Intelligent Energy Europe

Transfer of experience for the development of solar thermal products

Common Information Package

TranSolar
ΚΑΠΕ
CRES
arsenal research
Ein Unternehmen der Austrian Research Centers
ESTIF

PART IV: SUPPORT ACTIONS AND PROJECTS

– EDUCATION IN SOLAR THERMAL (CRES)

“Education in Solar Thermal”

Charalampos Malamatenios

Training Department

Centre for Renewable Energy Sources & Saving

“Solar Thermal Systems” Module

Project FIP-TREET

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- Introduction
- Technical Principles of Operation
- Technical aspects having an impact on cash flows over the whole life of Solar Thermal Systems (STSs)
- STS Systems Economics
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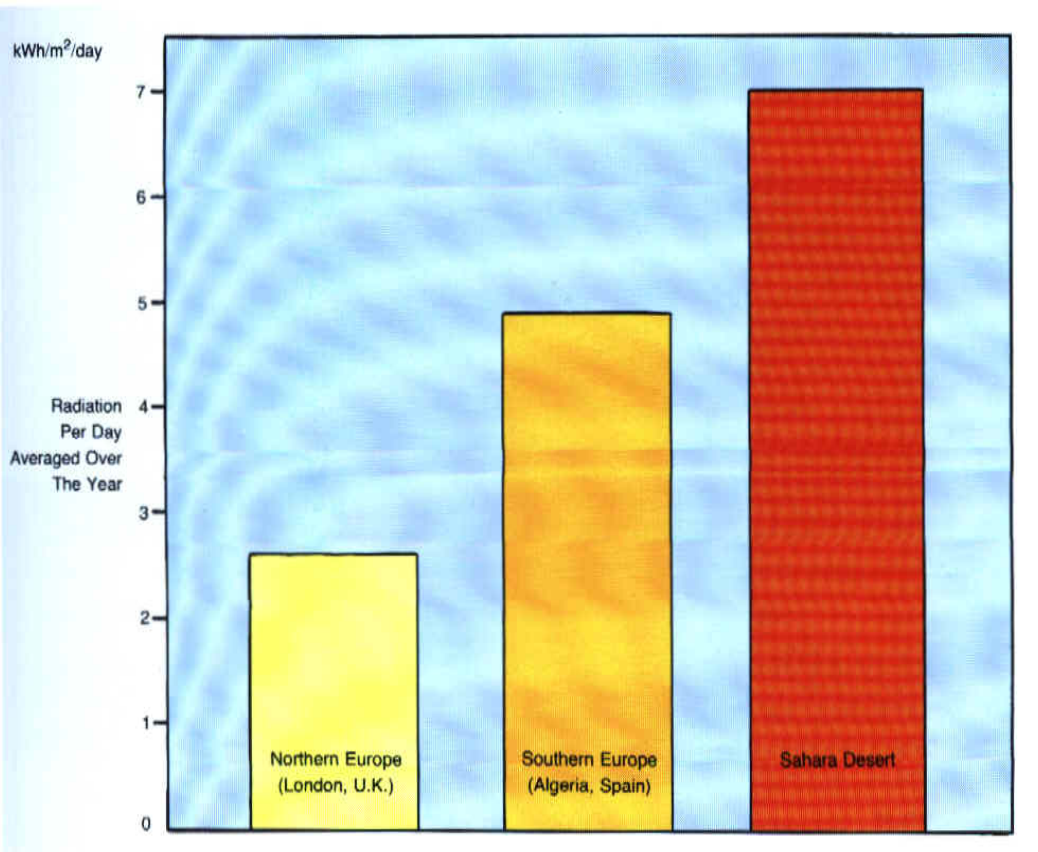
Introduction

✓The Solar Resource Power

- The energy from the sun arriving on the earth's surface is enormous. It is estimated that it is in the region of 15000 times the total energy required by humanity for all its activities.
- The diagram shows that the energy insolation in kWh per square meter per day is about three times as large in the Sahara than in northern Europe.



✓Heat transfer mechanisms:

Conduction:

As solar energy is absorbed in a material, the energy distributes itself as it is conducted between molecules.

Convection:

Heat can be transferred to a fluid, either a gas or a liquid, by convection. Energy is transferred to molecules of the fluid, which then physically move away taking the energy with them.

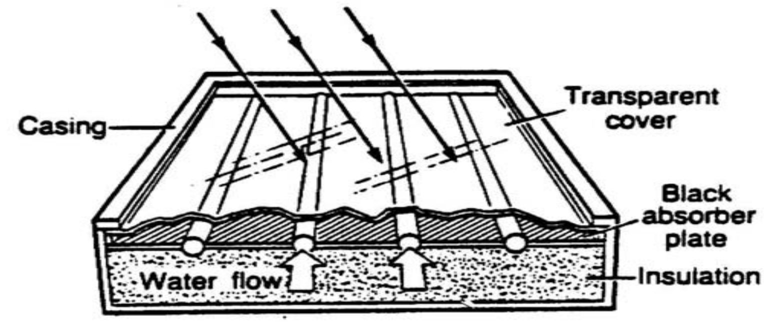
Radiation:

Heat energy can be radiated in the same manner as it is radiated from the sun to earth. The quantity of radiation and wavelength content is strongly dependent on the temperature of the surface.

