equipment, security areas…);
- To identify the possible/desirable type of collectors' installation (on the roof or over the roof);
- To identify the roof structure (tiles layered of concrete increase the installation costs);
- To identify the resistance characteristics of the roof;
- To set the best way of installing the pipelines (well insulated) and draw its passage lines on the roof;
- To take into account the existence of a chimney (namely its location on the roof and its network in building);
- To verify the existence of a central water heating boiler;
- To set a procedure for a storage tank installation (e.g. a 400l tank weights 145kg, is about 1,7m high and has a diameter of 0,6m);
- Location of the auxiliary heating system (integrated with the existing heating system);
- To set the type of electrical installation (main connections, grounding, control system);
- To verify the existence of a connection to the sewage network close to the storage tank;
- Installation of network, sensors' cables and even a solar storage tank (for a future installation).

2.4.2 Example

Evaluate the economic interest of installing solar hot water production in a municipal sports pavilion (in North Alentejo region, Portugal) with an average of 75 users per day during the week and 167 users per day on weekend, which corresponds to an annual heat load of 49.079 kWh.

The solar radiation at the site (kWh/m^2) is shown in the following table:

Table 2: Solar radiation in kWh/m^2 in North Alentejo region

Month	Horizontal Solar Radiation [kWh/m2]	Tilted solar radiation (south azimuth, 40° inclination) [kWh/m2]
January	69	103
February	83	108
March	128	137
April	159	145
May	203	159
June	219	154
July	238	179
August	214	186
September	156	160
October	111	135
November	75	109
December	61	92
ANNUAL	**1.716**	**1.668**

The following table illustrates the yearly distribution of the thermal energy required to meet the needs of the above municipal sports pavilion:

Table 3: Thermal Energy required [kWh] for the operation of the municipal sports pavilion in North Alentejo region

Month	Thermal Energy required [kWh]
January	4.081
February	3.767
March	4.186
April	4.081
May	4.081
June	4.081
July	4.186
August	4.081
September	4.186
October	4.081
November	3.977
December	4.291
ANNUAL	**49.079**

Simulation:

It is considered as the base value of investment in solar thermal systems the average value of 1.000 €/m^2.

According to the simulation results carried out, the solar thermal system to be installed in the municipal sports pavilion should be supported by a solar collectors' area of about 30 m^2 with an investment of approximately 30.000 €.

Although the costs of operation and maintenance (O&M) are variable, can be estimated on average by 1% per annum of the total investment, i.e., corresponded to about 300 € per year.

Thus, we conclude that the total investment will be approximately 30.000 €.

Currently the installation uses electricity for water heating.

The annual thermal energy required for both devices, as mentioned above, is approximately 49.000 kWh, which corresponds to an annual cost of 6.300 €.

The simulation was performed assuming the installation of two water tanks with a capacity of 1.500 L each.

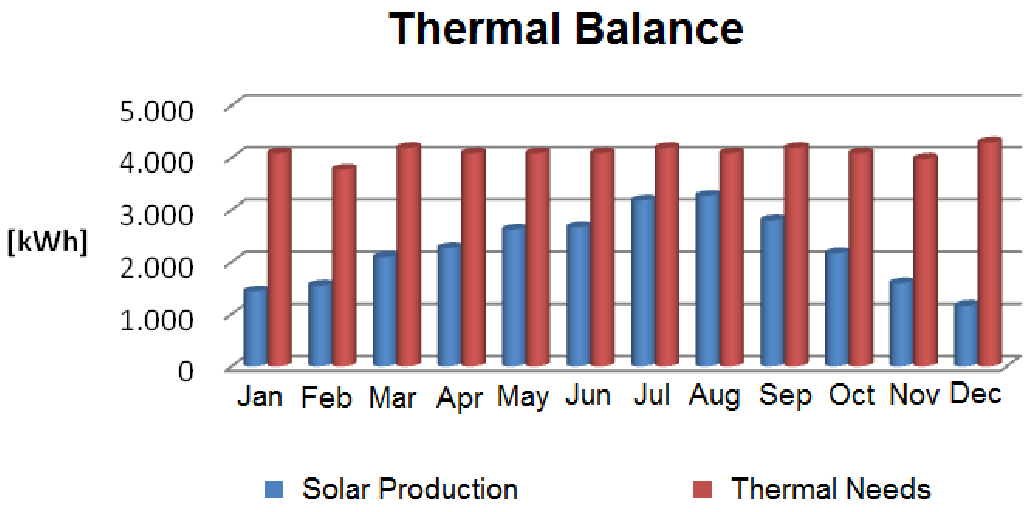


Figure 14: Thermal balance[31]

Table 4: Main results to obtain with the implementation of the solar thermal systems

	Main Data/Results
Reduction in energy costs for heating water	55%
Lifetime of solar thermal systems	20 years
Initial investment	30.000 €
Yearly maintenance and operation costs	1% of the investment
Solar fraction of the solar system	55%
Overall performance of the scaled system	63%
Payback period (with no subsidies)	8 years

In the case of a subsidy the payback period is, obviously shorter.

[31] www.areanatejo.pt

2.5. USEFUL RESOURCES

> Energia Solar Térmica, Manual sobre tecnologias, projecto e instalação, Instituto Superior Técnico, Janeiro 2004
> P. Coroyannakis, T.Tsoutsos, Z. Gkouskos, S. Ruginetti, S. Castaldo “Solar Cooling. Overview and Recommendations”, pp 36, European Commission, DG Energy and Transport, 2009 (GR, EN, IT)
> www.estif.org/st_energy/technology/introduction/
> www.solarge.org/index.php?id=2
> www.estif.org/solarkeymarknew/
> www.cres.gr/kape/pdf/download/HIGH%20COMBI_brochure.pdf
> www.solarordinances.eu/STODatabase/tabid/60/Default.aspx
> elle-kilde.dk/altener-combi/index.htm
> M.Delorme, R.Six, D.Mugnier, J.Y.Quinette, N.Richler, F.Heunemann, E.Wiemken, H.Henning, Th.Tsoutsos, E.Korma, G.Dall’O, P.Fragnito, L.Piterű, P.Oliveira, J.Barroso, J.R.Lopez, S.Torre-Enciso, “Solar Air-conditioning Guide” (ALTENER, 2004)
> www.nvenergy.com/brochures_arch/conservation/heatingcollectors.pdf
> www.renewableenergyworld.com/rea/tech/solar-energy/solarprocessheat
> www.estif.org/fileadmin/estif/content/projects/prosto/downloads/prosto%20brochure.pdf
> www.ecoarchitects.gr/research_docs/1171236197.pdf

3. ELECTRICITY PRODUCTION FROM PV

Drafted by TUC

According to ‘Europe’s growth strategy’ the EU countries aim to increase the share of renewable energy sources (RES) to 20% of the EU’s **gross final energy consumption** until 2020. Energy production from PV can play a significant role to the fullfilment of this goal.

Photovoltaics generate electricity from sunlight. The electricity can then be sold to the grid or used on the spot. When designing a photovoltaic system location, orientation and inclination, as well as temperature and shadowing should be taken into account, as they are factors that affect the system’s efficiency.[32]

Table 5: Advantages and disadvantages of PV[33]

+	-
Clean- green energy	Electricity production depending on weather conditions
No harmful GHG emissions during operation	Additional equipment is required to convert direct electricity (DC) to alternative electricity (AC)
Electricity production even in isolated locations - off grid	For continuous supply batteries are also necessary
Suitable for smart energy networks	In case of land-mounted-PV, large areas should be occupied for at least 15-20years
Initial costs are expected to continue reducing the following years	Solar panels efficiency levels are relatively low in comparison with other RES
Low operating and maintenance costs	PV panels are very fragile and thus insurance costs necessary
Totally silent during operation	

[32] PVTRIN- Installing Photovoltaics, Practical aspects for installers
[33] www.renewableenergyworld.com/rea/blog/post/2012/12/advantages-and-disadvantages-of-solar-photovoltaic-quick-pros-and-cons-of-solar-pv

3.1. THE PHOTOVOLTAIC EFFECT AND HOW SOLAR CELLS WORK

A photovoltaic system consists of cells that use layers of semi-conducting material to convert solar radiation into electricity. When solar radiation reaches the cell it creates an electric field across the layers, causing electricity to flow.

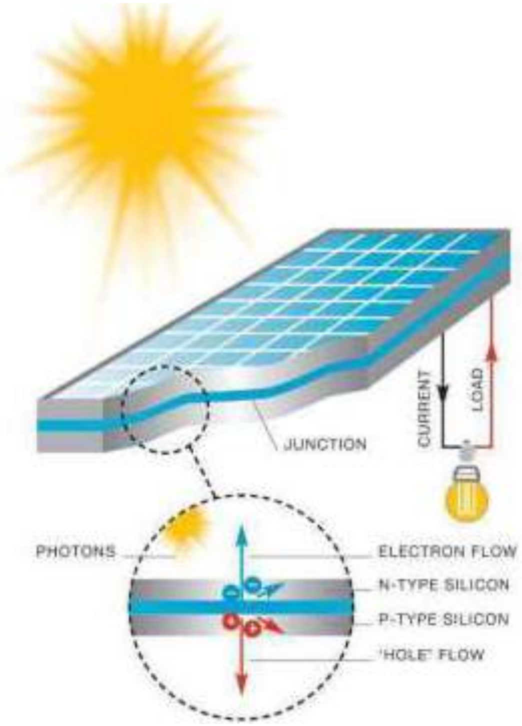


Figure 15: The photovoltaic effect (source: EPIA)[34]

3.1.1. PV technologies

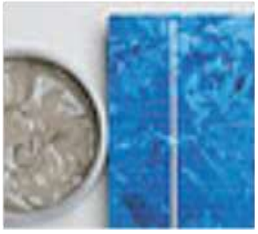
The most commonly used cell types are mono-crystalline, multi-crystalline and thin film.

Crystalline cells are made of a two-layer semiconductor with a screen-printed metallic network to collect the electrical current. To increase their generated voltage they are joined together inside a protective, highly transparent glass to create modules. Modules with crystalline cells have a high efficiency and long life.

Thin film modules are created by the deposition of a thin layer of semi-conductor onto a surface (glass, metal, flexible plastic etc.). Thin film modules have lower efficiency than crystalline cells but they are cheaper because they require less semi-conductor. Furthermore, they can easily be integrated on building materials and therefore they have a lot of applications.[35]

[34] PVTRIN Training course – Handbook for Solar installers
[35] PVTRIN- Installing Photovoltaics, Practical aspects for installers

Table 6: Comparison of different mature PV technologies[36]

Comparison of PV technologies			
Type	Monocrystalline	multicrystalline	thin film
Appearance	 [37]	 [37]	 [37]
Efficiency	11-19%	11-16%	4,5-12%
Surface per kWp	5,5-9 m^2	7-9 m^2	9-25 m^2

3.1.2. PV System – Components and types

The main components of a PV system are:

- PV modules that collect the sun
- Inverter that transforms direct current (DC) to alternate current (AC)
- A set of batteries for stand-alone systems
- Support structures to orient the PV modules toward the sun

3.1.3 Life Cycle: Design – Installation – Performance – Maintenance – Recycling

Through a **life cycle assessment** (LCA) the **energy payback time** (EPBT) of a PV system can be calculated. The EPBT is the time that the system has to be on operation, in order to compensate for the energy consumed for its production. The EPBT is an important factor that determines the sustainability of PV.

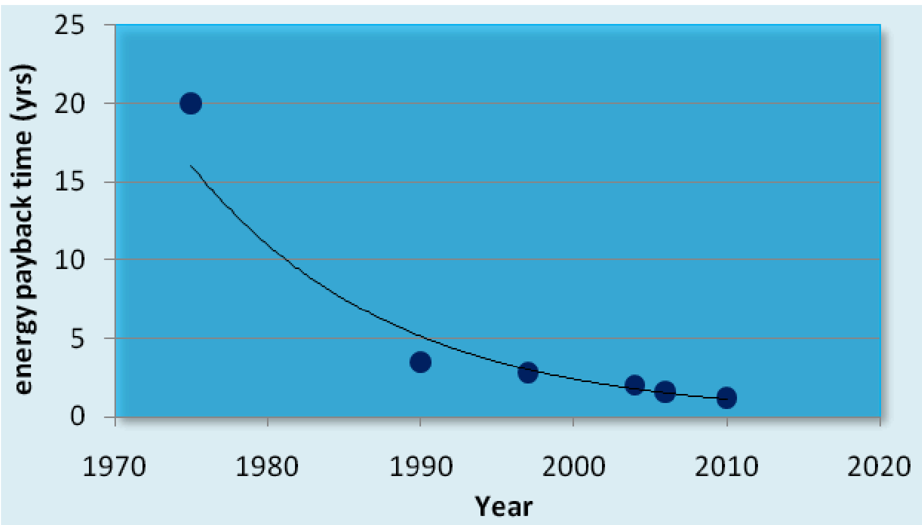


Figure 16: Historic trend in energy payback time of crystalline silicon PV modules[38]

[36] Hellenic association of photovoltaic companies 'Photovoltaics – A practical technical guide', 2013
[37] PVTRIN- Installing Photovoltaics, Practical aspects for installers

The life cycle of a PV system starts from the **design** stage. The design should take into consideration some important parameters:

- Correct choice and matching of components should be made.
- Shading of the modules, from each other or from other obstacles, must be avoided as this makes a big impact on the performance of a PV system.
- Both the modules and the inverters should be designed to be sufficiently ventilated to achieve a maximum in performance.
- In case of stand-alone systems the designer must determine the demand for energy, estimate generated energy and determine the storage system.
- The optimum orientation is south and the inclination angle is Latitude-10° [39]

The **installation** of the system should be made from qualified staff, according to the design considerations and the manufacturer's recommendations. Special attention should be paid to the stability of the existing structure with the additional loads and also to the grounding of the system.

