THE ROLE OF HISTORY IN REDISCOVERING THE LOST CULTURE OF SOLAR ENERGY

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Abstract

This paper presents an update regarding the ongoing project of an Italian Archive and Museum on the History of Solar Energy, i.e. the energy contained in the direct and diffuse energy radiated every day from the Sun to Earth as well as its indirect forms of air and water currents and forests and other forms of biomass resulting from photosynthesis. The purpose of the Archive and Museum is to make available literary sources and archeological evidences of significant inventions for the use of solar energy preserved at Italian historic sites and Museums.

The focus of the Solar Archive and Museum (SAM) is on two solar ages: the primitive or ancient solar age, from antiquity up to 200 years ago, essentially based on empirical solutions, and the modern or future solar age, which has just begun, based on the knowledge and methods acquired from the scientific and technological revolutions of the last 500 years, primarily on the understanding of the composition of light and how it can be manipulated for producing steam, electricity, and fuels.

Keywords: *Solar energy, solar light, solar energy history, Italian solar energy pioneers, solar heat, solar steam, solar electricity, solar fuels, solar energy in agriculture, solar energy in architecture and urban planning, climate change, solar culture, solar education.*

1. Introduction

The 50th anniversary of the first international solar congress in 1955 in Arizona was celebrated in Florida (USA) on the occasion of the ISES SWC 2005. A book on The Fifty-Year History of the International Solar Energy Society and its National Sections was published in two volumes (Böer, 2005). This celebration emphasized an interest in the history of solar energy use, which in Italy has continued to be promoted and developed over the last ten years by the Italian Group for the History of Solar Energy (GSES, www.gses.it).

The recorded history of solar energy use by humans is a discipline that crosses many years and many disciplines. The work of GSES focuses on what it considers to be two distinct solar ages: the ***primitive or ancient solar age***, from antiquity up to 200 years ago, essentially based on empirical solutions, and the ***modern or future solar age***, which has just begun, based on the knowledge and methods acquired from the scientific and technological revolutions of the last 500 years, primarily on the understanding of the composition of light and how it can be manipulated for producing steam, electricity, and fuels.

GSES has placed special attention on research concerning discoveries and inventions that have had a great impact over centuries and millennia, which are likely to have a lasting impact on human life for much time to come.

Another important area of research for GSES has been that of the many events marking the past few decades with hopes as well as disappointment of those who expected major summits and international conferences to result in concrete programs.

The UN adopted programs, such as "Nairobi Programme of Action for the Development and Utilization of New and Renewable Sources of Energy" in the eighties and Agenda 21 following the 1992 UN Conference on Environment and Development (UNCED) held in Rio de Janeiro, are nowadays for the most part forgotten.

The cycle of major summits and international meetings continues. In 2015 there is a great deal of attention by science, business, environmental and media communities on events by international and national institutions such as the four listed below:

- Year of Light and Light-based Technologies (IYL 2015), http://www.light2015.org/Home.html
- International Year of Soils, http://www.fao.org/soils-2015/en/
- Universal Exhibition, Feeding the Planet, Energy for Life, http://www.expo2015.org/it
- 21st Session of the Conference of the Parties to the UNFCCC, http://www.cop21.gouv.fr/fr

Selection and/or peer review under responsibility of Scientific Committee
doi:10.18086/swc.2015.09.08 Available at http://proceedings.ises.org

The topics of these four events, in principle, are all closely related and linked to solar energy. In practice, however, the lack of communication and interaction among the four events, treated as separate subjects, shows that the challenges we are facing today are not only specific, technical and scientific issues, but first and foremost cultural. Our lack of capacity to connect various topics to others, in order to understand the key problems that world faces, from climate change, to energy and scarceness of resources, to poverty, geopolitical conflicts, etc..

The use of solar energy is an age-old experience marked by fundamental discoveries in different ages, to artificially convert it into other useful forms for human beings: food, heat, fuel, mechanical energy, chemical energy, and, more recently, since the late 1800s, electricity from hydro, wind and light energy directly or indirectly coming from the Sun.

The introduction and diffusion of fossil and nuclear fuels derailed the solar energy civilizations developed over millennia, which were built on the basis of centuries old inventions that are still valuable in our lives today.

