X International Conference
on Science, Arts and Culture

SUSTAINABLE ENERGY CHALLENGES AND OPPORTUNITIES

23-27 August 2010

Veli Lošinj, Croatia

ECSAC
European Centre for Science Arts and Culture

SOLAR THERMAL TECHNOLOGY

WATER HEATING (MARKET, BARRIERS AND EUROPEAN STANDARD) AND ELECTRICITY GENERATION

DR. VINOD KUMAR SHARMA
SENIOR SCIENTIST
ENEA RESEARCH CENTRE TRISAIA
E-MAIL: SHARMA@ENEA.IT

Research Centre Trisaia, Italy

Mr. Chairman, distinguished delegates, dear colleagues, ladies and gentlemen.

At the outset let me most heartily congratulate the organisers of this conference for organising this important event in a very critical area of **Energy and Environment**, an important Scientific topic that needs special attention by the scientific community World-wide and, more so, in the context of the developing countries.

World is certainly moving in this direction and let us commit ourselves, as well, to the development of pollution-free renewable energy technologies, as one of the most important instrument for the socio-economic development, eradication of poverty and unemployment in our countries.

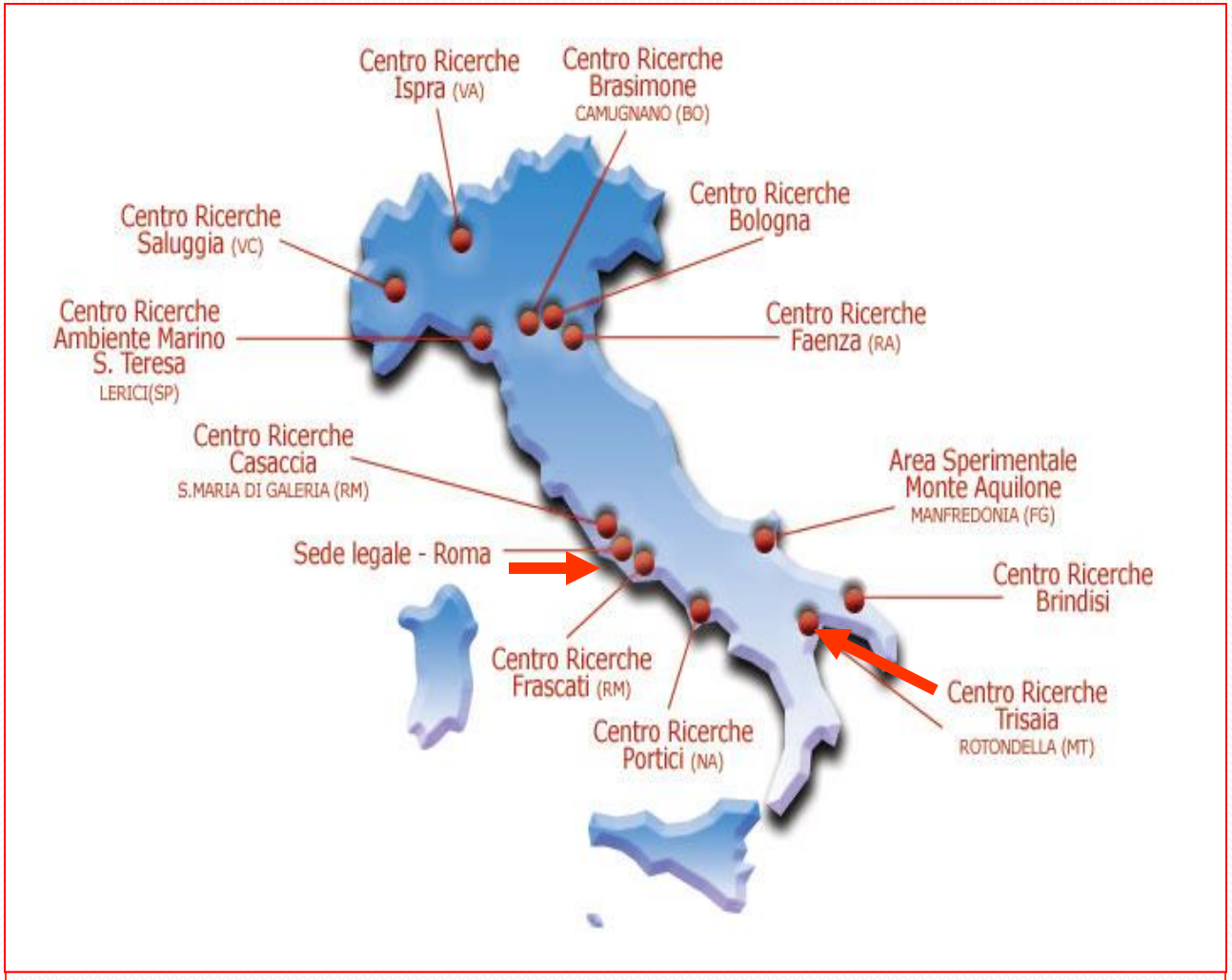
WHAT IS ENEA?

ENEA is the name for the **Italian National Agency for New Technologies, Energy and Sustainable Economic Development.**

The Agency's activities are targeted to research, innovation technology and advanced services in the fields of energy - especially nuclear.

ENEA performs **research activities** and provides **agency services** in support to public administrations, public and private enterprises, and citizens.

In order to achieve the main programmatic objectives, presently, the agency has nearly 3200 employee working in 13 different research centres located over the national territory. With its Head office, in Rome, The agency bases its operations on the development and application of innovative, leading-edge technologies, in which it has achieved excellence.



For the most part, the work is carried out in the framework of programmes aimed at strategic goals. To implement various research projects (involving the European union and other international organizations such as United nations and the OECD as well as nongovernmental organization on technology and applications of mutual interest) ENEA works with the:

- **Ministry of Industry;**
- **Ministry of Environment;**
- **University & Research and**
- **Agriculture and Cultural Resources**

ENEA also provide scientific and technological consulting and support to national and local governmental bodies in the solution of complex, urgent and serious problems, preparation of regulations, participation in international initiatives and projects.