Figure 17: Shading[39]

The good **performance** of the PV system throughout its lifetime can be assured with an appropriate **maintenance**. In field inspections, environmental and electrical measurements in a regular basis, cleaning of the modules and prevention of new shadows, mainly from vegetation are very important. Monitoring of the system is also advisable, in order to predict the behaviour of the system and determine in advance possible failures or degradation.

The final stage in the life cycle of the PV system is **recycling**. Both thin-film and silicon modules contain materials (glass, aluminum, a variety of semi-conductor materials) that can be recovered and reused in new products. Recycling not only benefits the environment by reducing the volume of waste, but it also helps to reduce the amount of energy required to provide raw materials and therefore the costs and environmental impacts of producing PV modules.[39]

[38] www.epia.org/index.php?eID=tx_nawsecuredl&u=0&file=/uploads/tx_epiafactsheets/110513_Fact_Sheet_on_the_Energy_Pay_Back_Time.pdf&t=1395140415&hash=0541782614d40af0ce8fcb39c2cedcb9a8c2c846

[39] PVTRIN- Installing Photovoltaics, Practical aspects for installers

3.1.4 Benefits of the PV technology

PV technology unlike other sources of energy has a negligible **environmental footprint**. The energy for its manufacturing is recouped by the energy costs saved over one to three years. PV systems have a typical lifetime of 20-25 years, so that every panel produces many times the power that it costs to be produced. PV systems can both be **connected to the grid** and work as a **stand-alone system** in remote areas. 40% of the total electricity demand by 2020 can be covered if the suitable building roofs and facades in EU 27 are covered with PV.[40]

Special characteristics of photovoltaic technology that differentiates them from other RES technologies:

- Greenhouse gas emissions and noise free during operation
- They can be located on the roof or integrated in building elements to minimize aesthetic disturbance
- They need minimum maintenance
- Reliability, 20-30years durability
- They are connected to each other delivering different capacity outputs
- They can be combined with other energy sources creating hybrid systems[41]

PV is an increasingly competitive choice in many EU/MED regions. Grid Parity –the moment when electricity generated from solar photovoltaic is competitive against other sources– is in sight in many European countries for the residential and commercial consumers. As the PV PARITY Project results shows grid parity is achieved already, in 2012, in Germany, Southern Italy, Netherlands and Spain; to be followed by Northern Italy, Portugal and Austria by the 2014, and then progressively by other countries (see figure below). Net-metering and the promotion of self consumption are support schemes of great importance for the achievement of PV competitiveness. With both instruments the production of solar electricity can be better linked to the direct consumption. The consumer produces electricity and becomes prosumer.

The PV PARITY has also proposed strategies and measures for supporting the PV sector after PV competiveness is reached, so as an increased PV penetration in EU electricity markets and grid will be accomplished at the lowest possible price for the community.[42]

[40] EPIA, Greenpeace, 'Solar Generation 6 – Solar photovoltaic electricity empowering the world', 2011
[41] T.Tsoutsos, I. Kanakis."Renewable energy sources, technology & environment", 2013
[42] www.pvparity.eu/

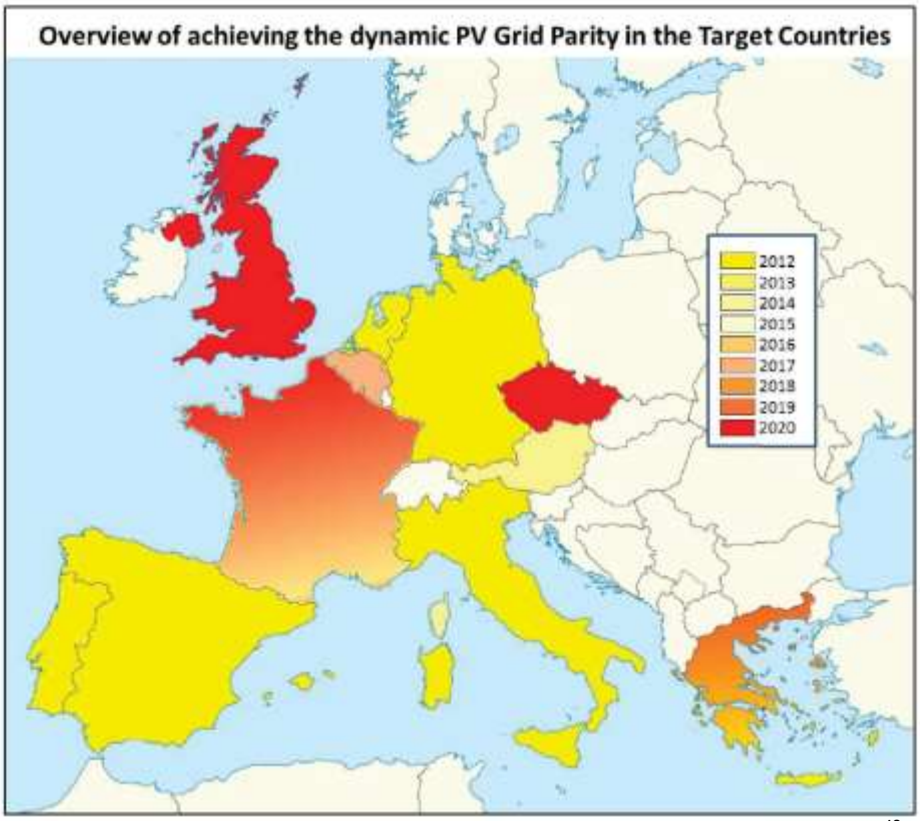


Figure 18: Overview of achieving PV Grid Parity in selective EU countries[43]

3.1.5 PV Installation alternatives

Photovoltaic power systems could be classified in different ways. Regarding their connection to the grid there is the possibility of **isolated** and **grid connected systems**. The first alternative is usually used for remote recipients. The second alternative aims on producing as much energy as possible. Depending on the local legal framework the entire production is exported to the grid and can be sold either in the same price (**net metering**) or at a different price (**feed-in-tariff**). Alternatively, energy production supplies the building's needs, and any excess production is fed into the grid. Regarding the method for capturing solar energy the systems are divided in the **sun-oriented fixed systems** and the **solar tracking systems** with one or two axis of movement for daily and seasonal tracking of the sun.

[43] PV Pariy Project - Definition of competitiveness for photovoltaics and development of measures to accompany PV to grid parity and beyond

Figure 19: Sun-oriented fixed system[44]

Figure 20: Solar tracking system with one or two axis[44]

Regarding their location PV systems provide the following alternatives, on the ground application, in building and street furniture and in transport.

3.2. PV ON BUILDINGS (BAPV AND BIPV)

The use of PV systems on buildings can be made as an addition of the PV modules on the roof or the façade, by using a metal structure, this is called a **Building Adapted Photovoltaic System** (BAPV). The PV system in this case is an independent structure used for generating energy. On the other hand **Building Integrated Photovoltaic System** (BIPV) has a dual function the role of the building element and that of producing energy. BIPV can be used in the building envelope to provide weather protection, heat insulation, sun protection, noise protection, modulation of daylight and security.[45] BIPV has until now a relatively low penetration in the PV market. Regarding to its potential the use of this technology should be encouraged.

BIPV can be part of the roof, which is the element of the building that has a lower shadowing probability and is often unused. Facades offer also several alternatives for PV integration such as curtain walls, double skin facades and rain screen systems. PV modules of different shapes can provide shadow when placed above windows or as an overhang.[46]

[44] PVTRIN- Installing Photovoltaics, Practical aspects for installers
[45] SUNRISE project, 'Building integrated photovoltaics – A new design opportunity for architects
[46] S. Roberts, N. Guariento, 'Building integrated photovoltaics-a handbook'

Figure 21: BIPV as shading elements[47]

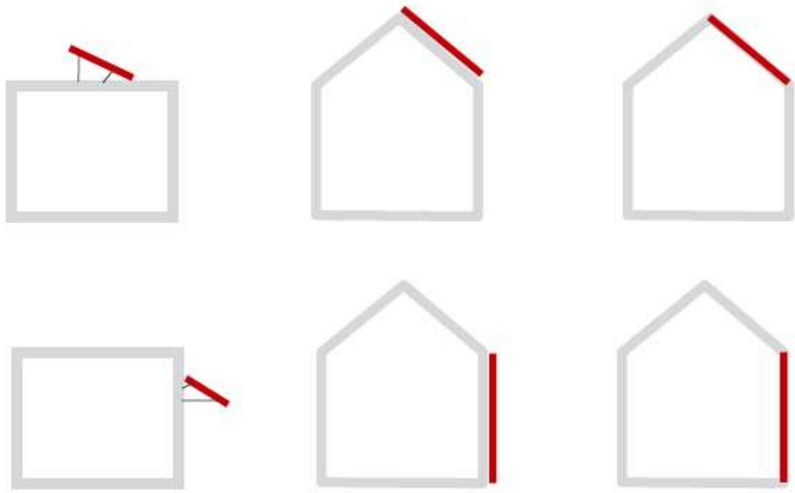


Figure 22: Alternatives on PV integration in buildings[48]

Table 7: Potential of producing energy by building integrated PV, Sunrise project/EPIA[49]

Potential for solar power in the EU-27 in 2020	
European population	497.659.814
Total ground floor area	22.621 km2
Building-Integrated solar potential (roofs and facades)	12.193 km^2 or 1.425 TWh/a
Expected electricity demand	3.525 TWh/a
Potential share of electricity demand covered by building-inegrated PV	40%

[47] PVTRIN- Installing Photovoltaics, Practical aspects for installers
[48] Hellenic association of photovoltaic companies 'Photovoltaics – A practical technical guide', 2013
[49] EPIA, Greenpeace, 'Solar Generation 6 – Solar photovoltaic electricity empowering the world', 2011

Best practice examples

BIPV installed in the building of Chemical Engineering School of the National Technical University of Athens. The project has a total capacity of 50kWp and it was built in 2001. The modules are distributed along the facade of the building with various inclinations and orientations.[50]

Figure 23: Integration of PV in the building of Chemical Engineering Dept., NTUA

BAPV plant on the roof of Athens' trolley main station. The project has a total capacity of 19,95kWp and covers a roof area of ap.100m^2. It was built in 2009 with a total cost of 80.500€, partially financed from a state subsidy. It produces 29,50MWh/a and feeds into the grid for 0,45€/kWh.[51]

Figure 24: BAPV at Athens trolley main station roof [52]

In the old historical European cities there is a large building stock of historic buildings that waste large amounts of energy and suffer the threat of demolition. By retrofitting these buildings according to the proposed approach, the energy demand will be reduced and fossil fuels replaced. The European initiative **new4old** worked towards the integration of new technologies in historical buildings and came out with the following recommendations.[53]

[50] pvcert.gr/assets/media/PDF/Publications/Other%20Publications/39.BIPV%20BEST%20PRACTICES.pdf
[51] PVTRIN – Design common professional framework and training methodology, List of good examples of PV installations, 2012
[52] PVTRIN – Design common professional framework and training methodology – List of good examples of PV installations, 2012
[53] www.new4old.eu/

TIPS

When retrofitting an historic building, regard should be given to:

- Ensuring that the building's structure and function is well understood
- Minimum disturbance of the existing fabric
- Reversing the changes easily without damaging the existing fabric (especially changes to services)
- Introducing modern materials: new materials and techniques designed for new construction should be treated with caution

[54]

3.3. IMPLEMENTING A PV PROJECT

Once the project location, PV technology and size are determined the project is ready to be implemented. There are several steps that need to be followed for the implementation of a PV project.

The design stage has to be finalised, in this stage the parameters mentioned above need to be taken into consideration. From this stage a good estimation of the initial cost as well as the amortization time will be available. If there is already a sufficient existing budget the problem is solved, either wise an external funding or an innovative financing plan in accordance to the European framework needs to be considered. Finally, the system's installation begins following the design consideration and safe working practices. The system will be afterwards connected to the grid (connected system) or to the storage system (stand-alone system) and it is ready to start working.

3.3.1 Economics and environmental issues

The financial aspect of a PV project involves both the income of a feed in tariff and the costs for equipment, project development and maintenance. The **total installed cost** of a PV system varies between different countries and regions according to the maturity of domestic market, the local labour, manufacturing costs and a range of other factors.[55]

Table 8: Typical cost and performance values for solar PV systems[56]

	Module cost, factory gate or spot (€/W)	Installed cost (€/W)	Efficiency (%)	Levelised cost of electricity (€/kWh)
Residential				
c-Si PV system	0,74-0,90	2,77-4,22	14	0,18-0,47
c-Si PV system with battery storage	0,74-0,90	3,64-4,37	14	0,26-0,52
Utility-scale				
Amorphous Si thin film	0,61-0,68	2,62-3,64	9	0,19-0,43

[54] www.new4old.eu/guidelines/4_Technical%20Guidelines%20For%20Building%20Designers.pdf
[55] www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-SOLAR_PV.pdf
[56] /www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-SOLAR_PV.pdf

The price of modules and inverters has fallen significantly the last few years. This is due to economies of scale based on the extended use of the PV technology. To estimate the cost of a PV system the total lifetime of the system should be considered (20-25 years). With a rough estimation, the average value for a grid connected system is approximately 1,500€/kWp including the replacement of the inverter in 12-15years.[57]

An indicator of the environmental impact of a PV project is the **energy payback time** (EPBT), which is the time needed for a system to generate the energy that was consumed during its life-cycle (production, installation, disassembling and recycling).

The **emissions of greenhouse gases** is also an important issue and can be estimated by conducting a detailed **Life Cycle Assessment** (LCA), which includes extraction and purification of raw materials, manufacturing processes, installation, operation and recycling or disposal of waste products.

In the case of ground mounted PVs, **land use** is also an important issue, although PV installations have the lowest land occupation compared to other RES or coal and nuclear fuel cycles.

Regarding the **raw materials** used for the production of PV panels, silicon, the most common material is a nontoxic element. However, several hazardous chemicals are used in the production process, such as solvents like nitric and hydrofluoric acid or solders containing lead. **Decommissioning** and **recycling** of PV systems ensure that hazardous materials are not released to the environment and reduce the need for virgin raw materials.