The ***primitive or ancient solar age*** was characterized by discoveries such as: fire, which enabled humans to use the solar energy stored in forest wood and other forms of biomass; agriculture and the first human settlements; solar architecture and urban planning, in which streets and buildings were oriented so as to exploit the sun's light and heat directly and naturally as well as to protect inhabitants from the sun's rays, a concept used over and over and handed down for centuries by all civilizations.

One important example of this is the Romans' discovery of transparent window-pane glass in the first century A.D., to bring daylight inside buildings and at the same time preventing cold and winds from entering them.

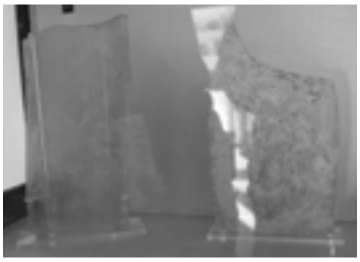

Fig. 1: Flat transparent window-pane glass from Pompeii, 1st century A.D. to capture sun's light and heat for houses and baths (Photo National Archaeological Museum, Naples, Italy)

These discoveries evolved over the ages and are still of the greatest importance in our daily lives. Think of the millions upon millions of window-panes that provide day lighting to homes and workplaces all over the world, thereby saving on artificial light from electricity generated by fossil and nuclear fuels. Think of the role of solar energy as a primary and principle source in farming. Think of solar architecture and urban planning that have shaped entire territories, from small villages to large cities, as well as the construction of buildings.

Fig. 2: An aerial view of Spello, a typical Italian small town, whose shape and relationship with the surrounding farmland is a clear reminder of its past. Ancient cities' near total dependence on solar energy set a limit on their size (Photo G. Reveane, 1993)

Prior to the discovery of fossil fuels and the beginning of the industrial revolution, human civilizations subsisted for thousands of years exclusively on solar renewable energy in its direct and indirect forms, in Italy up to 100-150 years ago. Therefore, the importance of the sun is deeply engraved in the history of our living and working environments, in large cities and small towns, in rural areas and their landscapes.

An example is illustrated by the photograph in Fig. 2, which shows the small Umbrian town of Spello, surrounded by farmland, where the production of food and its transportation to the places of consumption depended entirely on solar energy. Spello and the hundreds of similar towns throughout Italy, show us how it was possible in the past to develop "solar energy systems" in which the built environment and the agricultural fields around it worked together as a “whole” relying exclusively on solar energy, even though in a "primitive or ancient," way, namely on an empirical basis.

This ancient renewable-solar-energy “system” still exists in our modern world. It is like an ancient “solar soul” we are used to, that we take for granted, nearly forgotten, certainly not accounted in official energy-use and economic data statistics, it is fully part of us. In fact, this solar heritage, even if widely present in modern societies and in our daily life, is often unnoticed and unknown.

In the last century people saw the rapid growth of a new energy infrastructure based on abundant use of fossil and nuclear fuels and with it, the growth of cities’ in size and population. Urbanization and mega cities, and the depopulation of rural areas became the sides of the same coin.

Over the last decades, hundreds of millions of people throughout the world left their villages and moved to cities in search of new opportunities and welfare.

“With 75 per cent of Chinese expected to be living in cities within 20 years, the demand for more transport, energy, water and other vital infrastructure is set to test resources and city planners” (Simpson, 2012).

Fig. 3:The city of São Paulo, Brazil. With about 20 million inhabitants, it is one of the most populated cities in South America. We can only imagine, but we can not see the farm fields that produce food for the city as in the case of Spello in Fig.2. Photo www.scattidigusto.it (2014).

A trend that started with the discovery and diffusion of fossil fuels continues today everywhere in the world. According to experts, urbanization is an irreversible phenomena. Is it really? We will consider this question again in the Section 6 Habitat and Agriculture.

According to The United Nations Population Fund, “Urbanization has the potential to usher in a new era of well-being, resource efficiency and economic growth. But cities are also home to high concentrations of poverty. Nowhere is the rise of inequality clearer than in urban areas, where wealthy communities coexist alongside, and separate from, slums and informal settlements” (UNFPA, 2015).