ENEA's activities in Energy include:

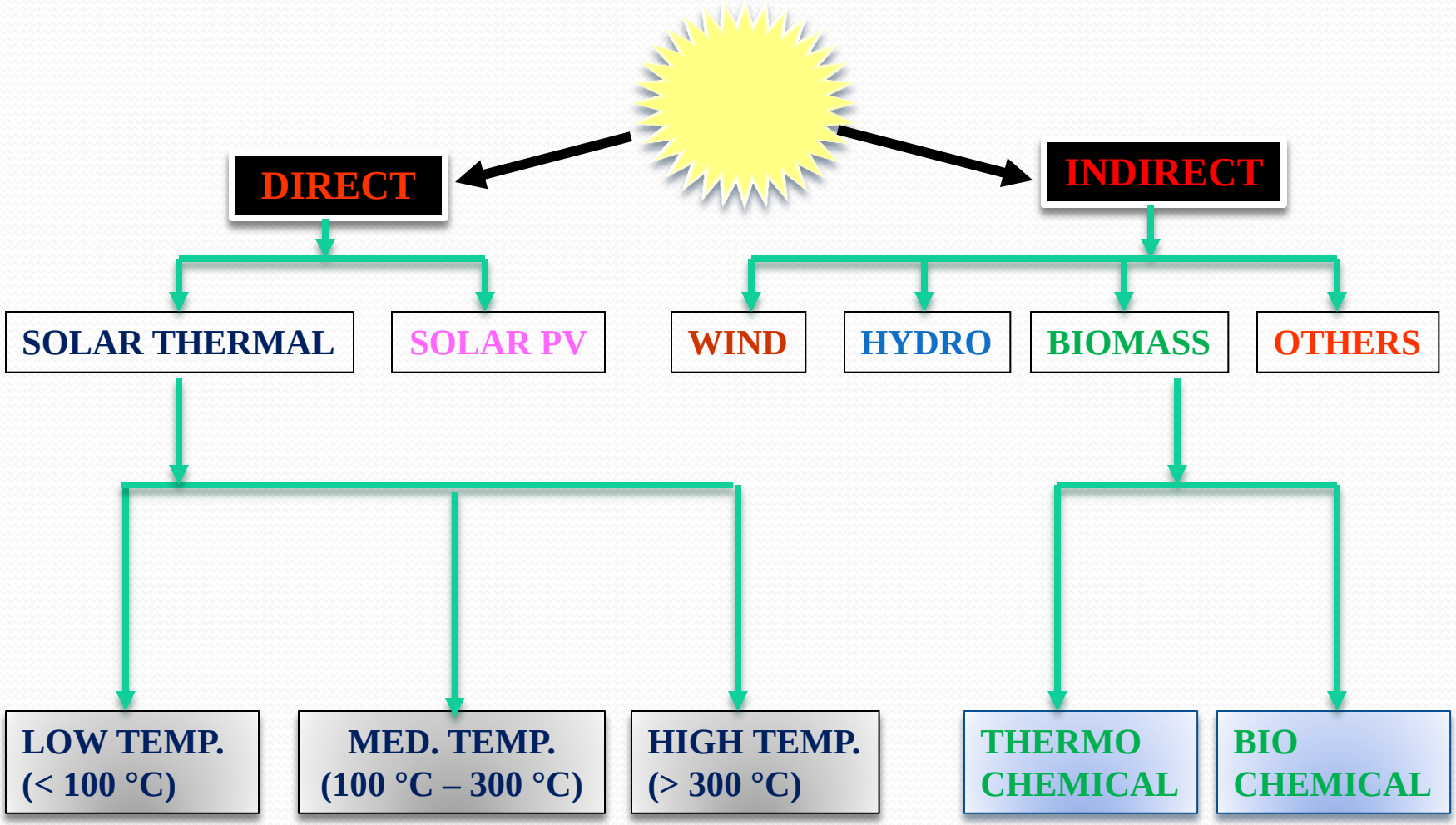
1. **Research** and development on alternative energy sources such as solar energy, wind energy, energy from biomass and organic solid waste, new materials for photovoltaic technology, etc.

2. **Development** of energy saving systems & components, energy systems and new technologies related to power generation, transmission and use.

3. **To** co-ordinate Italian national fusion Programme and conduct research in collaboration with the National Research Council and universities under an association agreement with EURATOM.

4. **To** conduct research on nuclear fission in collaboration with Italian National Electrical Utility (ENEL), industrial concerns and the universities. Development of innovative and high-safety reactor designs, efficient fuel-cycle technologies and decommissioning of older nuclear plants, are other topics of interest.

TRADITIONAL CLASSIFICATION OF RENEWABLES



Solar thermal energy is a technology for harnessing solar energy for thermal energy (heat). Solar thermal collectors are defined as low-, medium-, or high-temperature collectors.

Low temperature collectors are flat plates generally used for domestic water heating and swimming pools.

Medium-temperature collectors are also usually flat plates but are used for creating hot water for residential and commercial use.

High temperature collectors concentrate sunlight using mirrors or lenses and are generally used for electric power production.

Solar Thermal Energy is different from photovoltaic, which convert solar energy directly into electricity.

While only 600 megawatts of solar thermal power is up and running worldwide in Oct. 2009, according to Dr David Mills, another 400 megawatts is under construction and there are 14,000 megawatts of the more serious concentrating solar thermal (CST) projects being developed.

PART - 1

LOW TO MEDIUM TEMPERATURE SOLAR THERMAL COLLECTORS

RE-THINKING 2050: 100% RENEWABLE-BASED EU

The European Renewable Energy Council (EREC), outlines in its new report RE-thinking 2050 a pathway how the European Union can switch to a 100% renewable energy supply for electricity, heating and cooling as well as transport, examining the effects on Europe's energy supply system and on CO_2 emissions.

RE-thinking 2050, outlines a pathway towards a 100% renewable energy system for the EU as the only sustainable option in economic, environmental and social terms. It assesses how the different renewable energy technologies can contribute to a fully sustainable energy supply by 2050 provided there is strong political, public and economic support for all renewable energy technologies. "The potential benefits of a future based on renewable energy are multiple: mitigating climate change, ensuring energy security and creating sustainable future-oriented jobs.

Renewable energy deployment by 2020 will reduce annual energy related CO_2 emissions by about 1,200 Million tonnes against 1990 emissions.

By 2050 the EU would be able to reduce its energy related CO_2 emissions by more than 90%. This reduction would result in an additional total CO_2 benefit in 2050 of € 3,800 billion.

Higher upfront investment for renewable energy do pay off in the long-run, as the capital investment cost will be outweighed by the avoided fossil fuel and CO2 costs.

Considering pathway set out in RE-thinking 2050, it is estimated that the renewable energy sector will employ more than 2.7 million people in 2020 and about 4.4 million in 2030 in the EU.

By 2050, employment will bring 6.1 million people into work”.

“Clearly, the precondition for this to happen is that the commitment towards a 100% renewable energy system for the European Union needs to be established as the guiding principle for all European policies in the fields of energy, climate, R&D, industry, regional development and international cooperation”.

Achieving a 100% renewable energy fuelled economy is not a matter of availability of technologies, rather it is a matter of political will and of setting the course today for a sustainable energy future for the European Union.

“A 100% renewable energy society is one where the benefits greatly outweigh the costs, be it in economic terms or in social terms, and the renewable industry is ready to prove it”.

The world saw a rapid growth of the use of solar warm water after 1960. Technical innovation has improved performance, life expectancy and ease of use of these systems.

Installation of solar water heating has become the norm in countries with an abundance of solar radiation, like the Mediterranean.