Technical Principles of Operation

✓*Solar Collectors*

- The collection of solar radiation is based on the "*greenhouse effect*".
- The solar collector is mounted on or near the house, facing south (in the northern hemisphere).
- A large proportion of the sun's radiation can pass through the glass or plastic glazing and strikes a light-absorbing material.
- The material converts the sunlight into heat, which is prevented from escaping by the glazing because most of the resulting infra-red waves are reflected.



Flat plate (water)

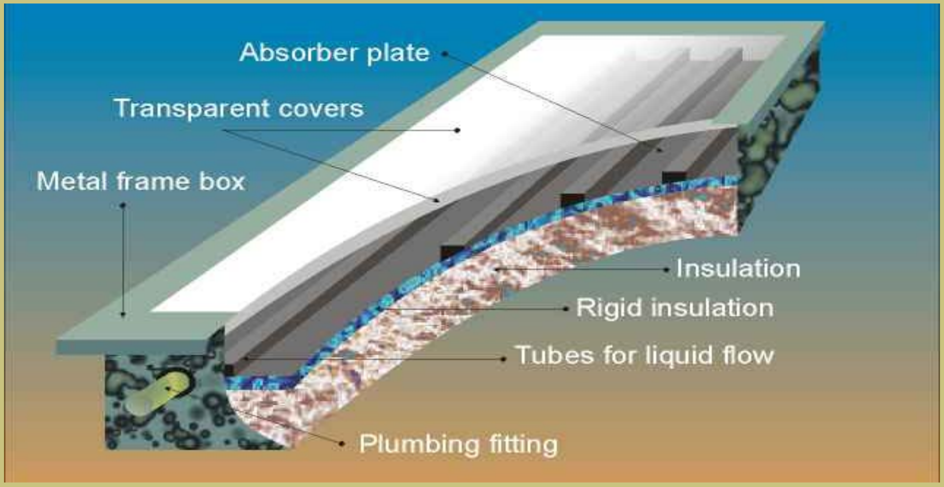
➢Types of Solar Collectors

✓ Batch solar water collectors:

- the simplest type of solar water collectors
- the collector is the storage tank - water is heated and stored a batch at a time.
- used as pre-heaters for conventional or instantaneous water heaters
- a low cost alternative to an active solar hot water system, offering no moving parts, low maintenance, and zero operational cost
- the acronym for a batch solar water collector is: *ICS* (*Integrated Collector & Storage*)

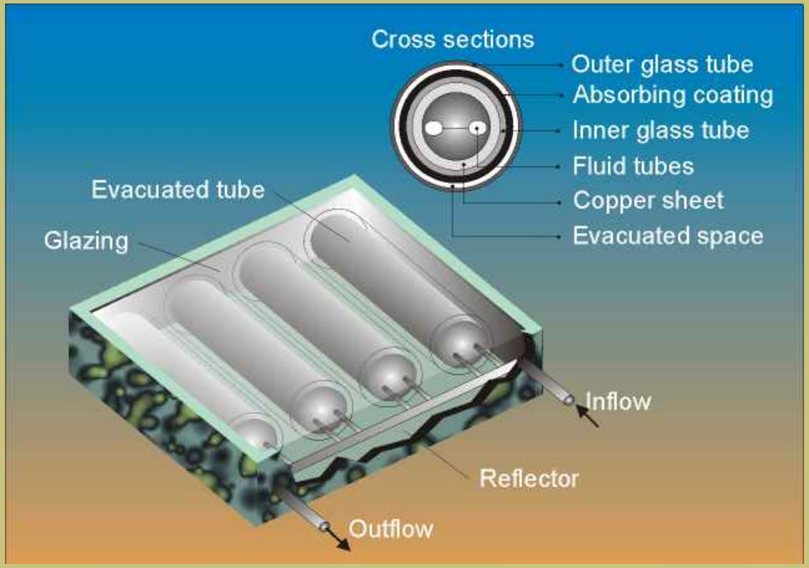
✓ Flat-plate collectors:

- the most common collectors for residential water-heating and space-heating installations
- flat-plate collectors are categorised in: *liquid collectors* (see figure) and *air collectors*
- both liquid and air collector types can be either *glazed* or *unglazed*



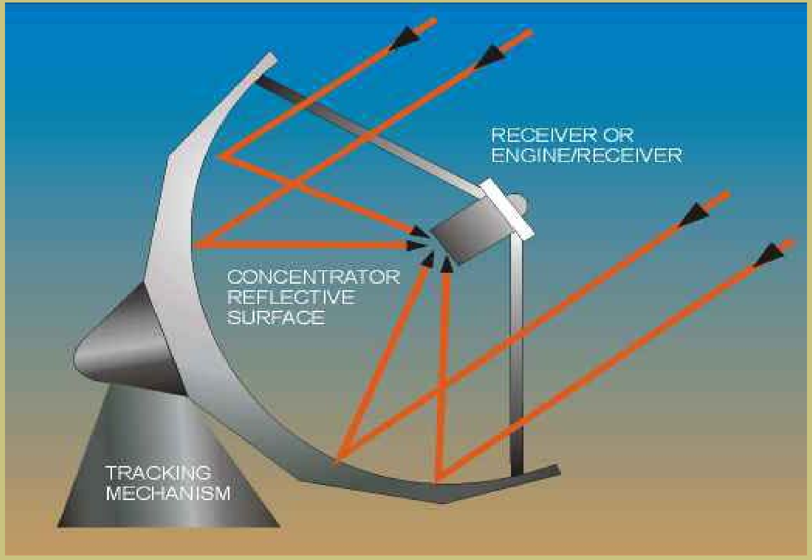
✓ Evacuated-tube collectors:

- they heat water in applications that require higher temperatures.
- they consist of rows of parallel transparent glass tubes, each of which contains an absorber tube covered with a selective coating (see figure).
- the heated liquid circulates through heat exchanger and gives off its heat to water that is stored in a solar storage tank.