3.3.2 Legislative framework and financing opportunities

Photovoltaics are implemented in a complex framework of regulations, funding arrangements and planning policies. EU has designed a series of policies in order to reach the ambitious 20-20-20 targets until 2020. The most important of these are:

- Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC[58]
- Action Plan for energy efficiency: Realising the Potential (2006)[59]
- A strategy for competitive, sustainable and secure energy (2010)[60]
- Energy Efficiency Plan 2011[61]

There are several financing opportunities for the implementation of a PV project. Many governments have provided in the past capital grants or FITs to encourage the investment in PV systems. In addition, feed-in tariff is a successful measure that promotes self-financing of private or public sector. Finally, the practice of leasing of a roof or a ground area for building a PV plant is an alternative that benefits both the owner of the building and the operator of the plant.[62]

[57] PVTRIN training course – Handbook for Solar Installers'
[58] eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0028
[59] ec.europa.eu/energy/action_plan_energy_efficiency/doc/com_2006_0545_en.pdf
[60] eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0639:FIN:En:PDF
[61] eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0109:FIN:EN:PDF
[62] B. Gaiddon, H. Kaan, D. Munro. 'Photovoltaics in the urban environment – Lessons learnt from large-scale projects. 2009

3.4 CONCENTRATED SOLAR POWER

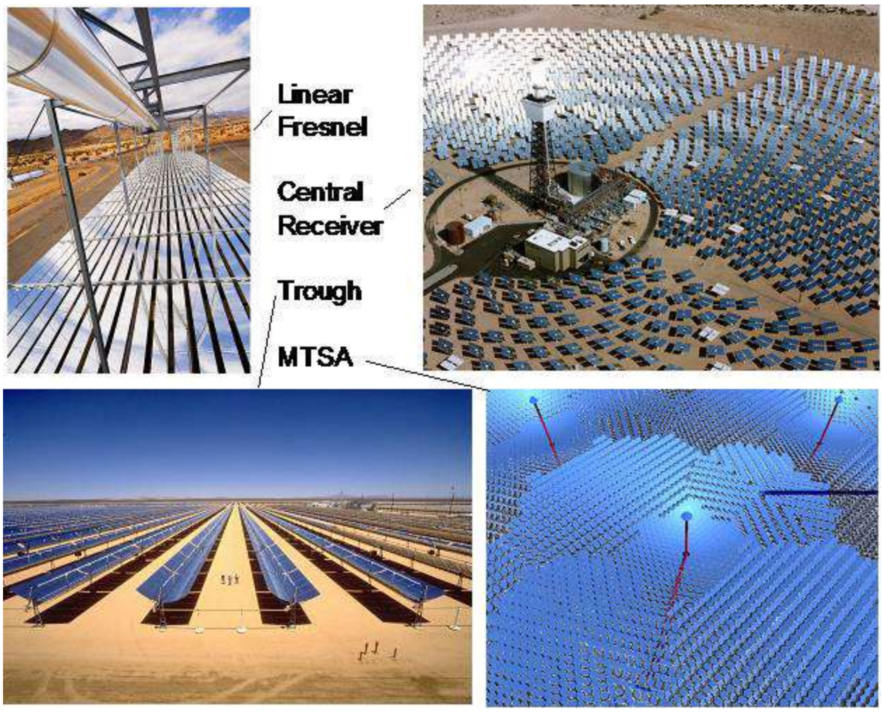


Figure 25: Land use of different concentrating solar collector concepts[63]

Concentrated solar power (CSP) concentrates solar energy in a focal spot and produces electricity. Solar energy is used to heat up a fluid to the point of producing steam that will activate the turbines and produce electricity. There are several techniques to achieve the focusing of sunlight such as parabolic trough, dish or central tower receiver. Parallel with the electricity production, heat is also produced in a CSP plant that increases the efficiency of the system.[64] This system requires clear skies and strong sunlight in order to perform well. Some **critical aspects** regarding this technology is that it occupies a considerable area, consumes a huge amount of materials and water, both for the electricity production and the cleaning of the plant and its conversion efficiency should be further raised.[65]

Investment cost for the implementation of a CSP plant range from 3,1 to 6,1 €/W depending on several factors, such as the cost of labour, land and the technology used.[66] CSP plants are large scale projects that require an initial investment of some million €. Therefore, there are often funded or co-funded by EU.

[63] www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/projects/reaccess/DNI-Atlas-SP-Berlin_20090915-04-Final-Colour.pdf
[64] ec.europa.eu/research/energy/eu/index_en.cfm?pg=research-csp
[65] ec.europa.eu/research/energy/eu/index_en.cfm?pg=research-csp-background
[66] International Energy Agency, Renewable energy essentials: Concentrating Solar Thermal Power. OECD/IEA, 2009

Table 9: Main advantages and disadvantages of CSP systems

+	-
CSP systems can be established in desert locations, where no human and wildlife lives	It is not applicable in small scale systems
huge amounts of electricity or thermal energy can be produced	Expensive transmission lines must be used to transport produced electricity, energy losses will also occur
	The system requires clear sky and strong sunlight to perform well

PS10 is the first solar thermal power plant based on tower and heliostat field technology that generates electricity in a stable and commercial way is located at Sanlucar la Mayor, southern Spain. It was co-funded by the EU with a contribution of 5 million in a total of 16.7 million €. It has a capacity of 11,02 MW, occupies 55ha (550.000m^2) and gives an annual electricity production of 23GWh.[67]

Figure 26: Aerial view of PS10 tower plant[68]

[67] European Commission, Concentrated Solar Power from research to implementation, 2007
[68] European Commission, Concentrated Solar Power from research to implementation, 2007

3.5 USEFUL RESOURCES

Information – Technical aspects

> www.pvresources.com – International information on PV technology and news
> www.iea-pvps.org – Publications and documentation on Photovoltaic Power Systems
> www.eupvplatform.org/ - European photovoltaic technology platform, information on PV latest developments and publications
> www.solarbuzz.com – Solar Market Research and Analysis
> www.yoursunyourenergy.com – Benefits of photovoltaics in different sectors
> www.pvparity.eu/

Legislation & finance

> www.pvlegal.eu – Legislation regarding implementation of PV projects
> www.iec.ch – International standards and conformity assessment for all electrical, electronic and related technologies
> ec.europa.eu/easme/finance-for-sustainable-energy-in-H2020.pdf – Horizon 2020 Finance for sustainable energy
> ec.europa.eu/research/horizon2020/pdf/work-programmes/secure_clean_and_efficient_energy_draft_work_programme.pdf – Draft Horizon 2020 Work Program 2014-2015
> www.semi.org/eu/node/8516 - Public funding
> europa.eu/legislation_summaries/energy/renewable_energy/index_en.htm – European legislation for renewable energy

Guides & best practices

> www.pvtrin.eu – Training of Photovoltaic Installers in Europe
> www.seai.ie/Publications/Renewables_Publications_/Solar_Power/Best_Practice_Guide_for_PV.pdf - Best practice guide for Photovoltaics
> www.epa.gov/oswercpa/docs/best_practices_siting_solar_photovoltaic_final.pdf - Best practice for siting Solar Photovoltaics on Municipal Solid Waste Landfills
> www.bre.co.uk/filelibrary/pdf/rpts/Guide_to_the_installation_of_PV_systems_2nd_Edition.pdf - Photovoltaic in Buildings – Guide to the installation of PV systems 2nd Edition
> pvcert.gr/assets/media/PDF/Publications/Informational%20Material/Installing%20PV-Practical%20guide/65.pdf – Installing Photovoltaics, practical aspects for installers
> pvcert.gr/assets/media/PDF/Publications/Other%20Publications/41.BIPV_FOR%20ARCHITECTS.pdf – Building integrated Photovoltaics, a new opportunity for architects
> www.pvsunrise.eu/pv-diffusion-in-the-building-sector-bipv/introduction.html - Project that aims to improve the cooperation between the photovoltaic and the building sector
> pvcert.gr/assets/media/PDF/Publications/Other%20Publications/40.BIPV-overview_of_existing_products_PVSUNRISE.pdf – Building integrated photovoltaics: an overview of the existing products and their fields of application
> www.resel.tuc.gr/images/stories/docs/13.BIPV%20BEST%20PRACTICES.pdf – BIPV, technical solutions and best practices
> www.islepact.eu - Sustainable energy actions for islands

- > http://www.new4old.eu//guidelines/3_Introduction%20Technical%20Guidelines.pdf – Retrofitting of historical buildings

Tools & software

- > re.jrc.ec.europa.eu/pvgis – Photovoltaic Geographical Information System
- > www.meteonorm.com – Meteorological software
- > www.sunearthtools.com/ - Tools for consumers and designers of solar
- > PV*SOL (valentin-software.com) – Planning software for photovoltaic systems

Associations

- > www.estelasolar.eu/ - European solar thermal electricity association
- > http://www.epia.org/home/ - European photovoltaic industry association
- > www.energy-cities.eu/cities/case_studies.php?id_keyword=002003008&id_country=&id_city=&id_pop=&id_lang= - The european association of local authorities in energy transition
- > www.bipv.ch/ - Swiss BIPV Competence Centre

Database

- > www.pvdatabase.org – Urban scale photovoltaic systems database
- > www.enf.cn/database/panels.html - Database of companies that manufacture solar photovoltaic panels
- > www.posharp.com/photovoltaic/database.aspx - Database of companies that manufacture solar photovoltaic panels
- > www.nrel.gov/pv/performance_reliability/failure_database.html - Photovoltaic module field failure database
- > regions202020.eu/cms/inspiration/resources/ - Database of resources regarding regional and local sustainable energy communities in the process of developing sustainable energy action plans (SEAPs) and projects (SEPs)

Guidance for Local authorities

- > www.covenantofmayors.eu/actions/benchmarks-of-excellence_en.html - Convenant of Mayors committed to local sustainable energy action plans
- > www.covenant-capacity.eu/ - Capacity building of local governments to advance local climate and energy action
- > toolbox.climate-protection.eu/ - Guidance for local governments and their partners : Toolbox of methodologies on climate energy
- > www.pvcycle.org/ - PV recycling
- > eu-smartcities.eu/ - Smart Cities and Communities
- > ec.europa.eu/energy/intelligent/projects/en/projects/enerintown – Monitoring and Control of Energy Consumption in Municipal Public Buildings over the Internet (ENERINTOWN)
- > ec.europa.eu/energy/intelligent/projects/en/projects/towards-cl – Towards Class A – Municipal Buildings as Shining Examples (TOWARDS CLASS A)

4. WATER TREATMENT USING SOLAR ENERGY

Drafted by HEIS

Generally, municipal water and waste water systems / treatment plants are great energy consumers. Energy consumption varies depending on treatment technology which often depends on pollution control requirements and number of pumping stations needed.

Electricity is a critical input for delivering municipal water and wastewater services and these costs are usually between 5 to 30 percent of total operating costs among water and wastewater utilities (WWUs) worldwide. These energy costs often contribute to high and unsustainable operating costs that directly affect the financial health of WWUs. Based on the review of existing literature, most of the commonly applied technical measures regarding EE issues at WWUs generate 10 to 30 percent energy savings per measure and have 1- to 5-years payback period[69].

Regarding the issues mentioned above, municipalities could, as first step, analyze and calculate how much energy are consuming water and waste water systems and plants and perform energy audits on these systems. This means to analyze and to establish which the main energy consumers are and to try to find solution and reduce energy consumption. Municipalities could also make their own energy efficiency strategies and energy management plans for improving energy efficiency and consider use of renewable energy sources (sun-solar panels, wind-wind farms water-hydropower plants etc.) in the future. In this way, municipalities would reduce energy consumption, save money and minimize dependence on traditional energy sources. Namely, by tracking energy usage, benchmarking, and making operational improvements, all municipalities can begin their efforts to reduce energy use and realize financial savings. Understanding and improving of energy pattern and efficiency opportunities is the best practice that municipalities can adopt.

4.1. ENERGY CONSUMPTION IN MUNICIPALITY WASTE WATER TREATMENT PLANTS

Energy represents a substantial cost to wastewater utilities, because it is required for all stages in the treatment process, from the collection of sewage to the discharge of the treated effluent.

Main energy consumption in Municipal WWTP refers to the following[70]:

- Energy consumption in building - lighting, heating, cooling, and ventilation systems,
- Energy consumption in treatment process - Mechanical Aerator, Centrifuge, Influent Pump, Blowers, Mixers, UV System (depending on type of treatment process).

[69] A primer on energy efficiency for municipal water and wastewater Utilities, Technical report 001/12, ESMAP, World BANK

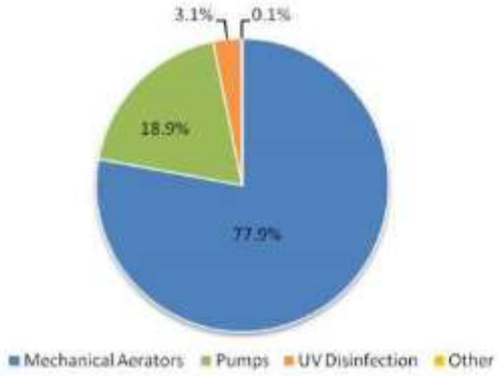


Figure 27: Typical WWTP energy consumers[70]

Data on energy consumption given in Figure are the results of energy audit of the WWTP in Crested Butte, Colorado USA, as part of the Energy Efficiency Strategies for Municipal Wastewater Treatment Facilities[70]. In the case Study are presented best practices of WWTP energy audit which aim was to show the share of energy that is used in every part of a WWTP and strategies for improving energy efficiency in municipal WWTP. As you can see from Figure the biggest consumer of energy in WWTP process is aeration (mechanical aerators). Aeration is the addition of oxygen to wastewater. Aeration chambers are used in packaged and extended aeration plants to provide an aerobic environment for the bacteria breaking down the organic matter[71]. Also, use of anaerobic digestion (carbon-neutral technology) to produce biogas can be used for heating, generating electricity, mechanical energy, or for supplementing the natural gas supply. Wastewater treatment facilities use anaerobic digesters to break down sewage sludge and eliminate pathogens in wastewater[72].