Solar water heating systems have become popular in China. It is said that at least 30 million Chinese households now have one, and that the popularity is due to the efficient evacuated tubes which allow the heaters to function even under gray skies and at temperatures well below freezing.

Israel and Cyprus are the *per capita* leaders in the use of solar water heating systems with over 30%-40% of homes using them.

Today, low-temperature (<100°C) solar thermal technologies are reliable and mature for the market.

World-wide, they help to meet heating needs with the installation of several million square metres of solar collectors per year.

Solar thermal technologies can play a very important role in advanced energy saving projects, especially in new buildings and structures.

SOLAR COLLECTORS FOR WATER HEATING

- ⇒ **The conventional collector is the core element of a solar system for DHW or space heating.**
- ⇒ **Low temperature panels supply the carrier fluid at a temperature usually lesser than 80 °C.**
- ⇒ **Differently from concentrating collectors, conventional solar panels work with both direct and diffused irradiation, thus producing hot water in cloudy days also.**

Two large families:

Unglazed solar water heater

Glazed solar water heater

UNGLAZED SOLAR WATER HEATER

Working principle: **the water, flowing into the panels tubes, is instantly heated by the sunbeams and then sent to a storage tank or even directly to the final user**

- **low cost**
- **easy to install**
- **surrounding air temperature > 20 °C**
- **required temperature for water < 50 °C**
- **summer uses (camping, hotels, swimming pool, etc.)**

GLAZED SOLAR WATER HEATER

Working principle: **the panels tubes, in which the carrier fluid flows, are protected by a single or multiple transparent covering, made of glass or plastic, thus improving the performances thanks to the greenhouse effect**

Most common type:

flat plate collector

TUBULAR COLLECTORS

An advanced type of glazed collector:
Tubular collector

In this type of collector, the absorber strip is located in a pressure proof glass tube.

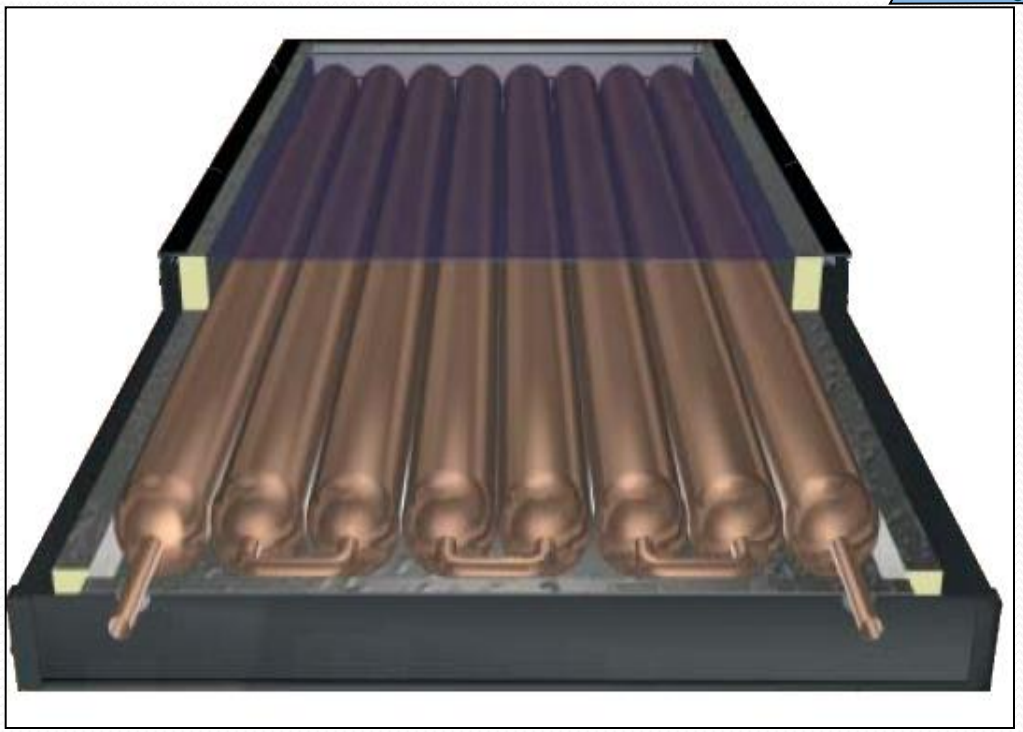
The heat transfer fluid flows through the absorber directly in a U-tube or in counter-current in a tube-in-tube system.

In case, superior performances are required, the air between the glass tube and the absorber inside it, is aspirated (evacuated tubular collector).

INTEGRATED COLLECTOR STORAGE

The Integrated Collector Storage system (ICS) also called batch water heater, is not a much widespread type of passive system.

The water is produced and stored inside the collector.



main remarks

- **suitable only for mild climates where there is no risk of freezing**
- **efficient heat transfer to the water**
- **superior simplicity, compactness, and economics**
- **unfavourable heat loss coefficient**
- **profitable storage only in the very short term**
- **typically used as a pre-heater to an existing gas or electric water heater**

SOLAR SYSTEMS FAMILIES: FACTORY MADE

Solar systems can be divided into 2 main categories:

Factory Made Systems

- **Pre-assembled by the manufacturer**
- **Natural circulation (thermosyphon)**
- **Single family**
- **Total area typically 4 ≤ m^2**

SOLAR SYSTEMS FAMILIES: CUSTOM BUILT

"Custom Built" Systems

- **Assembled with properly chosen components**
- **Forced circulation (pumped)**
- **Collective users**
- **Total area usually > 10 m^2**

SOLAR ENERGY FOR DISTRICT HEATING

District and block heating applications offers good conditions for the use of solar thermal for existing buildings and there are a number of demonstration plants with ground-mounted as well as roof-mounted collector arrays.

A major advantage is that the solar plant can be of considerable size that leads to lower specific costs. The largest solar district heating plant comprises 18.300 m^2 of collector area (~10 MW thermal capacity).

The main barriers to growth are low alternative fuel costs and lack of confidence for solar heating in thermal utilities. Once cost-effective seasonal heat storage will be widely available, large-scale applications will become more competitive, resulting in a strong increase of the potential for solar thermal.

COMBINED DHW AND SPACE HEATING (COMBISYSTEMS)

In Central and Northern Europe it has become common to install solar thermal systems that provide heat both for domestic hot water and for space heating.

The collector size of these so called combisystems is typically in the range of 7-20 m^2 and the tank(s) in the range of 300-2000 litres. Combisystems are often more complex, than solar systems supplying DHW only. As a consequence, system design must be adapted to the specific requirements of the building.

Different practices are used in different countries. In Southern Europe, combisystems are still rarely used, but there is a big potential for systems generating space heating in winter, air-conditioning in summer and DHW throughout the year.

SOLAR THERMAL FOR COOLING

The trend to architecture with greater glass surfaces and growing comfort demand made the energy consumption for air-conditioning increase dramatically in the last years. In some country this has already led to an electrical grid overload and break down. This dread and the need to reduce green house gases for electricity production make the introduction of cooling with renewable energy sources indispensable.