Our grandparents and great-grandparents would certainly never have imagined a transition from solar energy to fossil and nuclear fuels in the proportions we see today. It’s impossible to imagine what the world might look like in 2100. However, we should ask ourselves whether it’s reasonable to think of an epochal transformation in which our industrially and technologically advanced societies make the switch to a ***modern or future solar age***, in which we return to the exclusive use of solar energy.

History can have an important role in helping and educating us in rediscovering the lost culture of solar energy, making it possible to power advanced societies only with solar energy.

In the following pages we treat five topics seen in a historical perspective, enriched here and there with information from The Italian National Archive and Museum on the History of Solar Energy:

- Terminology concerning energy sources on Earth;

- Earth systems and science;
- Ancient and modern solar ages;
- Solar or nuclear in the 1950s and today;
- Habitat and agriculture.

2. Terminology concerning energy sources on Earth

An important aspect in dealing with solar energy is represented by the continuous change of the terms we use when referring to it in different periods of human existence on our planet.

Energy, Solar Energy, Renewable Energy, wind energy, hydro energy, biomass etc., are common words for us today. It is very likely that they would not be understood just a few decades ago, even by the most educated people, and they were not known at all by our most recent ancestors.

What about the future? As we see it, the current terminology, though widely used, is still far from being valid for the promotion of solar energy use.

Indeed, the term “renewable energies” leads people to believe that various energy forms, such as wind, biomass, hydro, each originate from different source, with their own market niche and technology, whereas in reality they all come from the same source - the Sun. The more the solar market and technologies are integrated and promoted as a whole, the better they can be understood and defended from other proposed energy sources. There have been extraordinary developments on our understanding of how the Earth works and of its relationship with our life and the radiant light energy from the Sun. We need to develop the terminology to reflect these developments.

At the beginning of the 1900s, the Italian chemist Giacomo Ciamician (1857-1922), founder of the Institute of Chemistry of Bologna, Italy, which bears his name, in his famous speech, "The photochemistry of the future” (Ciamician, 1912), called the energy coming from the Sun *current solar energy*, i.e. the energy that the earth receives from the sun every day to distinguish it from *fossil solar energy*, i.e. solar energy accumulated by nature over centuries. Ciamician asked himself: “Is fossil solar energy the only energy source that may be used in modern life and civilization? He then concluded that it would be better to use the daily “current solar energy.”

In 1951, on behalf of the USA Atomic Energy Commission, Palmer Putnam conducted a study on the future energy for the period 1950-2050. He grouped energy sources on Earth into three broad categories: a) capital energy sources (coal, oil, gas, etc.); b) Income energy sources (direct and indirect solar energy and other forms of income energy); c) nuclear fuels. The language used by Putnam implies an economic characteristic for sources a) and b).

Fossil fuels are a "capital" created for us by the savings made by nature over millions of years. The use of “renewable energy” is an income energy that comes from the Sun and it does not undermine the consistency of our annuity that is available for us and will be for future generations. The terms used by Putnam have by now been forgotten.

The term "renewable energies" came into common use in 1981, when the United Nations organized the Nairobi Conference on New and Renewable Sources of Energy in Kenya. Its predecessor, the 1961 U.N. Conference on New Sources of Energy in Rome (Italy), presented solar, wind and geothermal energy as if they were new sources, while they had existed on Earth from the start.

Agostino Capocaccia from the University of Genoa (Italy) in 1972 reminds us that for centuries man used only *surface energies* (living beings, water, wind, wood). In the last two centuries, *energies of darkness* (coal, oil, endogenous forces, uranium), responsible for most of the pollution, have taken over. He also gathers energy resources on Earth in energies with limited supplies and energies with an unlimited supply (Capocaccia, 1972).

Most of the terms reviewed above became obsolete after the first oil shock of 1973, with the introduction of the term "alternative energy", still often used to indicate the energy from the sun, but at the time referring to all forms of energy alternatives to oil, including nuclear power.

As this brief review shows, energy forms have been referred to by different names at different times. Currently, the most prevalent terms contain the word “renewable” or “solar”.