In the table below are presented strategies that can be adopted by municipal waste water treatment facilities in order to improve energy efficiency and to use available renewable energy sources[70].

Table 10: Energy Efficiency Strategies for Municipal WWTPs[70]

Focus efforts for energy savings	
Process energy	Focus on bigger energy consumers at WWTP
Operational controls	Tailor operations to meet seasonal and daily changes
Quality vs. Energy	Balance water quality goals with energy needs
Repair and replacement	Consider equipment life and energy usage to guide repair and replacement

[70] National Renewable Energy Laboratory, Energy Efficiency Strategies for Municipal Wastewater Treatment Facilities, January 2012
[71] water.me.vccs.edu/concepts/staeration.html
[72] www.c2es.org/technology/factsheet/anaerobic-digesters

After energy efficiency, implementation of renewable energy technologies (i.e. use of solar panels) is another effective way to save money by reducing energy purchases in WWTPs and to reduce dependence on traditional energy sources. There are some examples of installation of solar panels and use of biogas for production of electricity to cover the needs of WWTPs (see Chapter 4.3).

4.2. ENERGY CONSUMPTION IN WATER PUMPING AND MANAGEMENT

Regarding the water pumping and management, the main energy consumption activities in water systems are the following: raw water extraction (pumping, building services), treatment (mixing, pumping, water sludge processing and disposal, building services, other treatment processes), clean water transmission and distribution (pumping).

Energy efficiency in water pumping activities and management can be provided through identifying old pumps that no longer perform on their pump curves, determining energy costs for different operating levels to find the best operational strategy, detecting pumps that no longer match well with the distribution system, determining how to take advantage of time-of-day energy pricing, purchasing the right pumps etc.

Regarding the fact that consumption of energy in water pumping and management is designed and predicted as described before, installation of solar panels has great advantages over other renewable energy sources in this field. Namely, the main advantage of using solar energy is that small solar panels can be installed on many locations for pumping water (water sources, reservoirs, administrative buildings, etc.). In this way, the necessary investment can be partially realized in planning period, and one part of the savings can be invested somewhere else. As an example, if the pumping of water is obtained at the water source by using solar energy, savings can be invested in buying and installing new solar panels on pumping stations.

Water pumps on solar energy are the same as regular electricity driven pumps, and the only difference is the source of electricity. These pumps are plugged in into a solar panel which works by absorbing light from the sun and through the chemical reaction produces electricity. The basic characteristics of these pumps are: zero operating cost, ease of maintenance, user friendly, long life, safe to operate, environmental friendly etc[73]

[73] www.kavitasolar.com/solar-water-pumps.html#solar-water-pump

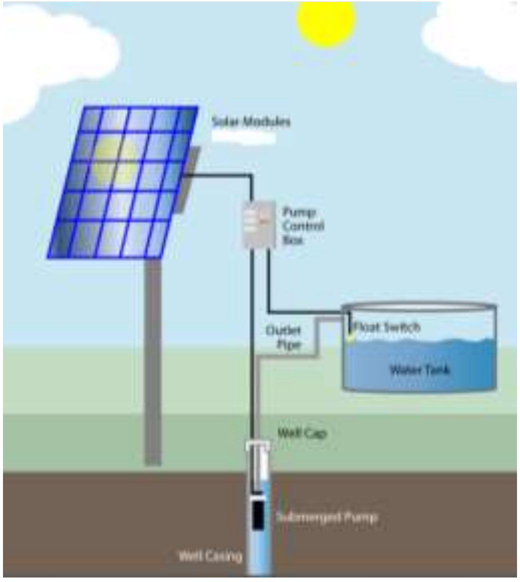


Figure 28: Simple scheme of pump station powered by solar energy (left)[74] and example of pump station (using solar energy)-right[75]

There are some examples of smart use of solar energy in water treatment works. For example, in Scotland were installed solar panels to help reduce energy costs at six water treatment works. Each of the panels are capable of generating up to 0.2GWh of electricity per year providing 25 percent of the power needed to run the water treatment works (some of the panels are installed on the roof and some are self-standing)[76].

Figure 29: Use of solar panels in water treatment works in Scotland[76]

[74] www.theenergyconscious.com/solar-water-pumping.html
[75] www.solar-stream.com/
[76] www.renewableenergymagazine.com/article/scottish-water-installs-solar-panels-at-water-20140306

4.3. BEST PRACTICES AND EXAMPLES

Benefits of using solar energy for WWTPs and water pumping and management are:

- Sustainable energy source: the sun is an infinite resource;
- that generates zero pollution during operation;
- Carbon-free electricity, corresponding to peak demand periods;
- Reduced electricity bills;
- Reliable performance;
- Minimal maintenance;
- Fast commissioning;
- Flexibility and scalability of systems;
- Efficient land use;
- Low risk.

Some of the examples and best practice of using solar energy in WWTPs with basic characteristics are given bellow:

1. The City of Boulder in Colorado (USA)

WWTP in Boulder (Colorado) is serving over 100.000 people and its energy consumption is app. 7.4 MWh annual electricity usage. It represented the city's largest single energy consumer, so the opportunity to reduce the plant's electricity costs was of a high priority. Within this project were covered 15–18% of its electricity load with clean power and the city realized savings of $43,000 in its first year of operation[77].

City of Boulder, Colorado

System	Fixed-Tilt
Nominal output	1.0 MW
Modules	4,452 modules, SOLON Blue 220
Annual energy output	1,553,000 kWh/a
Installation completed	QI/2010
Energy replaced	15 – 18%
Production over 20 years	28,957,776 kWh
Annual CO_2 savings	1,229 t/a

Figure 30: Example of good practice for using solar panels for WWTP in City of Boulder in Colorado USA[77]

2. City of Gresham in Oregon

City of Gresham (Oregon) wants to achieve the goal to make its wastewater treatment plant energy independent by 2014, by producing its electrical power onsite through a combination of cogeneration and solar power. The WWTP produces 50% of its energy by converting

[77] www.solon.com/us/Application_Sheets/SOLON_Solutions_for_Wastewater_Facilities.pdf

methane gas into energy and also purchases 18% of its electricity as renewable energy from wind farms in Oregon and about 7% from solar power (installed in 2010). The treatment plant is 75% sustainable[78].

Figure 31: WWTP in Gresham (Oregon) using renawable energy sources[78]

4.4. USEFUL RESOURCES

- www.energis.ba/
- www.energetska-efikasnost.ba/, accessed 03/2014
- www.sarajevo.ba/ba/stream.php?kat=466 accessed 03/2014
- www.nrel.gov/docs/fy12osti/53341.pdf accessed 03/2014
- ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2011/04/MDR0763Rp00013_Good-Practice_Final2.pdf accessed 03/2014

[78] greshamoregon.gov/city/city-departments/environmental-services/wastewater-division/template.aspx?id=4330

5. SOLAR ENERGY IN TRANSPORT

Drafted by Koprivnica

Green technologies and alternative propulsion systems became reality in almost all sectors of the transportation. Modern changes in traditional mobility systems are directed to make transport ecological, economical and sustainable. Green vehicles are powered by alternative fuels and one of the most effective solutions is the solar vehicle, an electric vehicle powered completely or significantly by direct solar energy. Only the energy provided from such a renewable source can result to a CO_2 neutral effect.

A real breakthrough of alternative propulsion systems can only be achieved by joint effort of national governments, industry and potential user group. Political decision makers at all levels should define clear and reliable political targets for the future and adapt taxation patterns to stimulate energy-efficient propulsion technologies in transport. Public authorities can take many complementary measures to foster the use of alternative vehicles: public charging stations, free parking in attractive inner-city areas, limited access for conventional cars, rotational funding schemes to avoid high interest rate for private investors etc. Such incentive measures are leading to energy autonomy in renewable energy supply for all households and businesses in municipality or region. Transformation of the transport system involves a great number of relevant stakeholders, and only by their intensive communication process, to spread knowledge and increase the motivation, new technologies can be implemented. [79]

5.1. ELECTRICAL VEHICLES[80]

An electrical vehicle is a transportation tool which reduces air pollution and greenhouse gas emissions, especially when it is using the electricity from renewable energy sources. They are propelled by one or more electric motors powered by rechargeable battery packs. An appropriate electrical vehicle can perform almost every task as a conventional one, ranging from personal mobility to goods transport. Generally, drivers quickly adapt to specific features regarding vehicle handling due to similarity with automatic transmission vehicles.

Existence of electrical cars was firstly recorded in the mid-19th century, when Robert Anderson invented the first electric carriage. In the early 20th century electric cars accounted for majority share in the total number of US cars. However, reduction of oil price, lack of suitable technologies and performance problems resulted to disappearance of electrical vehicles until the end of 20th century.

Nowadays, electrical vehicles are often closely connected to solar energy power. Contemporary vehicles are using solar energy in two different approaches, or combining them: directly installed photovoltaic cells convert sunlight into electricity to drive electric

[79] Renewable energies in Transport, Guidelines for decision makers - CO_2NeuTrAlp – CO_2 Neutral Transport in the Alpine Space
www.co2neutralp.net/docs/epaper/guidelines_dec_makers_english.pdf
[80] www.elen.hep.hr/El-vehicle-history.aspx
Renewable energies in Transport, Guidelines for Transport Professionals - CO_2NeuTrAlp – CO_2 Neutral Transport in the Alpine Space; www.co2neutralp.net/docs/epaper/guidelines_technicians_en.pdf
www.avere.org/www/staticAdminMgr.php?action=read&menu=1270804601
www.mnn.com/green-tech/transportation/photos/7-modern-solar-powered-vehicles/tindo-solar-bus

motor; or battery-powered electric vehicle that uses a solar array to recharge, which may be connected to the general electrical distribution grid. Both approaches are already developed on different types of transportation devices: solar buses, for free public transport service; electrical bicycles; PV trains; solar powered boats; solar powered airships or hybrid airships; solar powered spacecraft and space station.

Figure 32: Different type of electrical vehicles (solar car “Tokai Challenger”; “Vili Solar Train“, Hungary; “Tindo solar bus”, Australia; solar boat “Turanor Planetsolar”, solar plane “Solar Impulse”, International Space Station) [81]

There are two different types of hybrid vehicles: hybrid electric vehicle and plug-in hybrid electric vehicle. Hybrid electric vehicle is powered by both internal combustion engine and electric motor independently or jointly, doubling the fuel efficiency compared to a conventional one. A hybrid is designed to capture energy that is normally lost through breaking and coasting to recharge the batteries, which in turn powers the electric motor, without the need for plugging in. Plug-in hybrid vehicle has the ability, unlike other hybrid vehicles, to run on either electricity or internal combustion engine. It has larger batteries and can be recharged by plugging into an appropriate outlet.[82]

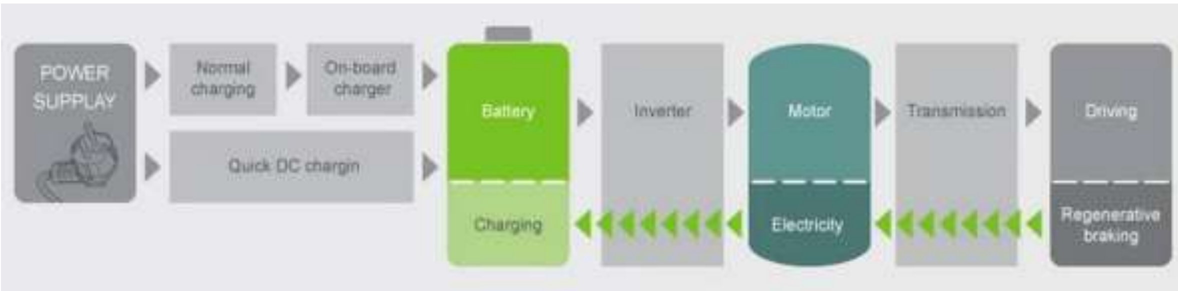


Figure 33: Schematic section of battery electric vehicle power system[83]

Prevalent are battery-powered electric vehicles. These vehicles are based on the system comprising of the charger, electric motor and energy stored in batteries, which are consisted of individual battery cells. Each cell is equipped with BMS (battery management system) for

[81] www.mnn.com/green-tech/transportation/photos/7-modern-solar-powered-vehicles
[82] Battery, Hybrid and Fuel Cell Electric Vehicles are the keys to a sustainable mobility, brochure www.avere.org/www/Images/files/about_ev/Brochure.pdf
[83] www.elen.hep.hr/EL-vehicle-definition.aspx

temperature and charge level control. Battery converts direct current to alternating which starts the engine. Important feature for city regime of “stop-go” driving is transformation of engine into generator when breaking and enabling charge of the battery. Duration and characteristics of battery depend on the type of lithium technology. Nowadays, system can stand up to 3.000 load cycles which makes it suitable for everyday usage. Over 90% of charging is done at home and at work-places. Public charging points, especially based on renewable energy sources, are stimulating the use of these alternative vehicles. There are two different approaches: fast charging, which may seem convenient, and slow charging, that sustains battery longevity.[84]

Table 11: Comparison of electric and internal combustion vehicle[85]

	+	-
Electricity vehicles	CO_2 emissions can be reduced by up to 40%. If electricity production was based on green power, the reduction could exceed 80%.	Higher price of electric vehicle and lower supply.
	Brakes, gear box and engine of electric vehicle require much lower and less costly maintenance.	Small number of charging facilities and long charging period of the battery.
	Increase of comfort due to production of far less roadway noise.	Compromised safety of other transport participants due to noise-free effect.
	Minimal energy losses, up to 10%, and possibility for energy storage.	Short distance range.
	Lower energy costs due to possibility of charging the vehicles from renewable energy sources.	Nowadays technology battery management system can stand 3 000 load cycles, what is sufficient for only 100.000 km.
Internal combustion vehicles	Lower price and higher supply.	Higher cost of maintenance.
	Great availability of charging facilities and short time-period for charging.	Negative impact on environment due to CO_2 emission.
	Far distance range	Variable price of fuel (oil) and dependence on market fluctuations.