In the end of last century it was still common view that solar cooling would only be profitable through photovoltaic driven compression cooling machines. However, as paradox as it might sound, the fact remains that cooling with solar thermal is feasible.

Optimized collectors, the improvement of other components and an enhanced system design made solar thermal cooling mature to a real technical alternative.

"Conventional" compression cooling systems just like heat driven cooling machines use the same physical principle. When a substance evaporates it removes energy from the surface it's been on, thus cools it. In a thermal cooling cycle evaporation is driven by the tendency of the substance, the so called refrigerant, to dissolve in/on a sorbent. But when concentration is to high, the sorbent has to be regenerated, by driving out the refrigerant with heat, e.g. with solar thermal.

PART - II

STANDARDS AND CERTIFICATION

STANDARDS AND CERTIFICATION

Ensuring a high quality solar thermal products is important for the industry. Standard test methods exist to check durability, safety and performance. These procedures are specified in European Standards (EN). The Solar Keymark certifies that a solar thermal collector or a factory-made system complies with the relevant European Standard..

National and regional subsidies are given in most places all over Europe, *but* only if the products are certified – and, the common European level of certification is already the requirements in the new European standards. Solar Keymark states conformity with these European standards and is valid almost all over Europe.

The Solar Keymark, valid all over Europe **will be necessary for obtaining subsidies.**

SOLAR KEYMARK

(Development and dissemination of standards and certification)

European Standards were published in 2000 for solar thermal collectors (EN 12975) and factory-manufactured systems (EN 12976). Very soon standard series EN 12977 will be available for custom built systems.

These standards specify how a product should be tested to assess its durability, safety and performance. Results from an accredited test laboratory are often required by financial incentive schemes to ensure good quality products.

And increasingly a Solar Keymark certificate is requested to attest to the compliance of a solar thermal product with the relevant EN standard.

Further information on the solar thermal EN Standards is available on the Solar Keymark website at http/www.solarkeymark.org

“QUALITY ASSURANCE” IN SOLAR THERMAL

The “Quality assurance” corresponds

SOLAR COLLECTORS ⟷ **Standard EN 12975**

Factory Made
SOLAR SYSTEMS ⟷ **Standard EN 12976**

Avvia il browser Internet Explorer.lnk

Custom Built
SOLAR SYSTEMS ⟷ **Standard ENV 12977**

STANDARDS FOR SOLAR THERMAL PRODUCTS

EN 12975-1:2006. Document title Thermal solar systems and components -Solar collectors- Part 1: General Requirements. CEN publication date 2006-03-29
EN 12975-2:2006. Document title Thermal solar systems and components -Solar collectors- Part 2: Test methods. CEN publication date 2006-03-29

EN 12976-1:2006. Document title Thermal solar systems and components - Factory made systems - Part 1: General requirements. CEN publication date 2006-01-25.
EN 12976-2:2006. Document title Thermal solar systems and components - Factory made systems - Part 2: Test methods. CEN publication date 2006-01-25

CEN/TS 12977-1: 2010 Thermal solar systems and components - Custom built systems - Part 1: General requirements for solar water heaters and combisystems

CEN/TS 12977-2 : 2010 Thermal solar systems and components - Custom built systems - Part 2: Test methods for solar water heaters and combisystems

EN 12977-3: 2010 Thermal solar systems and components - Custom built systems - Part 3: Performance test methods for solar water heater stores

CEN/TS 12977- 4: 2010 Thermal solar systems and components - Custom built systems - Part 4: Performance test methods for solar combistores

CEN/TS 12977-5: 2010 Thermal solar systems and components - Custom built systems - Part 5: Performance test methods for control equipment

TEST SEQUENCE FOR SOLAR COLLECTORS

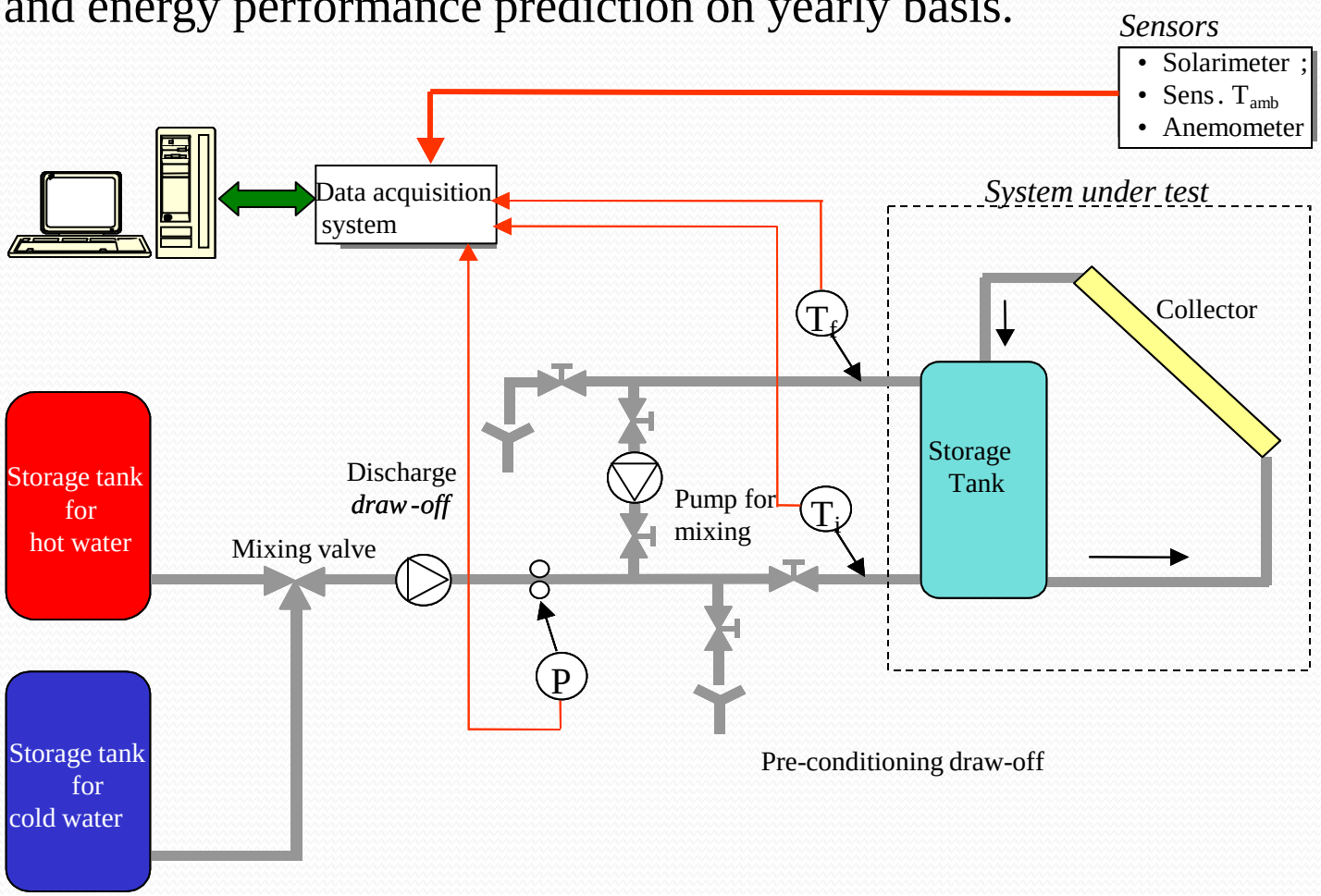
Standard EN 12975:

- Internal pressure
- High-temperature resistance
- Exposure test (dry stagnation)
- External and Internal thermal shock
- Rain penetration
- Internal pressure (retest)
- Mechanical load
- Thermal performance (efficiency test in steady-state and transient condition, time constant, thermal capacity, Incident Angle Modifier, pressure drop)
- Impact resistance (optional)

TEST FORESEEN AS PER NORMS FOR THE SYSTEMS

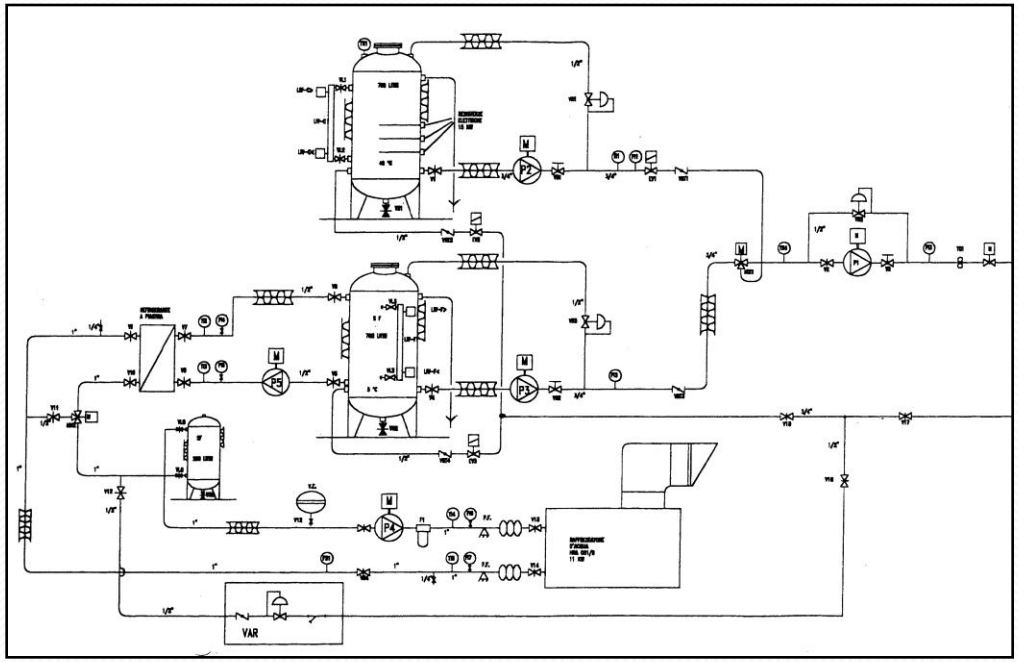
Standard EN 12976:

- outdoor characterization based on daily performance and energy performance prediction on yearly basis.



SYSTEM TEST FACILITIES

The plant allows the simultaneous performance characterization of two SDHW systems arranged in parallel.
The equipment consists of a control system that adjusts water temperatures and flow rates at the inlet of solar systems.



The adjustments are accomplished through digital PID, provided by self-tuning and controlled through a PLC.

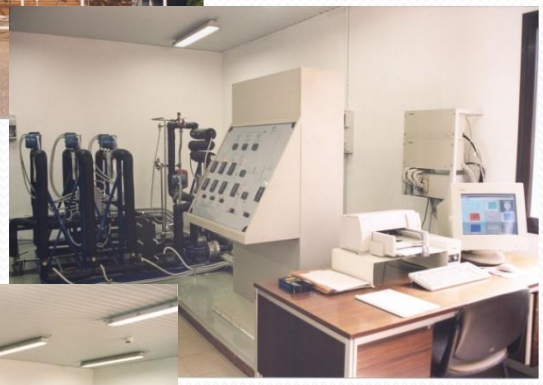
A fully automatic data acquisition system controls the different sections of the plant and collects thermo-hydraulic and meteorological data.

SOLAR ENERGY LABORATORY

External area of Laboratory

Solar Collector and Overall System Test Laboratory at ENEA Research Centre Trisaia

Collector Test Facilities



Factory Made System Test Facilities

The Laboratory performs:

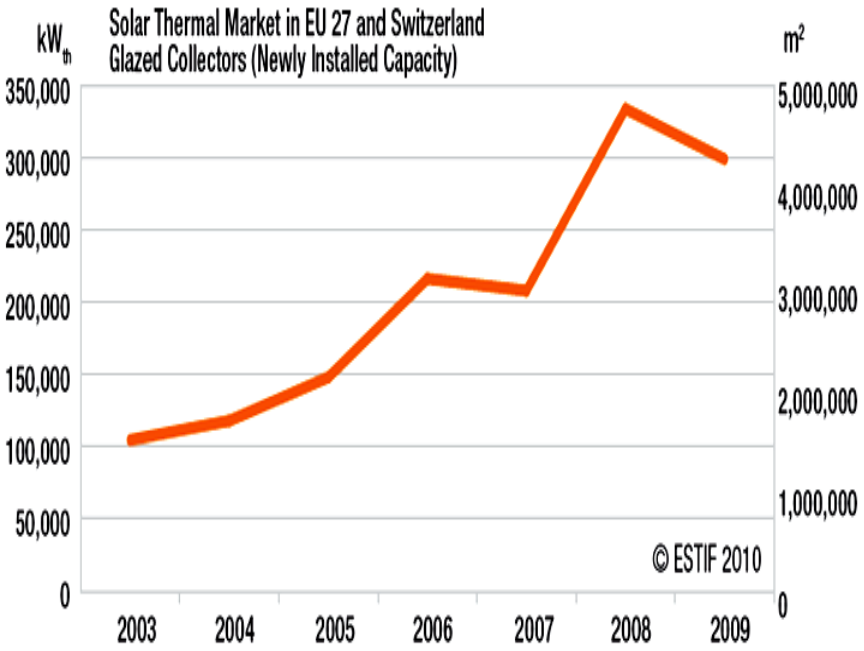
- efficiency tests both on glazed and unglazed solar collectors according to European (EN 12975) and international (ISO 9806-1 and 3) standards;
- qualification tests (Internal pressure, Internal and External thermal shock, etc.) according the same standards.