✓ Concentrating collectors:

- they use mirrored surfaces to concentrate the sun's energy on an absorber called "receiver"
- they achieve higher temperatures than flat-plate collectors, but they can only focus direct solar radiation
- used mostly in commercial applications as they are expensive and the trackers need frequent maintenance



✓*Storage of the collected heat*

- Two basic kinds of storage are used in solar-heating systems:

✓ the "*well-mixed storage*", most common with water storage in space-heating systems, *and*

✓ the "*stratified storage*", mandatory in air-heating systems and often used for domestic hot water systems.

- *Solar domestic water heaters* generally use a *tank* containing an electric immersion heater element.
- *Storage tanks are classified as:*

✓ *Pressurized tanks*: commonly available, as all conventional gas and electric water heaters are pressurized. They are readily available in 20 to 450 litre sizes and they are constructed of steel with a glass lining to prevent rusting.

✓ *Unpressurized tanks*: used to store larger amounts of water in space heating systems. They are built in sizes from 750 to 35.000 litres and larger, and are made from stainless steel, fibreglass or high temperature plastic. Hot liquid from the collectors flows through a coiled tube in the tank to transfer heat to the water.

✓*Solar System Circuit*

- The solar system circuit connects the solar collector to the storage tank

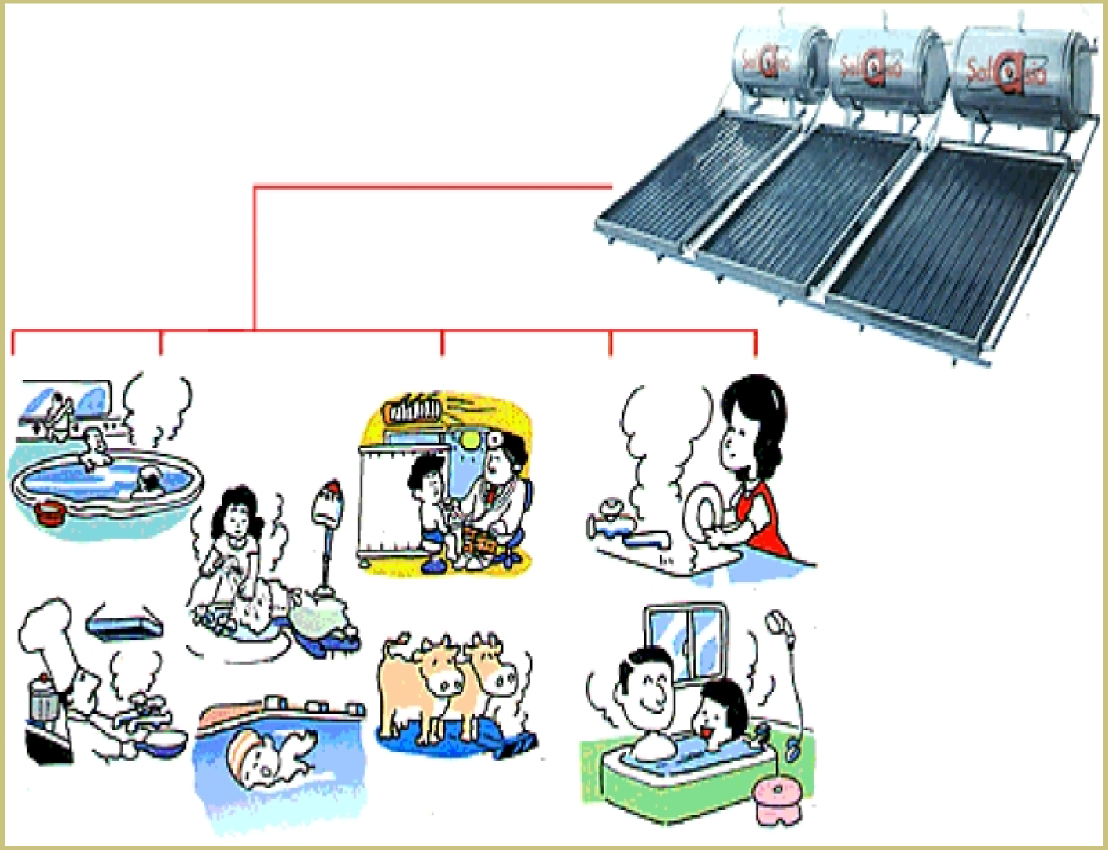
✓Components of the solar system circuit:

- a pump that ensures circulation (not needed in self-circulating systems)
- the pipelines connecting hot water storage tank and collectors
- a one-way valve which prevents that the solar collector fluid runs backwards at night, and empties the storage tank
- an expansion tank: an open container at the top of the installation, or a pressurised tank that contains minimum 5% of the solar collector fluid.
- overpressure protection: it must manage to let out the solar collector fluid, if the system is boiling.
- air outlets: they must be used at all height points in the system
- the filling valve
- a dirt filter for the pump, to remove dirt
- manometers and thermometers, according to need.
- the solar collector fluid, which must be able to stand frost, and must not be toxic.