Europe has announced electrical revolution. Many benefits of using electrical vehicle are incentive for future development. Solar charging stations that are already being used all over the Europe are, also, under development as part of intelligent house concept, a green concept which provides energy savings and environmental protection. Large parking and roof surfaces represent photovoltaic infrastructure potential, which can protect the car from

[84] www.elen.hep.hr/EL-vehicle-definition.aspx
[85] Battery, Hybrid and Fuel Cell Electric Vehicles are the keys to a sustainable mobility, brochure www.avere.org/www/Images/files/about_ev/Brochure.pdf
Guidelines for Transport Professionals, Renewable Energy in Transport – CO_2 Neutral Transport for the Alpine Space www.avere.org/www/Images/files/about_ev/Brochure.pdf

precipitation and overheating. “Give and take” electricity method will ensure increase of electric car use, energy efficiency, as well as zero greenhouse gas emissions.[86]

Figure 34: Comparison of fuel consumption and environmental impact of electric and internal combustion vehicle[87]

5.2. SUCCESSFUL EXAMPLES IN EU CITIES / TOWNS

Some European countries have taken an incentive in the promotion of energy-efficient and clean road transport vehicles. The biggest challenge is high investment costs for charging infrastructure and technology development. At the local level in Europe, municipalities, other administrative bodies and companies have to rely on their own financial capacities to overcome financial obstacles through tax rebate, cheap loans, purchase grant etc.

All Nordic countries are adopting measures to increase the number of electric vehicles. In Norway all electric vehicles are exempt from all non-recurring vehicle fees, including sales tax, annual road tax, public parking fees, and toll payments, as well as being permitted to use bus lanes. In Sweden it is possible to travel for free from Helsinki to Copenhagen due to number of free charging outlets set by merchants and private individuals. [88]

[86] elen.hep.hr/Environment-development.aspx
[87] www.elen.hep.hr/home.aspx
[88] www.uppladdning.nu

The Portuguese government launched in 2008 a national Programme for Electric Mobility called Mobi.E. The project has open-access and market-oriented philosophy combined with interoperable system. It was designed to be scalable and used in multiple locations. Within this project electric cars are free from circulation tax and taxes on acquisition price. In cooperation with car manufacturers, the government set up national charging network for electric cars. By 2011 1.350 charging stations were installed throughout Portugal. [89]

In the Republic of Ireland the initiative is that 10% of all vehicles on Ireland's roads will be electric by 2020, as part of the "Electric Transport Plan". Collaboration with car manufacturers will enable deployment of 1.530 recharging stations. Since January 2011 the "Plug-in Car Grant" has been available across the United Kingdom. Both private and business buyers are eligible for 25% grant towards the cost of new plug-in electric cars which qualify as ultra-low carbon vehicles. [90]

European energy politics involves many projects co-funded by different European Funds. One of them is "CO_2NeuTrAlp – CO_2 Neutral Transport in the Alpine Space", a transnational project which goal was to test alternative transport technologies and mobility management measures in 13 pilot projects (Italy, Austria, France, Slovenia, Germany), covering various fields of transport. [91]

Figure 35: The dispersion area of project Civitas Dyn@mo; Electrical vehicle in City of Koprivnica[92]

One of the recently initiated projects is "CIVITAS DYN@MO – DYNamic citizens @ctive for sustainable MObility". The project runs until November 2016 and the participating cities are: Aachen (Germany), Gdynia (Poland), Palma de Mallorca (Spain) and Koprivnica (Croatia). 28 partners from participating cities have three main goals: to develop "Mobility 2.0" systems and services by applying new web-based technologies; to implement innovative electric mobility solutions, using new electric and hybrid vehicles; to engage in a dynamic citizen dialogue for mobility planning and service improvement.[93]

[89] www.mobie.pt/en/homepage
[90] www.gov.uk/government/publications/plug-in-car-grant
[91] www.co2neutralp.net/index.phtml
[92] www.koprivnica.hr/novosti/predstavljeno-elektricno-vozilo/
[93] Civitas, Dyn@mic cities active for sustainable mobility, brochure www.civitas.eu/sites/default/files/documents/DYNAMO%20brochure%20web.pdf

5.3. USEFUL RESOURCES

- www.co2neutralp.net
- Guidelines for Transport Professionals, Renewable energies in Transport - CO2NeuTrAlp – CO2 Neutral Transport in the Alpine Space
- www.co2neutralp.net/docs/epaper/guidelines_technicians_en.pdf
- Guidelines for decision makers, Renewable energies in Transport - CO2NeuTrAlp – CO2 Neutral Transport in the Alpine Space
- www.co2neutralp.net/docs/epaper/guidelines_dec_makers_english.pdf
- www.elen.hep.hr/home.aspx
- The European Association for Battery, Hybrid and Fuel Cell Electric Vehicles
- Battery, Hybrid and Fuel Cell Electric Vehicles are the keys to a sustainable mobility, brochure
- www.avere.org/www
- www.avere.org/www/Images/files/about_ev/Brochure.pdf
- www.greenemotion-project.eu/home/index.php
- European Green Vehicles Initiative
- www.egvi.eu
- Mother Nature Network
- www.mnn.com
- www.mnn.com/green-tech/transportation/photos/7-modern-solar-powered-vehicles
- Assembly of European Regions, Political report – The Role for the Regions in Enabling a Future for Electric Vehicles
- www.aer.eu/fileadmin/user_upload/Commissions/RegionalPolicies/ActivityReports/rap port_hampshire_EN_compress.pdf
- Civitas, Din@mic cities active for sustainable mobility, brochure
- www.civitas.eu
- www.civitas.eu/sites/default/files/documents/DYNAMO%20brochure%20web.pdf
- www.koprivnica.hr/novosti/predstavljeno-elektricno-vozilo/#prettyPhoto
- DIRECTIVE 2009/33/EC of the European Parliament and of the Council on the promotion of clean and energy-efficient road transport vehicles
- www.eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:120:0005:0012:en:pdf
- European Strategy on clean and energy efficient vehicle
- www.eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0186:FIN:EN:PDF
- www.eltis.org/index.php?ID1=6&id=9
- www.mobie.pt/en/homepage
- www.uppladdning.nu
- www.gov.uk/government/publications/plug-in-car-grant

6. RECENT DEVELOPMENTS

Drafted by Koprivnica

Recent developments on the field of solar energy come from the unavoidable fact that the production of electricity from solar energy increasingly leads to periods of oversupply, in particular during the daytime, when the sun shines and photovoltaic systems generate more electric power than can be absorbed in the grids.

There are also times with very low electricity demand. Furthermore, in the early evening there may be a demand peak that is difficult to be satisfied and may even overload the grid. To fully take advantage of renewable, environment-friendly solar technology and to reduce investments in wide-area grids and transportation losses, a balance of supply and demand is required. This holds in particular for the highly volatile solar power.

To make renewable energy production predictable and competitive, and to ensure more green power is generated, developments on the field of energy storage and smart grids integration are two of the areas on which efforts towards the further expansion of solar power supply are centered.

6.1. SOLAR ELECTICITY STORAGE[94]

Solar installations have been and continue to be an important driving force for the change to a new, decentralized energy policy. The problem with using the power directly is that solar energy fluctuates and is often unavailable when you need it. That is why efficient energy storage systems will play a vital role in overcoming the current challenges – initially by integrating stationary energy storage systems in private homes and in commercial buildings. Storage solutions permit more solar power to be consumed on site; cuts in feed-in tariffs and rising electricity prices make them an attractive option for many consumers.

Solar electricity storage can also decouple electricity consumption from production. This has the added effect of reducing the need to expand local power grids for the absorption of high volumes of renewable energy sources. Combined with photovoltaic installations, solar electricity storage could double the amount of solar power consumed directly on site.

In a single dwelling with a photovoltaic system combined with a local battery storage system, consumers can effectively reduce their external electricity supply by up to 60 percent.

In addition to providing relief to the power grids, storage systems have also a stabilizing effect on electricity prices. The use of storage systems connected to the grid can reduce peaks in feed-in capacity by up to 40%. The absorption capacity of the local power grids would thereby be increased by up to two-thirds without additional grid expansion. And the distribution networks no longer need to be geared to maximum feed-in levels from solar power systems. That saves power line capacities, and fewer new power lines need to be built.

[94] Fraunhofer Institute for Solar Energy Systems (ISE), "2013 Storage Study"

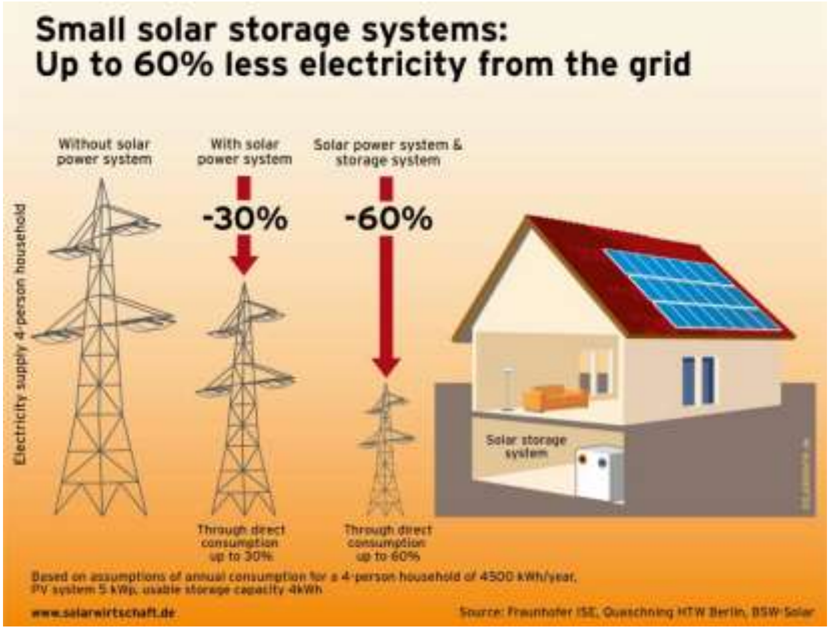


Figure 36: Electricity supply household – comparison of consumption:
Without solar power system (SPS), with SPS and with SPS & storage system[95]

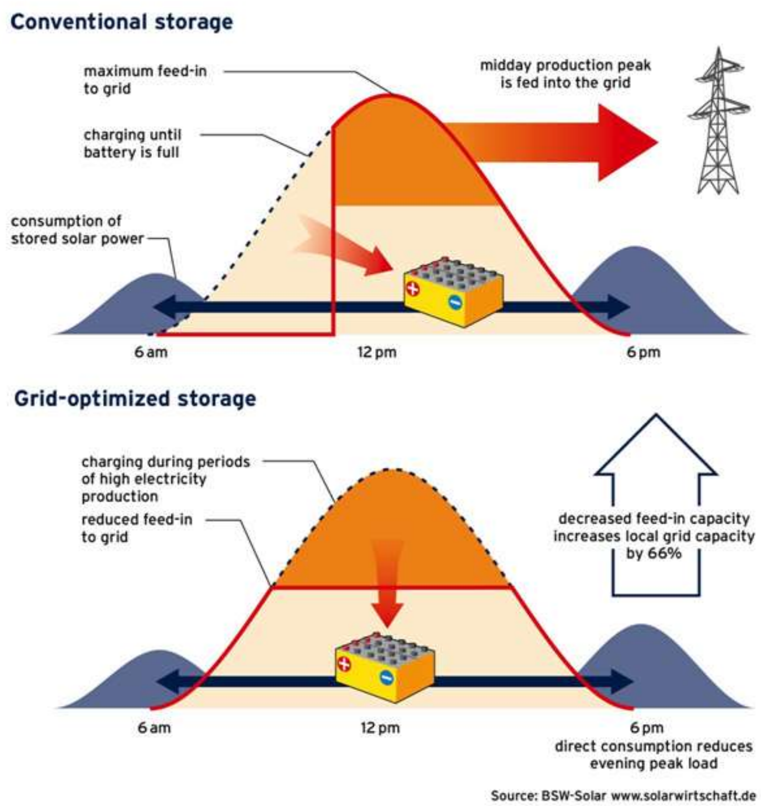


Figure 37: Solar energy storage – charts shows differences between work of Conventional storage and Grid-optimized storage [95]

[95] www.solarwirtschaft.de/en/national-activities/solar-energy-storage.html accessed 03/2014

Table 12: Solar electricity storage, advantages and disadvantages

	+	-
Solar electricity storage	consuming 60 – 80% self-generated solar power – greater independence	the cost of battery
	balancing out the feed-in peaks into the grid without losing solar power	the size of battery
	distribution networks no longer need to be sized to maximum feed-in levels from solar power systems; that saves power line capacities, and fewer new power lines need to be built	the life of battery

6.1.1 Latest technologies on the field of energy storage systems[96]

- Lithium ion batteries - able to achieve up to 10.000 full cycles, energy density is 80-200 Wh/kg;
- Lithium-air batteries - in the stage of development - manufacturers are planning to integrate the new technology into vehicles; can reach energy density values of 1.000 watt hours per kilogram, which is more than five times that of today's lithium batteries;
- Lithium sulphur battery – might be commercially available in ten years' time, already achieved an energy density of 600 watt hours per kilogram when used in practice; able to reach 1.400 charge cycles, during which around 60% of the cell's original capacity was restored;
- Lead-acid batteries – 5.000 charging cycles, (energy density 30-40 Wh/kg) and more modern lead-acid gel batteries;
- Aqueous Hybrid Ion (AHI) technology – still developing - focused on low-cost readily available elements such as sodium and carbon
- Redox flow batteries

[96] www.solarenergystorage.org

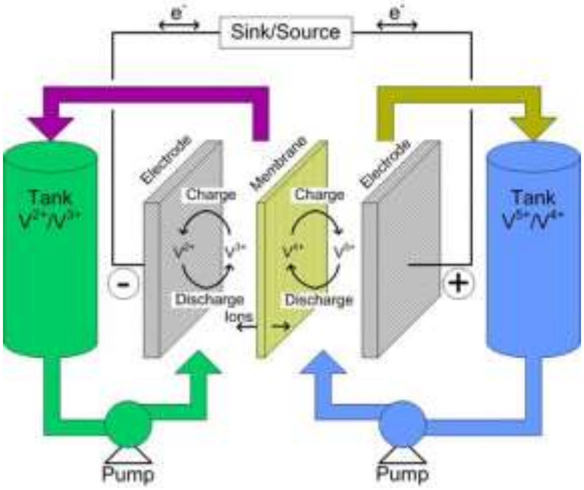


Figure 38: Principle of a vanadium redox flow battery[97]

The so-called all-vanadium redox flow battery (VRFB) is a mixture of system engineering, the construction of the stack and electrochemical engineering for the materials, essential advantages compared to conventional electric storage units: Separation of the conversion and storage units, high electric efficiency, good cycling stability and thus long lifetime.[97]

Energy density of VRBF is 25 Wh/kg, specific energy 10-20 Wh/kg, charge/discarge efficiency 75-80%, >10000 cycles.