Furthermore the Laboratory is able to assess the daily and annual performance of solar domestic hot water systems according to **EN 12976** and **ISO 9459/2** standards.

Solar Thermal Markets in EU 27 and Switzerland (Glazed Collectors)

Following an outstanding growth in 2008, the European solar thermal market decreased by 10% in 2009. Our initial forecast reflected the alarming news on the economic front as well as the concomitant recession in the building industry, and had prepared us for the worst. Finally, the market performed better than expected and for the second year in a row, over 4 million m^2 of solar panels were sold in Europe.

The outlook for 2010 remains uncertain while the financial and economic crisis continues to have a negative impact on both public spending and incentive policies. It is anticipated that the main markets may be adversely affected by lack of government incentive programmes and stagnation in the construction sector. However, this is likely to be offset by the effect on national policies of the RES directive (2009/28/EC) implementation and also because renewable heat incentives are already firmly on the agenda in several European countries. Interestingly enough, and surely another positive sign, large solar installations seem to be unaffected by the market downturn and are gradually consolidating their market share.



SOLAR THERMAL TECHNOLOGY IN ITALY

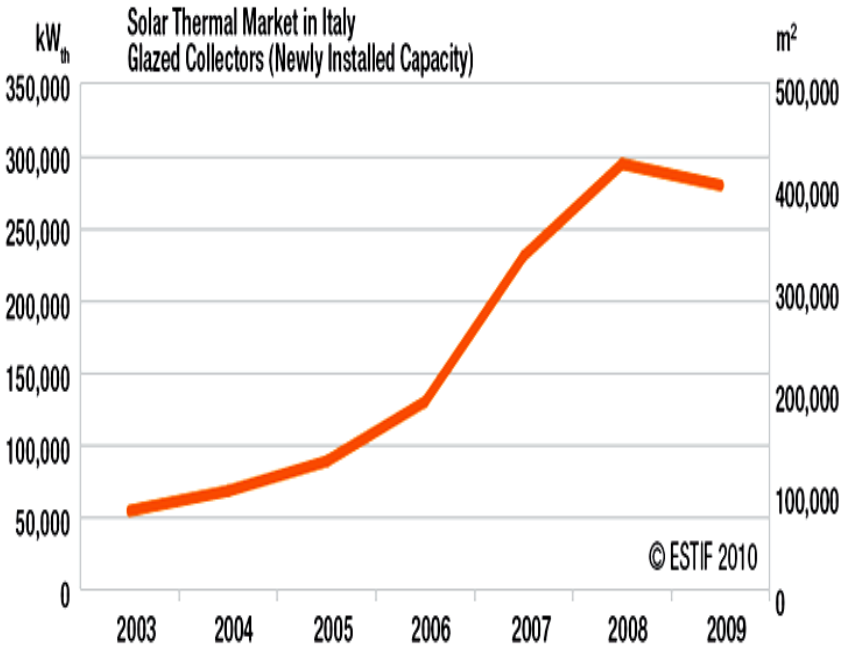
In 2008, we saw an impressive development in our market. Solar thermal heating and cooling solutions are gaining favour. While much of the market is in one- and two-family houses, demand by housing companies, office building operators and other commercial users is increasing significantly. Three factors are mainly responsible for the strong growth in solar thermal energy usage:

- Decision-makers realize that gas, oil and electricity are not a longer-term option.
- Building codes are more and more requiring the use of renewable energy and solar thermal offers a cost-effective solution.
- Solar thermal technology is widely available and is supported by a broad range of companies – from small installation companies to the leading heating equipment manufacturers, solar thermal is nowadays offered for all kinds of applications.
- Of course, to attain satisfactory adoption rates of solar thermal, a lot remains to be done. Further investment in market development will certainly leads to more buildings being equipped with solar thermal collectors.

The new European Renewables Directive aims at realising the European target of having 20% of all energy demand supplied from renewable sources in 2020. For the first time, heating and cooling – which account for almost 50% of the total energy demand – are covered by a European Directive. It is now up to the Member States to implement the Directive effectively and quickly.

Italy

Italy is now the second largest market in Europe, and much more stable than other emerging European markets. Compared with 2008, the Italian market has decreased by 5% in 2009, with 280 MW_{th} of newly installed capacity (400,000 m^2 of solar thermal collectors). Due to its geographical location and to its high-energy dependency (86,8% in Italy compared with a European average of 53,8%), this market still represents a very strong potential for solar thermal. The major growth in recent years can be credited to a 55% tax rebate covering various energy efficiency measures in existing buildings, including solar thermal installations. These provisions will remain in place until the end of 2010 and the experts predict a steady performance for this year. In the event that this measure is not maintained in the next years, this emerging and important market could face though an important slow down.



PART - III

SOLAR THERMAL – FUTURE R&D

SOLAR THERMAL – FUTURE R&D

The future R&D needs can be divided into two groups

- **FUTURE R&D NEEDS FOR MARKET PULL**

- **FUTURE R&D NEEDS FOR TECHNOLOGY PUSH**

FUTURE R&D NEEDS FOR MARKET PULL

AREA	MEASURES
LARGE SCALE SYSTEMS	promotion in the tourist and multiple-family house sector, together with promotion of use in combination with biomass district heating scheme **Demonstration** (including installations implementing the Guarantee of Solar Results scheme)

FUTURE R&D NEEDS FOR MARKET PULL

AREA	MEASURES
SPACE HEATING/ COOLING	Demonstration
INDUSTRIAL USES	Demonstration

FUTURE R&D NEEDS FOR TECHNOLOGY PUSH

Following R & D needs for technology push are necessary in all areas.

* **TECHNICAL AND ECONOMIC OPTIMISATION OF SYSTEMS**
* **COST REDUCTION (ESPECIALLY FOR SPACE HEATING SYSTEMS)**
* **DEVELOPMENT OF DESIGN ASSISTANCE SERVICES**

BESIDE THE ABOVE-MENTIONED GENERAL R&D NEEDS, IT IS NECESSARY TO DEVELOP NEW TECHNOLOGIES FOR COOLING SYSTEMS.