✓Technology applications

- Main applications of solar collectors:

✓hot water preparation in households, commercial buildings and industry
✓water heating in swimming pools
✓space heating in buildings
✓space cooling and refrigeration
✓drying crops and houses
✓water distillation,
✓solar cooking

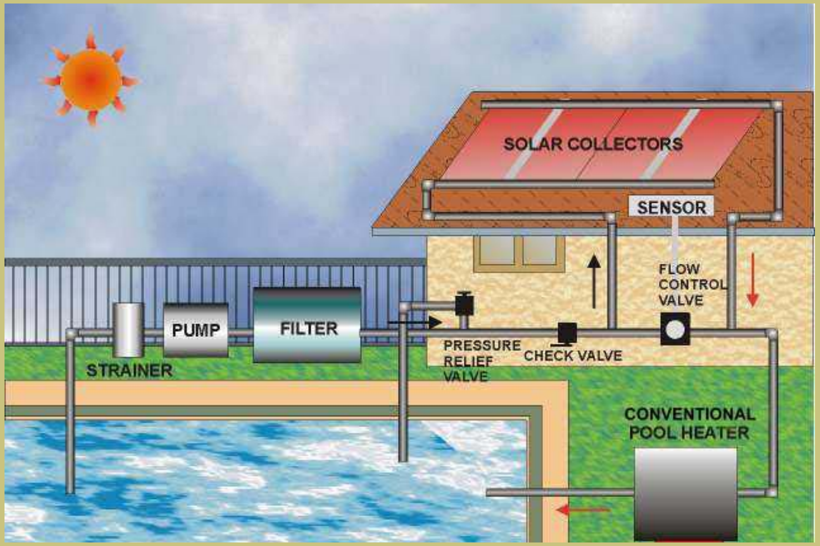


✓Domestic hot water production

- There are several different kinds of solar hot water systems: from low cost, simple *thermosiphonic systems* to more efficient, complex and costly "*forced circulation systems*" (see figure)

A solar collector heating an antifreeze solution for domestic water

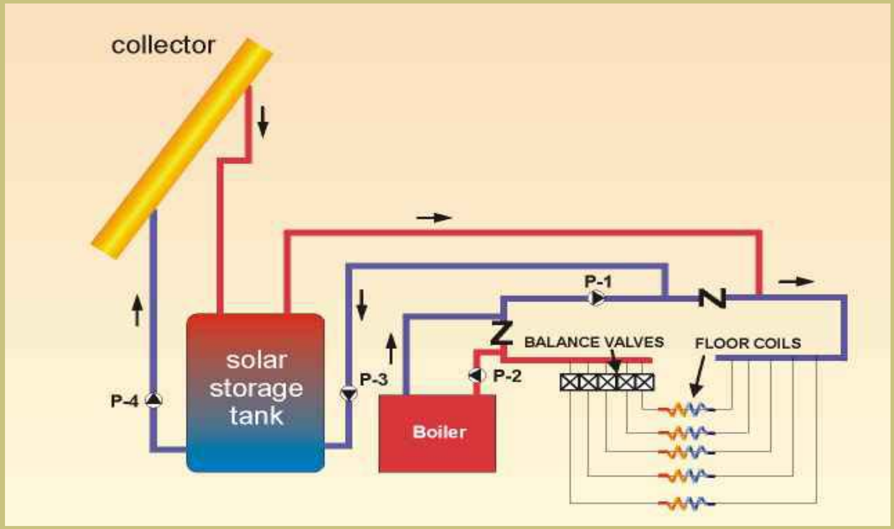
✓Solar pool heating



A typical layout of a solar assisted swimming pool heating system

✓Space heating

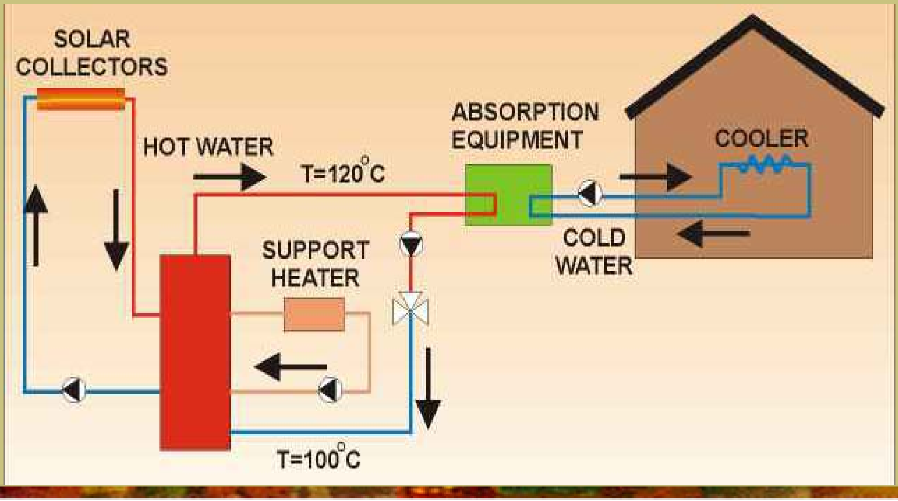
- Solar systems are usually designed to provide 40-80% of the annual heating needs of a house.
- Heat not provided by the solar system must come from a backup system, usually a conventional furnace.
- The two systems can use common duct-work and heat delivery circuits.