6.1.2 Successful example – MESSIB project[98]

The overall objective of MESSIB project is the development, assessment and display of a reasonably priced multi-source energy storage system (MESS) integrated in building, based on new materials, technologies and control systems, for major reduction of its energy consumption and active management of the building energy demand. Within the European project MESSIB, potential of the all-vanadium redox flow battery is investigated.

For the solar house a redox system with 1°kW power and 6°kWh capacity was developed.

[97] www.messib.eu/about_project/MESSIB_results/redox_flow_batteries.php
[98] www.messib.eu

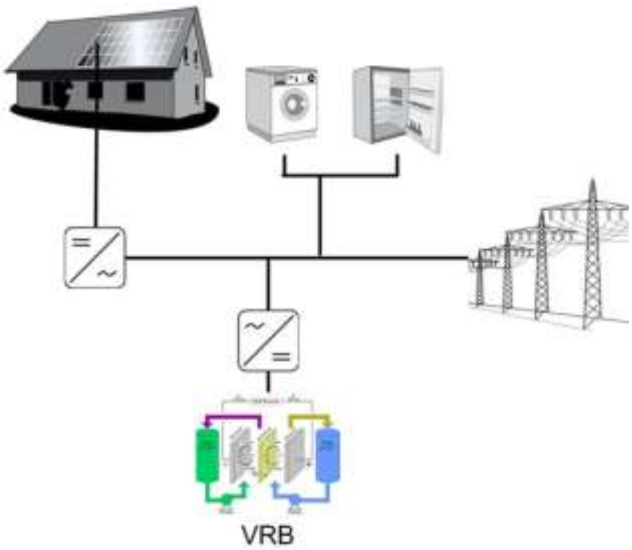


Figure 39: Overview of the system integration into „solarhaus“in Freiburg[99]

The stack design and construction oft the system was done by Fraunhofer ISE. The stack has 18 cells with an active area of 700 cm² and a peak power at charging of 1,6 kW. The integration of the Battery is on an AC Grid with a 3,8 KW PV on the roof. The Battery Management system is the interface between battery and the other system components of the MESSIB.

The main advantages compared to conventional electric storage units: Separation of the conversion and storage units, high electric efficiency, good cycling stability and thus long lifetime.

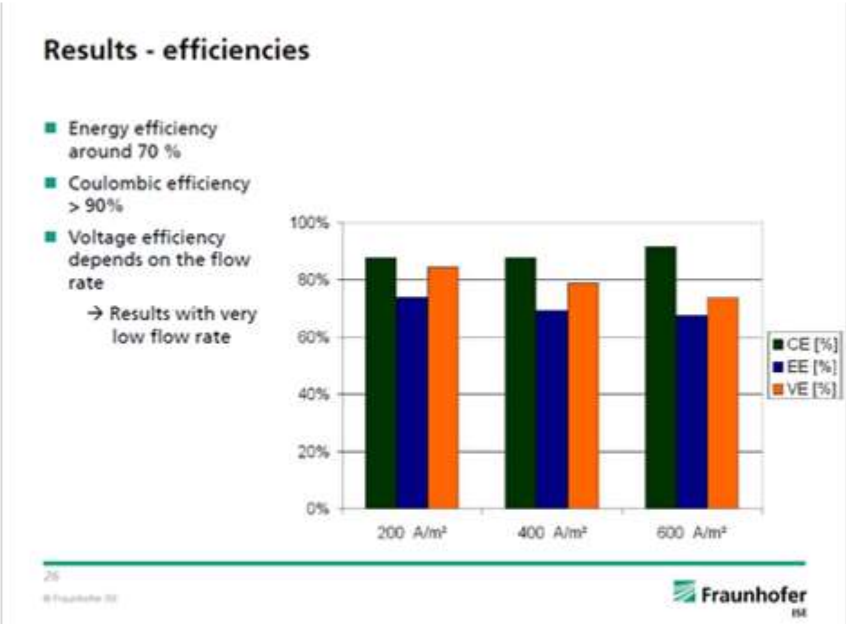


Figure 40: Results – battery efficiencies[100]

[99] www.messib.eu/about_project/MESSIB_results/redox_flow_batteries.php
[100] www.messib.eu/assets/files/docs/2011_05_04-WP3-article-FHG-Martin_Dennenmoser- Design, characterisation and operation strategies of 01 KW all-vanadium redox flow battery.pdf

6.1.3 Useful resources

- www.ise.fraunhofer.de
- www.sciencedaily.com/releases/2014/02/140210083100.htm
- www.solarenergystorage.org/en/category/energiespeicher-und-eigenverbrauch
- www.solarwirtschaft.de/fileadmin/media/pdf/infopaper_energy_storage.pdf
- www.solarwirtschaft.de/en/national-activities/solar-energy-storage.html
- www.solarwirtschaft.de/en/start/english-news.html
- www.solarenergystorage.org/en/energiespeicher-fur-die-zukunft-der-solaren-energieversorgung/
- www.messib.eu/about_project/MESSIB_results/redox_flow_batteries.php
  www.fraunhofer.de/en/press/research-news/2013/march/redox-flow-battery.html

6.2. SMART GRIDS

Advanced power networks or Smart Grids is common name for the new technology in the modernization of electric power networks at all levels from the micro-network (microgrids) to super-network (supergrid). Some of these innovations are still at the stage of research and development, and some of them are already implemented. The basic idea is effective use of advanced network (generation, transmission, distribution and consumption), while reducing costs and energy losses and increasing the quality and reliability of supply.

The smart grid is a planned nationwide network that uses information technology to deliver electricity efficiently, reliably, and securely. It's been called "electricity with a brain," "the energy internet," and "the electronet."

A more comprehensive definition is "a modernized grid that enables bidirectional flows of energy and uses two-way communication and control capabilities that will lead to an array of new functionalities and applications." [101]

Unlike today's grid, which primarily delivers electricity in an one-way flow from generator to outlet, the smart grid will permit the two-way flow of both electricity and information.

NRG Expert’s energy market research report says that current power generation causes 25,9% of global carbon emissions, but increasing the use of smart grids in energy infrastructure, can therefore play a significant role in helping to reach carbon reduction targets. The International Energy Agency (IEA) estimates that the deployment of a smart grid can result in a 0,9 to 2,2 gigatonne reduction in CO_2 emissions by 2050. [102]

Development of Smart grids is still in the beginning and with key components such as batteries and communication technology systems continuing to require a lot of development.

[101] www.nist.gov/smartgrid/beginnersguide.cfm
[102] www.nrgexpert.com/smart-grid-estimated-to-reduce-co2-emissions-by-up-to-2-2-gigatonnes-by-2050

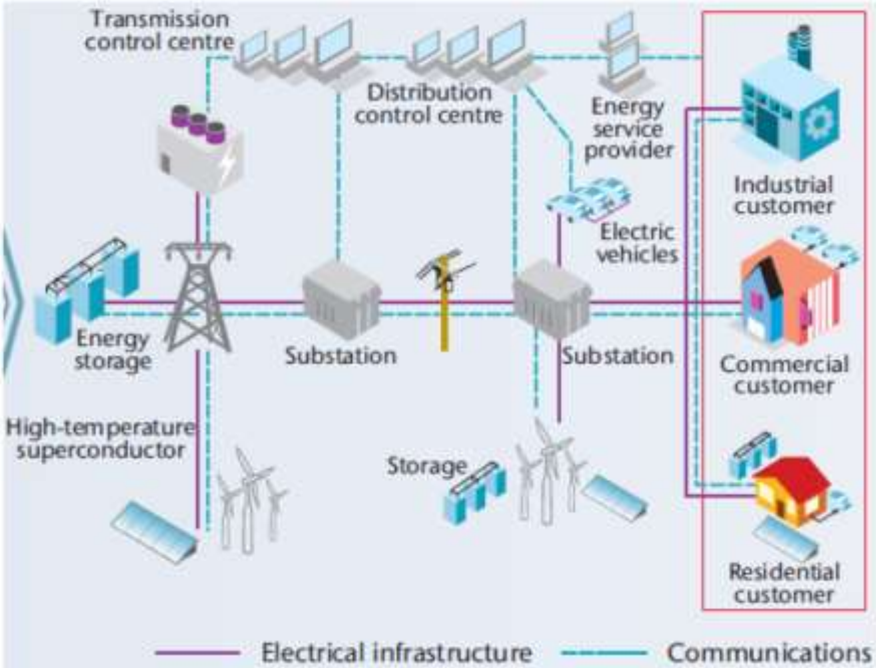


Figure 41: Schematic section of Smart Grid[103]

Smart Grid benefits:

- For consumers, the smart grid will offer up-to-the-moment information on their energy usage, enable smart appliances and devices to be programmed to run during off-peak hours to lower energy bills, and open up a wider range of electricity pricing plans;
- increase of grid reliability and reduction of frequency of power blackouts and brown-outs by giving utilities wide-area situational awareness, which includes monitoring, analysis, and decision-making;
- increase of grid resiliency by providing detailed information to enable utilities to more quickly restore power after outages;
- reduction of inefficiencies in energy delivery, lowering generation requirements;
- facilitating efficient and cost-effective charging of electric vehicles;
- integrating sustainable resources of wind and solar energy more fully into the grid;
- improvement of management of distributed energy resources, including microgrids and storage.

[103] www.obnovljivi.com/pdf/PDF_OBNOVLJIVI_COM/URH_T1_4.nova_energetika-vodice-smart_grid.pdf; Prof.dr.sc. Ranko Goić, dipl.ing.el.

Table 13: Comparison of Smart Grids and Traditional Power Grids[104]

	+	-
Smart Grids	Without SmartGrids technologies, the grid based system would become less stable and disruption in the supply may occur much more frequently	The integration of Smart grids requires fast data transfer architectures between grid control areas and between distribution and transmission system operators' systems, a huge amount of data has to be exchanged as much as possible in real time and with a high reliability between areas in order to promptly react to any change in the grid operation parameters.
	Increase of grid reliability and reduction of frequency of power blackouts and brownouts by giving utilities wide-area situational awareness, which includes monitoring, analysis, and decision-making.	High volumes of data coming from smart monitoring devices and smart (energy) meters must be managed efficiently.
	Increase of grid resiliency by providing detailed information to enable utilities to more quickly restore power after outages.	In future, power system operators must be trained to react faster in real time than on simulators, prepared for all kinds of dynamically simulated contingencies.
Traditional Power Grids	Less investment in building, operating and maintaining traditional grid than smart grid.	Inefficiencies in energy delivery.
	Operators need less training than to maintain smart grid.	Lack of information to enable utilities to more quickly restore power after outages.
	Private households and businesses don't have to be equipped with (expensive) smart meters and additional networked sensors for collecting, aggregating and analyzing the energy consumption data.	Higher frequency of power blackouts.

6.2.1. Successful example – GreenCom project[105]

Duration : 36 Months
Start Date : 1/11/2012
Total cost: 4.6Milllion Euros

The GreenCom project is a €4.6M project with the overall aim to balance the local exchange of energy at the community Microgrid level to prevent instability in the centralised grid. It is

[104] www.smartgrids.eu/documents/sra2035.pdf and author (Zavod)
[105] www.greencom-project.eu/

co-funded by the EU within the 7th Framework Programme, Objective ICT-2011.6.1 Smart Energy Grids (FP 257852).

The investment in heat pump and solar panel systems on the Island of Fur is co-funded by the Danish ForskEL-programme by €0,6M.

Fur is a small Danish island in the Limfjord at the northern tip of the Salling peninsula. The area of the island is 23 km^2, and its coastline measures 24 km. Fur has 855 permanent residents divided between 424 homes. In addition, there are roughly 500 summer houses. Each year, the island is visited by approx. 180.000 tourists. The island is linked to the mainland through a 24 hour ferry. The crossing of the Fursund takes 3–4 minutes.

Figure 42: The Island of Fur[106]

A consortium from industry and research had developed and evaluated for that project a "Smart Energy Management System" in a local level. Private households and businesses were equipped with smart meters and additional networked sensors, e.g. for measuring temperatures. Almost at real-time, the system collects, aggregates and analyzes the energy consumption data and the renewable electricity produced in the neighborhood. With these information the management system makes short-term (up to four hours) forecasts of local electricity supply and demand. The system takes also information from the major electricity-consuming devices in the households. In this way it can control the operation of heat pumps, refrigerators, washing machines or chargers for electric vehicles.