PART - IV

HIGH TEMPERATURE SOLAR THERMAL COLLECTORS FOR ELECTRICITY PRODUCTION

The ENEA's Way to Concentrating Solar Power

ENEA Concentrating Solar Energy Program Main Objectives

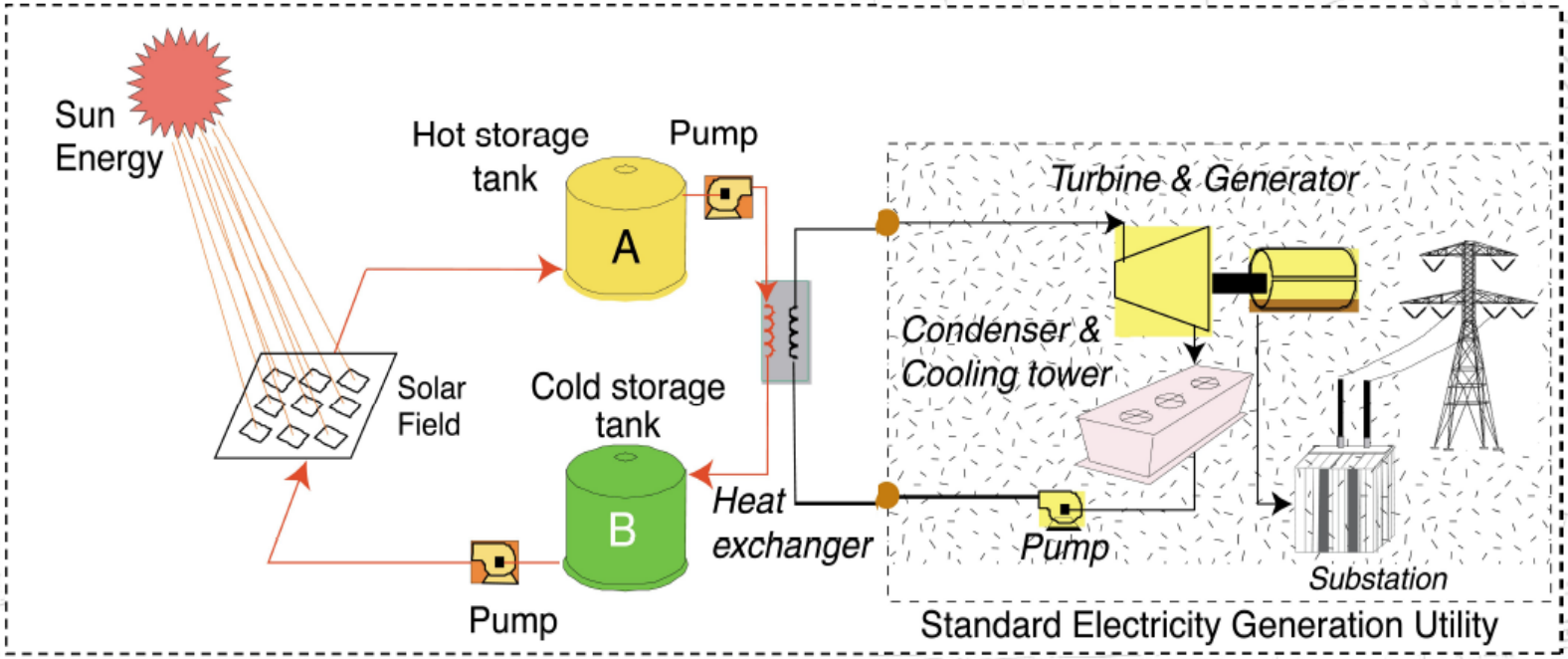
Since 2001, a vigorous ENEA programme has been launched on two main subjects. Both activities are suitably funded and organised as large projects:

- Medium temperature (about 550°C) heat collection and storage, primarily intended for electricity production.
- High temperature (greater than 850°C) heat collection for direct hydrogen production.

Both these applications are of priority strategic interest, in terms of their impact on the national energy and environmental sectors, as well as in terms of technological innovation aimed at increasing the competitive edge of the Italian companies.

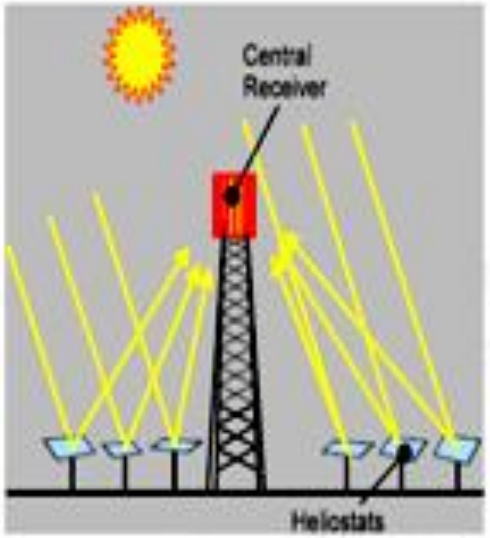
Why we need Concentrating Solar Power (CSP)

- The inherent advantage of CSP technologies is their unique integrability into conventional thermal plants: all of them can be integrated as " a solar burner" in parallel to a fossil burner into conventional thermal cycles

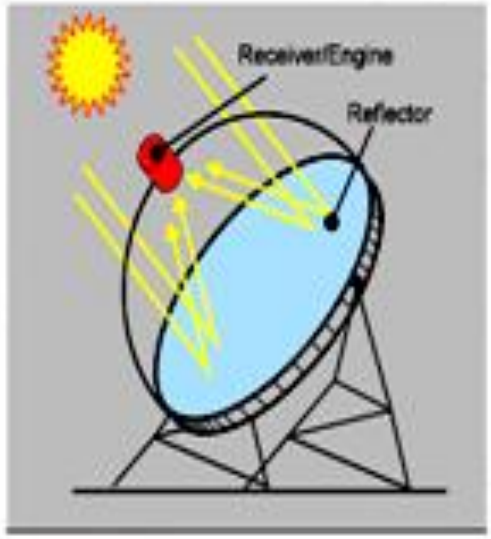


Why we need Concentrating Solar Power (CS)

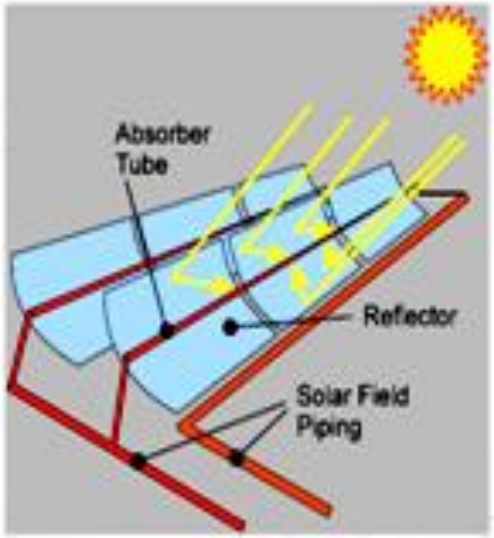
- With thermal storage solar thermal plants can provide firm capacity without the need of separate backup power plants and without stochastic perturbations of the grid