Solar radiant in-floor system (P-1 to 4: circulating pumps or fans)

✓Space cooling

Air-conditioning with the aid of an active solar system

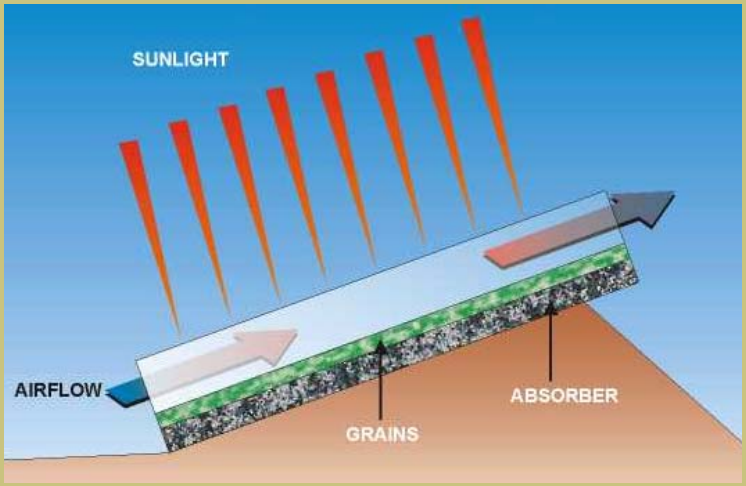


- Active solar cooling uses solar thermal energy or solar electricity to power a cooling appliance.
- Various types of cooling technologies utilize solar thermal energy: *absorption cooling* is the first and oldest of them.

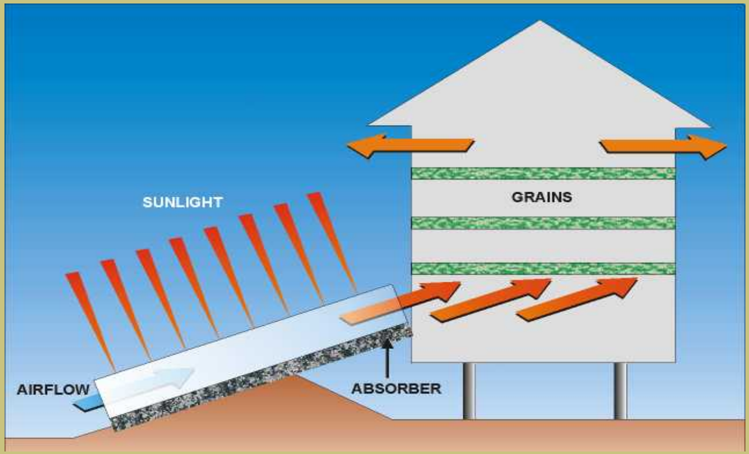
✓Drying of agricultural products

"Solar dryers" are classified into:

- Dryers in which the sunlight is directly employed
  traditional drying racks in the open air, *covered racks* or *drying boxes provided with insulation and absorptive material*



- Dryers in which the sunlight is employed indirectly



✓ Water distillation

- Solar energy is used for desalting sea water for agricultural use of it, and drinking.
- Solar thermal desalination technique: feeding a distiller with solar heated water using *multistage flash* (MSF) or *multi-effect distillation* (MED) plants.

✓*Electric power*

- A concentrating collector is required for the generation of electricity from solar thermal energy. The concentrating solar power systems, consist of two parts:

✓ one that *collects solar energy and converts it to heat*, and

✓ another that *converts heat energy to electricity* (through a steam turbine or heat engine).

- There are three main types of concentrating solar power systems:

✓ the *parabolic-trough (or solar farm) concept*,

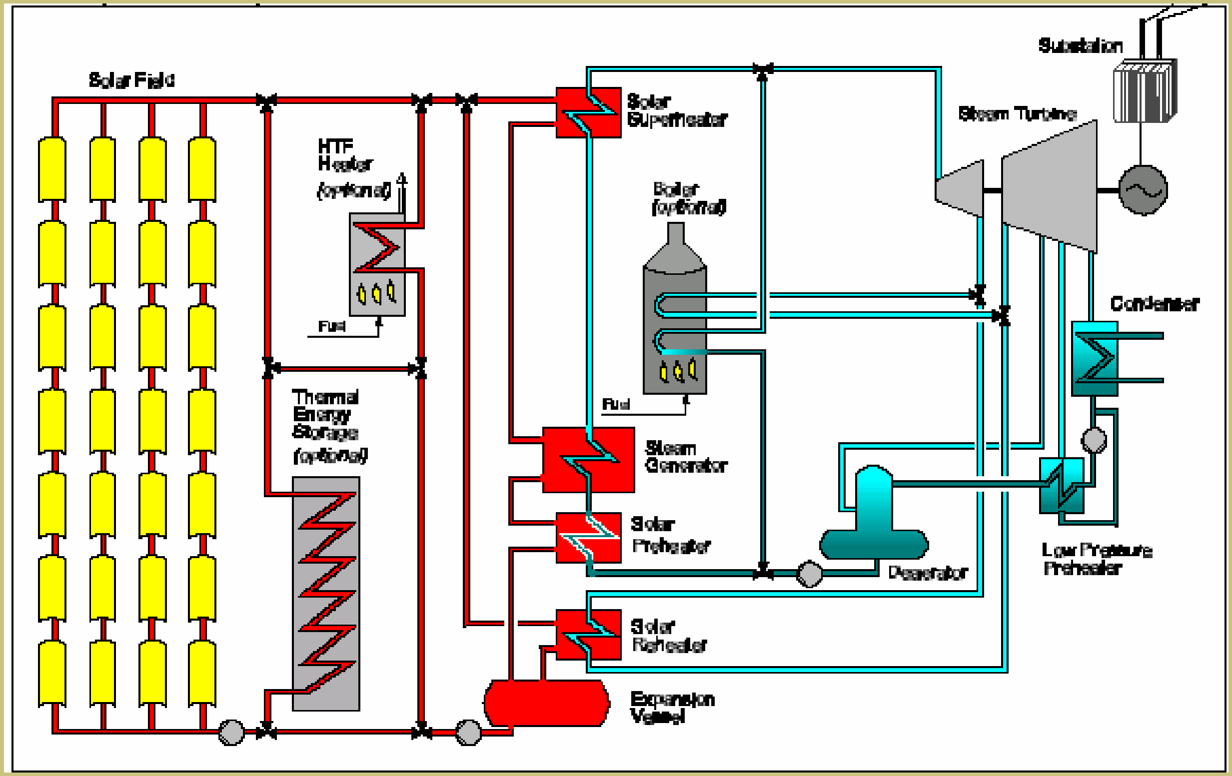
✓ the *solar power tower*,

✓ the *parabolic dishes or "dish/engine" units*

✓ Parabolic through system

- Parabolic-trough systems concentrate sun's energy through long rectangular, curved (U-shaped) mirrors
- Parabolic trough technology is the most proven solar thermal electric technology

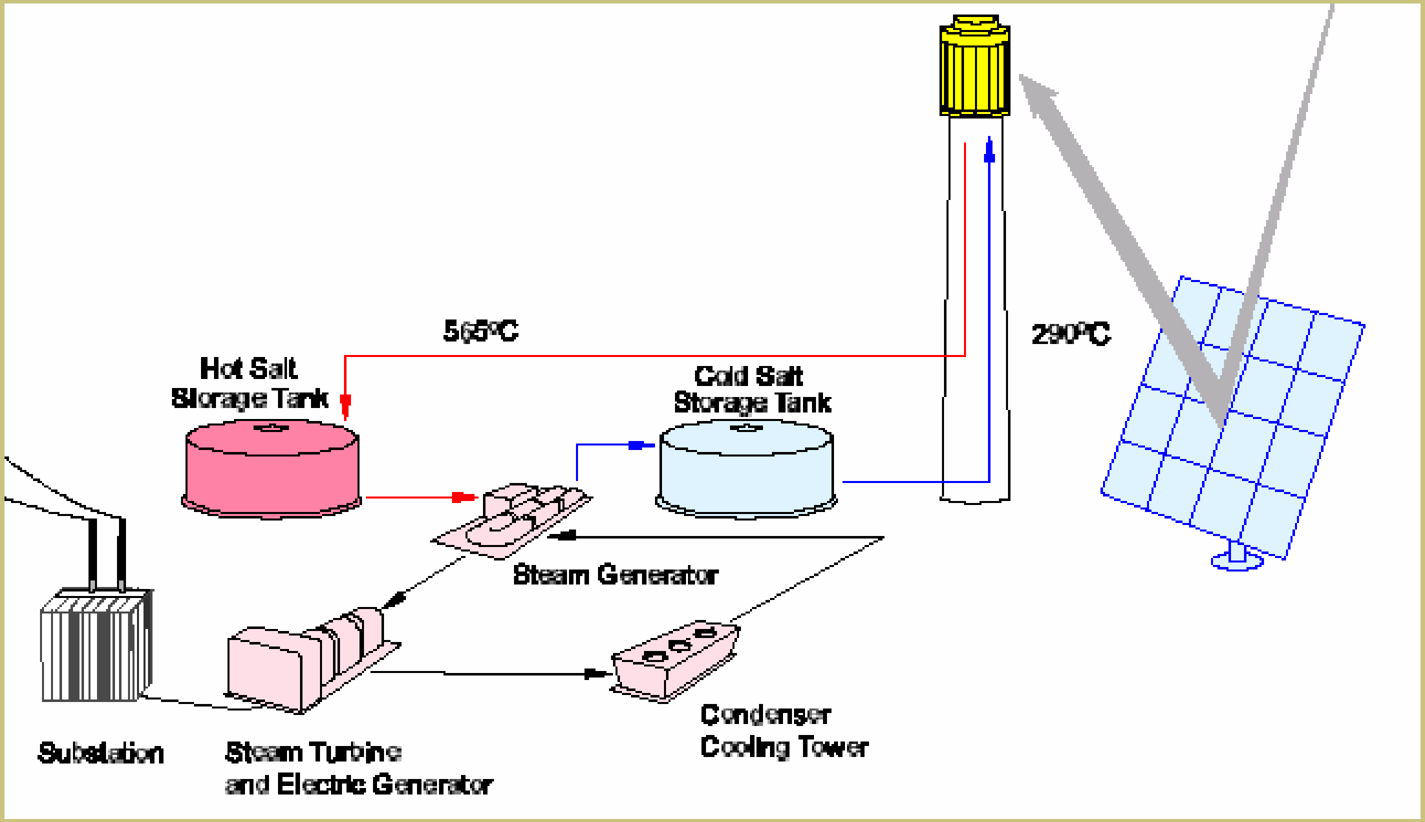
Schematic configuration of a parabolic through Solar/Rankine plant



✓ Power tower

- A power tower system uses a large field of mirrors (the “heliostats”) to concentrate sunlight onto the top of a tower, where a receiver sits