However, drawing inspiration from "The International Year of Light and Light based Technologies," proclaimed by the United Nations for the year 2015, we might want to consider using more widely another word: LIGHT! Over the past five hundred years giant steps have been made in the understanding of what light is and how light works by great scientists such as Galileo, Leonardo da Vinci, Newton, Huygens, Maxwell, Planck and Einstein.

More information on these developments can be found at the web site of the International Year of Light and Light Based Technologies (www.light2015.org) and at the GSES web site www.gses.it, devoted to the Year of Light, in particular the articles in English published in Clean Technica (Perlin, 2015).

The explanation of the photoelectric effect by Einstein contributed to underscore other aspects of the structure of the atom, the nature of light and the electrical origin of the cohesive forces in molecules and matter. All this has opened fascinating prospects for the use of direct solar energy in the modern or future solar age, from solar photovoltaic cells with efficiency ratings of 50% or more to smart glass, photon solar architecture and city planning.

We might propose to gather energy sources on Earth in two categories:

- ***Light energies***, energies from the direct or indirect solar radiation: those above the surface of the Earth, that include direct and diffuse solar radiation and indirect air and water currents, naturally or artificially powered by Sun's energy, and photosynthetic phenomena which are the source of biomass. Sun's light energies can be seen by anyone, anywhere, anytime.

- ***Darkness energies***, energies stored underground, below the surface of the Earth, that include fossil fuels - coal, oil, natural gas – nuclear fuels, and the internal heat of the Earth. Until a few centuries ago we did not even know about their existence. Today we continue to discover new fossil fuels fields.

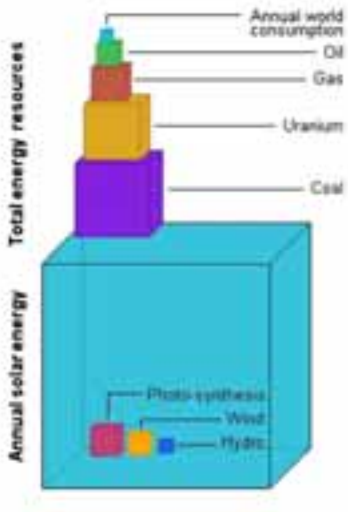

Fig. 4: Order of magnitude of energy sources on Earth (Lomborg 2001)

3. Earth systems and science

We live on Earth and need to understand how it works.

Think of it as a system made up of three subsystems, Earth's matter, Earth's energy and Earth's life, as suggested by Dr. Art Sussman in his Guide to Planet Earth (Sussman, 2000).

In terms of matter, the Earth is a closed system. It has practically the same amount of matter that it had at its origin and that cycles over and over. In terms of energy, the Earth is an open system, except for its internal heat. It receives a certain amount of energy from the sun and, after transforming it through the myriad natural processes operating on our planet, from the growth of plants to wind and water cycles, radiates that same amount back into space. As to the living world, the Earth is an interconnected system. The existence of every living being depends on a ramified network of relations with other living beings and with the matter and energy systems.

Today we're in the midst of a great new challenge: understanding that the Earth and its three subsystems work as a whole, and that for the first time ever, their operation can be affected by human activities, partly because never before have there been so many people living on the Earth, and partly because we humans are engaged in more and more activities that can significantly affect the natural mechanisms that make our planet work.

This new awareness of how the Earth works is gaining ground through increasingly evident cultural and political processes, as in the case of climate change due to greenhouse gases as well as to the production of artificial heat on the Earth's surface, as proposed by Prof. Giovanni Francia (1911-1980) in the seventies.

Despite the scientific uncertainty that veils phenomena as complex as climate change, we can plainly no longer shut our eyes to the way the Earth works. This should be standard knowledge for everyone, just like the knowledge that the Earth is not flat but spheroid.

Once we've learned how the Earth works, it should be easier to determine the best ways to know and use its natural resources, in particular its energy resources and solar energy, so as to maintain the environmental balances on which our lives depend.

4. Ancient and modern solar ages

It often happens that we think of solar energy as an aspect of our modern world, although it had powered everything on Earth until 150-200 years ago.