Central Receiver Systems



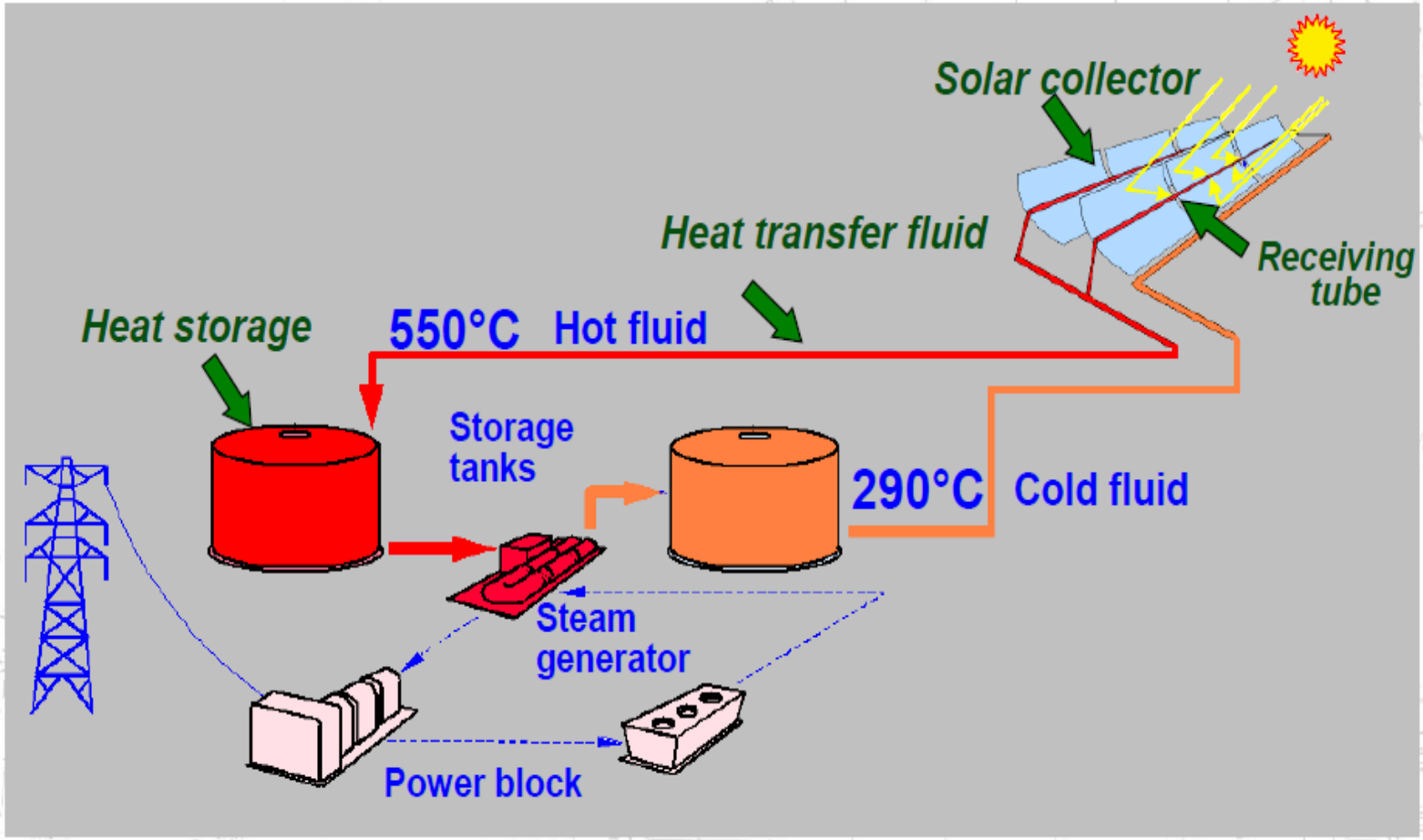
Dish-Stirling Systems



Parabolic-Trough Collectors

ENEA design introduces relevant improvements to the current technology

- The introduction of an adequate energy storage
- The use of an alternative transfer fluid
- A new solar collector design
- An innovative receiving tube design



ENEA Roadmap: by labs to industrial demonstration (10 years)

Industrial Demonstration plant

Test facility PCS

Lab R&D

2001 Project Start-up

2002

2003 Prototype Design

2004 Prototype Operation start-up

2005

2006

2007

2008

2009

2010

Components test and qualification

Demo design and construction

Industrial role

Government role

70 employers

WORLD'S FIRST SOLAR POWER PLANT

THE ARCHIMEDES PROJECT

WORLD'S FIRST SOLAR POWER PLANT INAUGURATED, IN ITALY (JULY 15, 2010)

The Archimedes project combining the best technology of today with that of tomorrow consists of a solar field, a storage system and a steam generator, is the first of its kind in the world. In the modular solar field the solar energy is collected in 360 linear parabolic collectors. The movable collectors are arranged in parallel rows each forming a single string.

ENEA introduced a new fluid heat carrier (molten salt eutectic mixture, 60% $NaNO_3$ - 40% KNO_3) in order to increase the operating temperature and the possibility of storing heat.

Another innovation of ENEA is the design of a new type of concentrator based on thinner mirrors that saves construction and installation costs.

The use of large scale heat storage (another innovation in the Archimedes project) enable the plant to provides heat to the steam generator at a constant rate 24 hours a day, regardless of variations in solar energy availability.

The steam generator consists of ‘tube and shell’ heat exchangers in which heat is transferred to water to produce super-heated steam for use in a conventional thermoelectric plant.

5 megawatt capacity solar plant costing nearly 60 million of Euro, has a unique characteristic to collect and conserve thermal energy of the sun for many hours thus enabling the plant to generate electricity both during off sunshine hours and the overcast sky.

It is true that cost for kWh produced is nearly five or six times more compared to cost of energy generated using conventional fuels but with 2.100 tons of oil saved and 3.250 tons of carbon dioxide emission reduced in a year, the present achievement is certainly an important milestone.

CONCLUSIONS

The importance of increasing use of renewable energy sources, especially the solar energy, in the transition to a sustainable energy base has been well recognised Worldwide. Since heat accounts for nearly half the final energy demand (required mainly for low to medium temperature applications) needless to say that significant contribution will be needed from the solar thermal systems to meet the substantial share of ever increasing energy demand for solar heating as well as solar cooling applications.

It is true that during the past quarter century, a significant effort has gone into the development, trial, induction and promotion of solar energy (covering varieties of applications) but truly speaking lots of R&D efforts still needs to be undertaken to exploit fully the large potential of solar energy use in both the domestic and industrial sectors.

Keeping in view the large scope for R&D collaboration, possibilities for the exchange of technical know-how (especially, in the field of solar thermal at low-medium temperature) together with significant financial contribution available from different financing institution such like World Bank/GEF and Kfw of Germany, it is highly recommended that appropriate initiatives must be taken at the Ministerial level to establish scientific contacts, seek investment by foreign investors and promote solar business.

ACKNOWLEDGEMENTS

Author of this paper would like to express his sincere thanks to Ing. Giacobbe Braccio, Ing. Agostino Iacobazzi, Ing. Mauro Vignolini and Ing. Domenico Marano, for their valuable cooperation.

THANKS

FOR

KIND ATTENTION

Max temperature in the solar plant

	T real	T max
	C	C
Flat collector 	122	-
Parabolic trough 	630	1.230
3D system 	2.330	5.330