Schematic diagram of the primary flow paths in a Molten-salt power tower system



✓ Dish/engine systems

A dish/engine (also called parabolic dish) system uses a mirrored dish, which is similar to a very large satellite dish

- Attributes of Dish/engine systems:

✓ *high efficiency*

✓ *versatility*

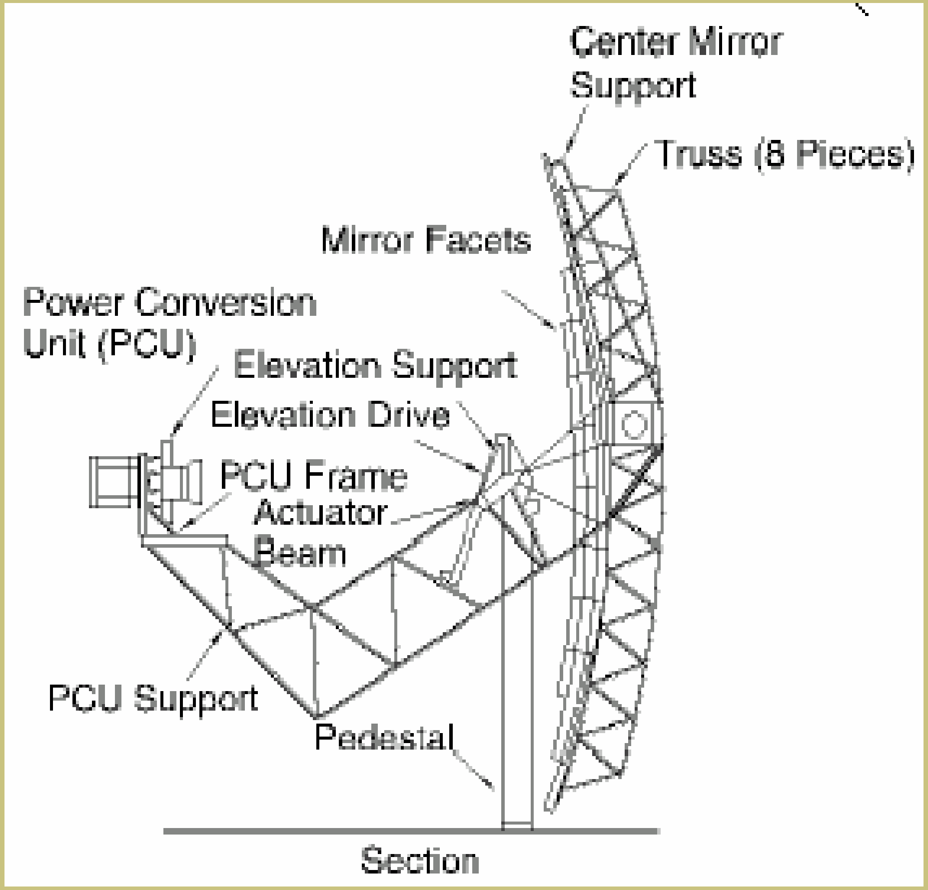
✓ *hybrid operation*

- Depending on the system and the site, dish/engine systems can reach the following targets:

✓ 1.2 to 1.6 ha of land per MWe installed

✓ system installed costs of 10,000 €/kWe for solar-only prototypes

✓ system installed costs of 1,000 €/kWe for hybrid systems in mass production



A Dish/engine system section

Comparison of major power producing solar thermal technologies

	Parabolic Trough	*Parabolic Dish*	*Power Tower*
Applications	Grid-connected power plants; process heat for industrial use.	Stand-alone small power systems; grid support	Grid-connected power plants; process heat for industrial use.
Advantages	Dispatchable peaking electricity; commercially available with 4,500 GWh operating experience; hybrid (solar/fossil) operation.	Dispatchable electricity, high conversion efficiencies; modularity; hybrid (solar/fossil) operation.	Dispatchable base load electricity; high conversion efficiencies; energy storage; hybrid (solar/fossil) operation.

Technical aspects having an impact on cash flows over the whole life of Solar Thermal Systems

✓*Factors affecting system performance*

- A Life Cycle saving analysis is applied for the calculation of the annual cost of fuel savings from the installation of a solar heating system. This requires a number of parameters concerning the thermal performance of the solar system and many economic factors.
- The *performance of a solar heating system* depends on:

✓ the local climatic conditions:

the availability of annual solar radiation in Europe ranges from 830 to 1660 kWh/m^2, a factor with a 2:1 variation.

Ambient temperature also has an important influence on system performance.

Solar water heating systems are potentially more cost effective the further south they are installed.

- ✓ collector area and type:

  the overall annual performance of a solar system is technically limited by the amount of energy that can be collected during the winter time, since a very high solar fraction is feasible in most locations in Europe during the rest of the seasons. Improvements in collector design can also have a significant effect on the overall system performance

- ✓ the thermal load:

  the heating load is a function of the *amount of hot water used*, the *delivery temperature* and the *cold water supply temperature*.

  The larger the load, the better the system will work.

  The amount of conventional fuel that can be saved by solar heating systems depends on the efficiency of the conventional water heater that would other-wise heat the water.