Expected results are:

- A *Smart Energy Management System (SEMS)* that will allow Grid Operator management of energy demand through intelligent control of the consumption devices and manage local energy generating and storage installations.
- Adoption of an approach where the control system is directly linked to end user contractual data that supports (near) real time information being delivered to users;
- Professional, consumer grade, Home Energy Management (HEM) & contractual awareness interfaces.

[106] http://www.greencom-project.eu/project-results/downloads/viewdownload/3-general-material/2-greencom-fact-sheet.html

- Gentle demand side management. For society as a whole this means lower energy costs (e.g., because peak loads are evened out and grid investments thereby may be postponed).
- A GreenCom analytic engine that will supply grid operators with novel and detailed knowledge about the near future (less than a day) energy needs in the microgrid.
- A fully operational Pilot system functioning on the Island of FUR.

There was the ''our conversion'' competition in Denmark. From the 380 projects entered, three judges - including European Commissioner for Climate Action - chose nine winners.

The green efforts on Fur will now be an inspiration to everyone else in Denmark. In just one year, the citizens of the island have reduced their CO_2 emissions by 20 per cent. The overall energy consumption of the citizens has dropped by 10 per cent – and electricity consumption in private homes has dropped by almost 18 per cent. [107]

6.2.2. Useful resources

Links:

> www.smartgrids.eu/ accessed 03/2014

> SmartGrids Startegic Research Agenda 2035: www.smartgrids.eu/documents/sra2035.pdf accessed 03/2014

National Platforms and initiatives:

> Czech Technological Platform on Smart Grid www.smartgridcz.eu

> Smartgrids Austria www.smartgrids.at

> Slovenian Technology Platform SmartGrids www.smartgrids.si

> Futured: Spanish Electricity Networks Platform futured.es

> E-Energy - Smart Grids made in Germany www.e-energy.info

> Smart Grids Flanders (Belgium) www.smartgridsflanders.be

> Smartgrids Hrvatska http www.smartgrids.hr

> www.sciencedaily.com/releases/2014/02/140210083100.htm

> ses.jrc.ec.europa.eu/

Projects:

> ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/documents/ld-na-25815-en-n_final_online_version_april_15_smart_grid_projects_in_europe_-_lessons_learned_and_current_developments_-2012_update.pdf

> www.greencom-project.eu/

[107] innovationfur.dk/index.php/en/presse-4/206-innovation-fur-named-one-of-denmarks-best-green-conversion-projects

7. CASE STUDIES

7.1. CASE STUDY 1- Solar Energy in transport, *by KOPRIVNICA*

Country	**Austria**
Entity	Wiener Linien – Vienna's city-owned transport company
Location	Vienna
Identification of the Best Practice	**Solar Energy in transport - A cleaner city: electric buses in Vienna (Austria)**
Main area	**Solar**
Summary	The public transport provider Wiener Linien took the initiative to help reduce emissions in the city centre of Vienna. The company gradually replacing buses powered by liquefied petroleum gas (LPG) to environmentally friendly electric buses. The goal is to create a zero-emission zone in the historic centre with low emissions in the wider centre. As it would have been difficult to obtain a planning and building permit for new power lines or charging stations in the historic environment, Wienner Linien decided to use the extensive existing network of overhead tram power lines to recharge the buses. This, of course, has required the development of new technology.
Target Group	Three target groups were detected: 1. Public transport users – travellers who actively use the electric buses; 2. Wiener Linien – Vienna's city-owned transport company which is saving between 25-35% on fuel and maintenance; 3. Local community due to lower air and noise pollution and added convenience that attracts additional passengers and tourists.
Description	Vienna has one of the largest tram networks in the world with a length of about 180 km and 1,031 stations. As the city has grown, trams have been supplemented with metro trains (75 kilometre long metro system, with 101 stops), gas-powered buses, and other forms of transport. An increasing number of travellers use public transport (up from 19% in 1993 to 29% in 2012) and the overall number of trips has grown to over 900 million, with an increasing share of regular costumers (500,000 in 2013). Vienna has a Transport Master plan (2003), which states that the main public transport goal for 2020 is increasing public transport from 34% to 40%. In 2011, the Wiener Linien decided to aim for zero emissions in the city centre. The zero emission ambition of the Wiener Linien meant replacing a number of the buses operating on the inner-city lines with electric buses. In order to choose a new drive system an extensive market dialogue and testing phase took place before tendering. The requirements of the Clean Vehicle Directive Methodology for considering CO2 and toxic emissions were met through specifying the vehicle type (electric). Further specifications were set relating to the technical performance of the vehicle: • Maximum width, length, height and wheelbase due to the narrow and winding inner city streets. • Two doors, low-floor buses (for the elderly) and a minimum of 30 passengers. • Charging either via overhead lines or induction. Outlets must not be the exclusive

	charging technique, but have to be additionally provided. • Charging time: max. 15 minutes • Range: min. 150 km • Reliability: Bus must not need to be removed from service for repair before 30,000 km is reached. Four potential buses were identified on the market. During initial testing two were rejected due to size or energy consumption. In the test phase only one consortium fulfilled all requirements, and was awarded the tender. Selected environmentally friendly "ElectriCitybusse" have two doors and are 7.78 metres long with a range of 150 km without recharging. In the winter the range decreases to 120 km, when the heating system consumes ca. 7 kW more energy. The buses can carry up to 46 passengers and have full electric heating and cooling systems for the passenger and driver area. "ElectriCitybusse" have a top speed of 62 km/h. Training on how to drive the new e-buses has been conducted for all bus drivers of Wiener Linien.
Date	2012 – 1st year of operation
Technical Aspects	The busses recharge their batteries at their end stations by hooking up to the overhead lines of the Viennese tram using an extendable pantograph, an arm on the roof. The overhead lines from the tram system supplies direct current, however alternating current is required to recharge the bus. As the bus needed to connect to the power lines without additional equipment, both the charger and inverter were requested to be included in the bus – a feature which had not been available on the market until then. The direct current is converted to alternating current by an IGBT power inverter included on the bus. Not more than 30% of the batteries' power is used for each circuit, so each recharging process only lasts five to eight minutes, during which passengers can get off and on the bus. At night, the batteries are recharged at the depot. With this recharging technique, it is possible to install a smaller battery system (nine lithium iron phosphate batteries with a total capacity of 96 kWh instead of the 180 kWh electric buses usually needed). Like this, the buses still need a stronger rear axle, but have space for 46 passengers, as many as a comparable diesel driven bus. Batteries also last longer (at least four years), because they are always being fully recharged. In addition to the drive system, the batteries supply all of the on-board electronics, the heating and the air conditioning. Thanks to regenerative ESB braking systems, the buses can also recover energy. So, the technology is specially designed for this project and currently 12 buses are fully operational on a daily basis. The buses charge over night at the depot, and during daytime operations stop at existing tram stations to recharge.
Implementation approach followed	• In September 2011 - Supply contract for 12 electric microbuses ''ElectriCitybusse'' launched by Wiener Linien; • In September 2012 - First buses operating; • Since July 2013 - Two inner-city bus lines rely entirely on ElectriCitybusse; • Vienna is an applicant city for the European Green Capital Award in 2014. • Wiener Linien wishes to expand their fleet with 12 meters electric buses in 2016 (the tender will be published in 2015).

Economic aspects	Investment cost of one electric bus is cca €400,000 – double the cost of a comparable diesel bus. Costs of the additional charging infrastructure: • charging points at the bus depot cost €320,000; • charging points at the end stations cost €90,000 each. Operating costs: • Prices for electricity are significantly lower than for diesel • Maintenance of electric buses will save about one third compared with diesel buses • "ElectriCitybusse" is less expensive than other hybrid or electric buses, because the quick recharging allows them to use a smaller battery, which makes them lighter.
Results	Reduction in fuel and maintenance costs – between 25-35%; 100% emission free – on location; Electricity comes from a renewable energy mix (50% water power, 8% photovoltaic, 15% wind and 27% gas); Each electric bus has lower emissions than the conventional bus / per year: • 5,3t less CO_2, • 1,7t less NO, • and 0,06t less NO_2; Reduction of air and noise pollution
Risks/Difficulties	Negative environmental and social effect is caused by the production of the Lithium-ferrit batteries. From spring 2014 on, Vienna will investigate how batteries could be reprocessed and reused, instead of being disposed of. The main challenges are: • Increasing the battery lifetime to 4-5 years • Reducing the price of the busses, which is still high compared to conventionally fuelled buses
Photos	 Photo 1: Recharging the bus at end station[108]  Photo 2: "ElectriCitybusse"[109]
Additional Documents	-
Links	www.eltis.org/index.php?id=13&lang1=en&study_id=4038 ec.europa.eu/environment/europeangreencapital/vienna-electric-buses/
Contact Person	Peter Wiesinger, Head of Technology Unit, Wiener Linien, peter.wiesinger@wienerlinien.at

[108] thecityfix.com/blog/friday-fun-its-a-bus-its-a-tram-itsviennas-new-public-transport/
[109] www.nytimes.com/2013/07/08/business/energy-environment/greener-transit-in-europe-built-on-top-of-older-infrastructure.html

7.2. CASE STUDY 2 - Solar Power Plant, application on elementary school, by HEIS

Country	**Croatia**
Entity	**Croatia**
Location	Town Novi Vinodolski , 45°17'39.5"N 14°47'22.1"E
Identification of the Best Practice	**Solar Power Plant on Elementary School**
Main area	**Solar**
Summary	Elementary school Ivana Mažuranića in town Novi Vinodolski in Croatia joined the group of public facilities in Primorsko-Goranska County, which rented their roofs to the investors in order to produce electricity from renewable energy sources (solar energy). On the roof of elementary school were installed solar panels. Project was realized in cooperation with Regional energy agency REA of Primorsko-Goranska County which is preparing and implementing of projects of EE and RES.
Target Group	Local community and Elementary School
Description	Elementary school in Novi Vinodolski is suited in Primorsko-Goranska County and was built in 1978. Total area of the facility is 5251 m^2. This school has a roof (reconstructed in 2009) with a good location with undisturbed southern orientation, with great intensity of solar radiation and the environment where exposure to dust is minimal.
Date	2012 – to date
Technical Aspects	Used technology for producing electricity from solar energy in elementary school Novi Vinodolski was “Photovoltaic cells for electricity generation in crystalline silicon technology, with 14% losses, panel performance, and fixed version, installed on the roof which relies on the support section of reinforced concrete slabs”. Basic parts of the installed photovoltaic system are: photovoltaic modules (modules are installed on the roof of school), photovoltaic inverter, prefabricated structure and connector terminal cabinet with protective equipment and installation. Total power of the system is 29,9 kW. Area of installation is about 240 m^2.
Implementation approach followed	This project was implemented by Regional energy agency REA (Regional Energy Agency) of Primorsko-Goranska County (Croatia) and investor was Primorsko-Goranska County. Investment was partially from the credits and one part was from its own finances. Elementary school rented roof to the investor for the period of 25 years, and school will get 3-5 % of the annual incomes from the sold electricity. School is planning to invest these incomes for improvement of educational standards of this institution.
Economic aspects	Investment costs of the solar power plant are 803.160,00 HRK. According to Croatian legislation, first 12 years of the project, Croatian Energy Market Operator is obliged to buy electricity by protected tariff and after that by regular tariff (total duration of the project is 25 years), since this electricity is produced from RES (renewable energy sources). Regarding operation costs, it was assessed that it will be necessary to buy 2 new photovoltaic inverters (during 2021 and 2031 year) and assessed costs are 88.828,30 + 112.603,24 CRO HRK.

Results	Annual production of electricity is 34.983 kWh/year (produced electricity is enough for 9 households). CO2 savings 10.565 t CO2/year. No additional jobs were created during this project.
Risks/Difficulties	Since the REA Kvarner was responsible for developing project documentation and getting approvals in administrative procedures there were some difficulties because administrative procedure was too long and complex, and getting all documentation and approvals from competent government authority took between 7 and 12 months. Since the REA Kvarner is public company, all equipment and financing needed to get through public procurement (although it does not get funds from the public budget). Also, approval of banks procedure made it more protracted.
Photos	 
Additional Documents	-
Links	osivanamazuranica.hr/ www.novi-vinodolski.hr/2012-05-28-10-41-23/vijesti/905-osnovna-skola-ivana-mazuranica-solarna-elektrana
Contact Person	osivanamazuranica.hr/ Andrej Čotar, associate in REA (Regional Energy Agency) Kvarner, mail: andrej.cotar@reakvarner.hr

7.3. CASE STUDY 3 – Solar electricity, BAPV in municipal building, by TUC

Country	**Greece**
Entity	Agios Basileios Municipality, Rethymno, Crete
Location	Agios Basileios, 35°14'49.5"N 24°27'07.5"E
Identification of the Best Practice	**Sustainable energy production plant with photovoltaic mounted on the roof of Agios Basileios Town Hall**
Main area	**Solar**
Summary	The municipality of Agios Basileios was the first municipality of Crete that finalised a project of mounting photovoltaic panels in the roof of a public building, providing the production of sustainable, CO_2 emissions free electricity on the roof of the Town Hall.
Target Group	Municipality of Agios Basileios
Description	The total capacity of the plant is 9,9 kW, for the implementation of the project priority was given to the use of Greek products, so the CO2 emissions for transportation were minimised and also the local community and the national economy were supported. The result was the creation of a high quality and automation production system.
Date	Starting-ending date of implementation:6/2012, 1st year of operation: 2012-2013
Technical Aspects	The minimum predicted energy production of the plant in an annual basis is 13.500kWh/a. The plant has 42 solar panels Type: Silcio (polycrystalline silicon), capacity 235 Wp, dimensions 1,66m x0,99m Inverter SMA 10kWp Mounting system from aluminium Connected to the grid
Implementation approach followed	a) Implementation steps that were necessary for the provision of the concept: The implementation of the project was realised in 30 days from the day of order. The installation process had duration of 5 days. Implementation steps: • Layout of roof • Planning of the system • Predicted electricity production – political decision • Application request from the Public Power Corporation • Approval from the Public Power Corporation • Payment of the connection to the grid cost and signing of the contract • Order of materials • Installation of the mounting system • Mounting of the solar panels • Installation of the inverter • Connection to the grid – beginning of operation b) Stakeholders involved to the development: Municipality of Agios Basileios
Economic aspects	The initial investment for the implementation of the project was 29.520€. The project was financed from municipal resources.
Results	Annual income from the electricity production (feed in tariff): 6.680€ Reduction in CO_2 emissions: 11.473,15kg/a

Month	kWh/month redicted	kWh/month actual
November	698,22	405,00
December	58,12	517,00
January	653,56	688,00
February	858,72	650,00
March	1.022,17	.094,00
pril	1.293,30	1.543,00
May	1.364,70	1.848,00
June	1.489,16	1.697,00
July	1.471,5	1.853,00
Total	**9.409,20**	**10.295,00**

According to the table above the actual energy production is 9% higher than the predicted one.