✓*Efficiency of solar thermal systems*

- The *efficiency of solar systems* depends on:

✓ the *efficiency of the solar collector*, and

✓ the *losses in the hot water circulation system*

The "*efficiency of a solar collector*" is defined as:

the amount of energy produced / the solar energy falling down on the collector

- Efficiencies are different for different collector types and depend on:

✓ the *solar intensity*

✓ the *thermal losses*, and

✓ the *optical losses*

➢ *In general higher losses mean lower efficiencies*

✓*Factors related to the environment*

(+): the operation of an active STSs minimizes the operation hours required by a conventional heating system during winter and between seasons; no operation of a conventional heating system is at all required during summer.

(+): environmental impact of materials used in manufacturing STSs: most suitable materials for the absorber are made-steel, aluminum and *copper* (both the pipe and the absorber are made of the same material, helping subsequent recycling)

(+): STSs are providing heating energy which otherwise would have been obtained from burning oil, gas or coal, at the point of use or at a power station.

(-): the space required for STSs: when solar collectors are installed on roofs, no additional space is required, but the situation is different when set on open land.

(-): whilst active solar heating technologies are generally “clean” in operation, the manufacturing, transport and installation of any system will necessitate the use of fossil fuels and hence the emission of greenhouse gases and pollutants

(-): the visual impact of STSs, especially when installed on historical or protected buildings, or in areas where conservation of the existing environment, natural or built is a sensitive issue.

Solar Thermal Systems Economics

✓*Initial investments required for solar thermal projects*

- Costs for SWH systems differ from country to country, even within the same country. They also depend on *hot water requirements* and the *climate conditions* in each area.
- The breakdown of an average sized natural circulation DHW system (ESTIF), is:

✓Materials: 33%,

✓Labour: 10%,

✓Promotion + general expenses: 43%,

✓Installation (labour and materials): 14%

- The life-cycle cost of a SWH system is lower than the one of a traditional heating system.
- The pay-back time for an investment in a SWH system depends on the prices of fossil fuels substituted by solar energy.
- The initial investment of solar systems includes the delivered price of the equipment, and installation costs. The total cost *C* of installed equipment is:

$$C = A * C_A + C_E$$

where,

C_A: the collector area dependent cost,

C_E: the cost of equipment that is independent of the collector area

✓*Other costs during the operation of solar thermal projects*

- An economic analysis must be carried out for a solar thermal project to determine whether the solar system is economically advantageous for the project.
- The operating costs of a STS are usually small compared to the costs of buying fossil fuels. Main operating costs consist of: *modest parasitic energy costs to drive and control the system* plus *repair and maintenance costs*. Nevertheless, fossil fuels must be supplied and paid for in proportion to the heat requirement. So, the user's benefit from a solar heat system is the saving in the expense of operating fuel. Maintenance and insurance are the recurring costs for keeping a system in operating condition and protected against fire or other losses.
- Property taxes are levied on many installations, tending to raise the life cycle cost of a solar heating system in relation to a conventional one.
- On the other hand, the income tax tends to reduce the life cycle cost of a solar versus a conventional system.
- Auxiliary energy costs: the fuel expense for running the auxiliary/back up energy source when requested.
- Parasitic energy, normally electricity, is required for the operation of pumps, blowers, and controls.

Key areas of project risks for STSs

✓*Correct sizing as a means to reduce risks*

- STSs must be *accurately sized* to avoid initial cost penalties for the owner STS should not be designed by rule of thumb
- Precise sizing based on *economic optimisation methods* is necessary to determine the economical size of a STS for a given application: "*find the point at which the sum of the solar and non-solar costs, is minimized*".
- The optimization procedure is facilitated by the *use of optimization models*. These require data inputs to calculate the building's energy requirements for heating or domestic hot water.
- Economic optimization requires the designation of some solar energy system design parameters, upon which performance of the system is dependent. Additionally, all costs and economic parameters associated with its operation must be considered.
- By determining the *life cycle costs of alternative system sizes* and the *life cycle savings associated with the performance of the system at each size*, the economically optimal collector size can be determined.

✓*Risks mitigation*

- There is no risk for a decision maker to choose well developed energy and water efficient DHW system design and components.
- The present generation of systems has proved to be reliable and systems usually have a lifespan of 15-20 years.
- It is more effective and cheaper to install solar systems during construction of new buildings or when an existing heating system or building is undergoing a major renovation.
- A "*Guarantee of Solar Results*" (GSR) scheme has been developed with support from the solar industry and the EC to combat the perceived risk of poor performance and to improve the quality of overall energy service provided: suppliers contract to compensate customers if the system fails to supply a designated minimum quantity of energy each year.
- The *ESCO contracts* are the preferred option for supply of solar heat to district heating schemes
- the "*Third Party Financing*" (TPF) scheme is basically applied to large scale applications for hot water production (e.g. in industry for process heat).

- The *TPF scheme* involves:
- the provision of the package of design and construction, as well as installation and maintenance from a specialized solar engineering organization (the *Project Office*)
- the *return of the invested capital* in proportion to the amount of measured solar energy supplied to the user, at a certain agreed rate
- the Project Office provides its *technical expertise* and carries out the *"business" of investing*, in order to supply the user with solar thermal energy
- throughout this financing scheme the *market expansion barriers are suppressed by the complete transfer of technical and financial risks to the Project Office*, which are:
  - ✓ *technical competence in designing, installing and maintaining successfully the solar plant*
  - ✓ *competence in rising the low cost capital from a third party, usually a financial institution*
- ❖ *The "TPF" in conjunction with the "Guaranteed performance" could be employed towards eliminating any perceived project risk.*