Risks/Difficulties

When implementing a photovoltaic system project the following aspects have to be taken under consideration:

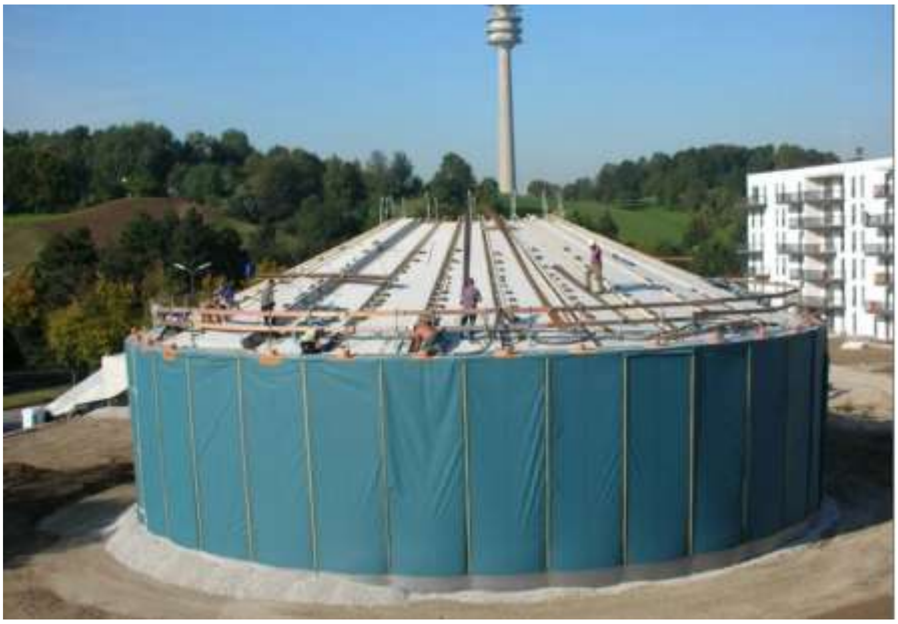
- The orientation and the tilt of the panels are affecting the efficiency of the system
- The place of installation should not be shaded for the majority of the year
- The electricity production is increased in locations with increased solar radiation
- With the development of the technology the initial cost for the system is decreased

Photos

Additional Documents	
Links	greecelands.blogspot.gr/2012/07/blog-post_4825.html
Contact Person	Papadogiannis Thomas thomas@tean.gr

7.4. CASE STUDY 4 – Solar District Heating, byTUC

Country	**Germany**
Entity	Steinbeis Research Institute for Solar and Sustainable Thermal Energy Systems
Location	Munich, 48°08'05.9"N 11°34'41.6"E
Identification of the Best Practice	**Solar District Heating with Seasonal Thermal Energy Storage in Ackermannbogen, Munich-Schwabing**
Main area	**Solar**
Summary	The municipality of Munich realised in the new developed area of Ackermannbogen in Munich-Schwabing a solar district heating system with seasonal thermal energy storage. The system serves 274 residential units, a kindergarten and some non-residential buildings and covers their needs in both space heating and domestic hot water (DHW) with use of solar energy and seasonal thermal energy storage.
Target Group	• The occupants of the district • Investors or developers that want to replicate the project • Raising awareness in the local community, regarding the benefits of the system
Description	The system provides space heating and domestic hot water for 24.800m^2 with use of 2.900m^2 solar collectors. The fraction of the total annual heat and DHW demand that is covered from the system is 47%. Additionally, workshops regarding the function of district heating were carried out to inform potential investors or developers. The system was decided to be monitored for its first three years of operation in order to identify weaknesses and evaluate the effectiveness of the individual components to the overall result. In addition to the project a socioeconomic research was carried out. The findings and results obtained from the project will be included in the planning of new energy supply projects.
Date	Starting-ending date of implementation: 1995-2007, 1st year of operation: 2007
Technical Aspects	24.800m^2 heated area (2.300MWh/a) 2.900m^2 solar collectors 5.700m^3 tank Solar fraction: 47%
Implementation approach followed	c) Implementation steps that were necessary for the provision of the concept 1995 Urban planning of the district, that was a military casern 1996 City council decision for a solar district heating system 1999 Feasibility study for Munich 2000 Preliminary study for Ackermannbogen, Munich Schwabing 2004 Architectural competition 2005 New system concept, planning and start of construction 2006 District heating installation 2007 Installation and beginning of operation of the solar system and storage d) Stakeholders involved to the development Municipality of Munich ZAE Bayern Ministry for Environment, Nature conservation and Nuclear safety
Economic aspects	The investment costs were covered from the Ministry for Environment, Nature conservation and Nuclear safety in rams of the solarthermie 2000plus project and from the Municipality of Munich.

Results	47% of the energy needed for space heating and DHW throughout the year is covered from solar thermal energy.
Risks/Difficulties	The aspects that need to be considered by the replication of the Best practice in different locations are the following: The solar irradiation The tilt of the solar collectors to achieve maximum efficiency The seasonal ground temperature
Photos	 
Additional Documents	
Links	www.solarthermie2000plus.de/hauptseite.php?pid=24&u=2 solarthemen.de/wordpress/wp-content/uploads/2007/06/muenchen.pdf
Contact Person	City of Munich Dipl.-Ing. Cornelia Sierks Tel: +49 89 2361-2267 sieks.cornelia@swm.de

7.5. CASE STUDY 5 – Passive and active Solar design by AREANATEJO

Country	**Portugal**
Entity	LNEG – Portuguese National Laboratory for Energy and Geology Lisbon – Lumiar Portugal
Location	Lisbon – Lumiar (38.772325, -9.177675)
Identification of the Best Practice	**Solar Building XXI - Passive and active Solar design**
Main area	**Solar**
Summary	Solar Building XXI is a demonstration building where renewable technology concepts have been incorporated at the design stage in order to provide an example of an "energy efficient" building, with low energy consumption, a set of solar passive and active systems integrated into the architecture in order to motivate its designers for the applicability and value of these concepts.
Target Group	Solar Building XXI has as target groups the technicians working in LNEG and especially all the students of engineering.
Description	Solar Building XXI has very special features because, since its conception, there was always the underlying intention of constructing a service building with demonstration activities related to energy efficiency and renewable energy, and as an adequate building used for research in these areas. A set of solar passive and active systems were integrated into the architecture and were adopted a set of constructive measures of great impact on thermal comfort inside the building. The introduction of passive cooling with a buried pipe system together with natural ventilation strategies is another innovative feature. The research work is still being performed, but allowed so far to emphasize that about 80% of its energy consumption is from renewable energy sources, therefore, Solar Building XXI will fit in the context of the future, that is, of buildings that have a net zero energy consumption ("NZEB, Net Zero Energy Buildings"). Solar Building XXI can function as an example of project methodology applicable in similar cases, opening an exciting field of formal and spatial research, which will result in the future new syntheses of energy efficiency in the relationship between architecture and systems.
Date	The building was opened in 2006
Technical Aspects	The main objective of the project for Solar XXI building was to design a service building with low energy consumption, integrating renewable technologies (solar thermal and photovoltaic – photovoltaic façade for electric use (100 m^2 and 12 kWp) and passive systems for heating and cooling. The strategies and systems were planned and integrated from the beginning of its conception and sought to be drivers in the formal concept of the building itself. The integration of photovoltaic systems in Solar XXI was an intention when designing the building. Being a demonstration building and a case-study in the field of Renewable Energies, "solar photovoltaic" alongside with "solar thermal" (active and passive) were an integral and fundamental part of its design. A photovoltaic system was designed to be

integrated into the south façade of the building with about 100 m^2 of multicrystalline silicon modules, performing a total of about 12 kWp of direct supply of electricity to the building. In the parking lot near the building another 6 kWp photovoltaic system has been implemented, also supplying electricity to Solar XXI building.
The solar collector system placed on the roof of the building, and a storage system in the basement, constitutes the auxiliary heating system assisted by a natural gas boiler.
The large windows are protected with external blade blinds adjustable by the user.
Cooling is provided by the air entering the building through buried pipes using the important cooling potential in the soil (cold source) to cool the outside air which will be insufflated inside the building. These PVC pipes enter the building by the semi-buried floor, since at this stage there is no need to promote the exchange of heat, going through central building ducts (metal pipe), and directly distributing air, individually in the rooms of the ground and upper floors, namely, each room receives two tubes, which the user can control in terms of opening/closing.

Implementation approach followed

e) Implementation steps that were necessary for the provision of the concept
   i. Characterization of the climate
   ii. Thermal characterization of envelope
   iii. Optimize the thermal quality of the envelope, by adopting appropriate thermal insulation of walls, roofs and floors.
   iv. Size all the photovoltaic systems and the solar thermal systems taking into account the energy need of the building
   v. Design and plan all the infrastructures
   vi. Modelling Research
   vii. Monitoring steps

f) Stakeholders involved to the development

To develop all Solar XXI concept there was special experts team in several areas, namely:
   i. Coordination
   ii. Architecture Project
   iii. Construction
   iv. Stability Project
   v. Electrical Installations Project
   vi. Adaption to the climate
   vii. Water and Sewage Project
   viii. Modelling Research
   ix. Photovoltaic System Project
   x. Innovation

Economic aspects

No data available.

Results

77% of users were very satisfied with the conditions in summer and winter, considering the global environment acceptable in both seasons. The highest percentage of users was satisfied with the conditions of lighting and acoustics. In terms of indoor air quality in the summer, 83% of users were satisfied, decreasing to 77% in winter.
Solar XXI presented an average daily consumption of about 78 kWh for the production of two coupled PV power stations, representing daily approximately 70% of the total electricity consumed in the building.

Risks/Difficulties	The biggest difficulties in the conception of Solar XXI were the initial designing of such a complex and coordinating systems. The climate conditions and the use of the building need to be considered by replication of the best practice.
Photos	 Photo 1 – South Facade  Photo 2 – Solar collector on rooftop
Additional Documents	Not applicable
Links	www.lneg.pt/lneg/
Contact Person	Mr Helder Gonçalves 351 210 924 600

7.6. CASE STUDY 6 – Photovoltaic systems in public buildings by LAKATAMIA

Country	**Cyprus**
Entity	Ministry of Commerce Industry and Tourism
Location	Urban and rural areas across Cyprus
Identification of the Best Practice	**'Photovoltaic systems in public buildings, schools and military camps'**
Main area	**Solar**
Summary	Enjoying more than 300 days of 75 % sunshine, Cyprus is a prime candidate to harness solar energy. The island already held the unofficial 'world record' in solar water heating with almost every household having a system installed, officials estimated that more than 750 000 m² of solar collectors were installed on the island. Cyprus has now expanded the coverage of photovoltaic systems to public buildings, schools and military camps.
Target Group	Public authorities/ schools/ military
Description	As an island, Cyprus is not connected to a larger electricity grid and cannot purchase electricity from a neighbour, meaning that it needs to generate itself all the electricity to fulfil its needs. However by implementing this programme it is coming into closer alignment with EU legislation in the field of energy through prioritising the promotion of saving energy and the use of renewable energy. 19 systems of 5 kW, 16 systems 10 kW, 3 systems 15 kW, 15 systems 20 kW, 4 systems 25 kW, 1 system of 30 kW, 1 system of 35 kW, 1 system 40 kW, 1 system of 45 kW, 3 systems 50 kW and 1 system of 100 kW were installed in public buildings, schools and military camps. All of these were connected with the national grid which then distributed the electricity produced. According to officials, the project helps to achieve a key commitment of Cyprus in the area of encouraging the use of renewable energy sources (RES) and the promotion of energy saving in the context of strengthening sustainability. The high cost of photovoltaic systems in relation to more conventional technologies meant that without EU funding, the project could not have been completed.
Date	2009-2010
Technical Aspects	Supply and installation of 65 photovoltaic systems ceilings on six public buildings, 54 schools and 5 military camps, with a wide range of kilowatt capacities.The total capacity of the systems is 1.100 KW.
Implementation approach followed	The project involved the supply and installation of photovoltaic systems ceilings on six public buildings, 54 schools and five military camps between 2009 and 2010. Fifty training models on photovoltaic systems were also introduced in the schools. The total capacity of the systems is 1100KW. The project contributes to the respect of the EU energy legislation, the reduction of the energy cost and the environmental protection.
Economic aspects	Total investment: EUR 5 043 989 ERDF contribution: EUR 3 134 474.
Results	As well as reducing the electricity cost of each building, the project also served to raise the awareness of students in photovoltaics through educational material - specifically 50 training models of photovoltaic systems which were purchased for schools.

Risks/Difficulties	
Photos	
Additional Documents	
Links	ec.europa.eu/regional_policy/projects/stories/details_new.cfm?pay=CY&the=68&sto=2702&lan=7&region=ALL&obj=ALL&per=2&defL=EN
Contact Person	Beneficiary: 'Ministry of Commerce Industry and Tourism' Tel.: +357 22409386 E-Mail: perm.sec@mcit.gov.cy