We should impress in our minds that for thousands and thousands of years, light, heat and fuel from solar energy alone shaped human settlements and cities, farming and forestry, architecture and buildings, landscapes and territories, religious beliefs and cultures, social relations and lifestyles - in a word, whole civilizations. The use of renewable solar energy is thus an age-old experience and we need clearly to make a distinction between ancient and modern solar ages and understand what has been changed moving from one to the other.

Solar energy resources, at least over the last 10.000 years, have not changed. What has changed is our knowledge of them. Our ancestors had neither the scientific knowledge nor the technical means available to us today to observe, measure and monitor direct solar radiation and its indirect forms, wind, falling water, biomass and other forms over days, months, seasons and years. With a combination of satellite data and field measurements, we can estimate the amount of direct solar radiation that reaches any part of the Earth. In a word, we can find out what energy resources are available at any point on our planet.

Basic principles of solar architecture and urban planning also have not changed, nor have the basic principles used to collect, convert or store sun's heat. What has changed, and that must be underlined, is that we have learned to convert solar energy into electricity, an expression of our modern solar age.

Since the 1800s we learned first to convert power of falling water into electric energy and, more recently also that of the winds and of sun's heat and light.

The foundations of these advancements are in the many discoveries and inventions made in the last five hundred years and lie chiefly in our ever more advanced understanding of optics, light and the structure of matter, which has opened fascinating prospects for the use of solar energy in the modern age, from solar cells with efficiency ratings of 50% or more to smart glass and photon solar architecture and city planning (Perlin, 2015).

By now we know for certain that it is possible to build large and sophisticated energy infrastructure powered by solar energy to produce electricity, low-, medium- and high-temperature heat, fuels and other useful forms of energy.

It must be recalled that electricity consumption in advanced societies accounts for less than 20% of the total, while 80% is in the form of fuels and heat, the last at low temperatures, i.e. those that the Sun makes available naturally.

What we do not know today is how to build a modern solar energy system as a ***whole,*** which is something we think necessarily in order to replicate in a modern way the ancient solar energy systems. Today, the idea that the systemic aspect of the use of solar energy, which was implicit in the lives of our forebears, is overlooked. It is a cultural deficit that span all fields: science, technology, organization, sociology, economics, politics, even our terminology and ways of communicating.

A cultural deficit that regards also the recent history of modern solar energy. In 1955, on the occasion of the first World Solar Symposium held in Arizona, the first comprehensive Directory of World Activities and Bibliography of Significant Literature on Applied Solar Energy Research was published and distributed by Stanford Research Institute for the Association for Applied Solar Energy (Stanford Research Institute, 1955).

Approximately 4000 citations relevant to 27 countries, from 1850 to 1955, are reported in this Directory. They show the human effort made to pursue solar energy in modern times, but strange to say, the prophetic visions, the inventions and the work of so many pioneers in the late 19th and early 20th century are little known today, even to solar specialists. Yet many of them, farsighted and with clear vision, anticipated problems that appear are constantly in the news today. They also anticipated the technical solutions or proposals necessary to deal with important dilemma, such as the question of favoring “Nuclear energy or Solar energy?”

5. Solar or nuclear in the 1950s and today

The solar or nuclear debate: Nuclear YES, Nuclear NO, Solar or Nuclear, continues today as did was fifty years ago.

Ahead of the Climate Change International Summit in Paris in December 2015, there are more and more voices claiming that climate change requires a technological response, and nuclear power could be an important element of that response (Guyer and Golay, 2015).

In the 1950s, solar pushed to the side with the promises of nuclear power. In fact, in the aftermath of WWII, modern solar technologies, except for hydro, and peaceful uses of nuclear energy to produce electricity were both in their infancies.

In January 1951, United States President Harry S. Truman appointed William Paley to chair the President's Materials Policy Commission to investigate the long-term availability of raw materials, making a clear distinction between those necessary for defense and those essential for the country's development. Paley thought that the United States could not afford a shortage of raw materials to jeopardize the nation's security or create a bottleneck in its economic expansion. On June 2, 1952, Paley submitted his report to the President. The committee had consulted experts in industry, academia and government, and one of the four volumes of its report on the analyses and conclusions of the study had a whole chapter devoted to what Paley called **“The possibilities of solar energy”** (Paley, 1952)**.**

The chapter summarized the results of a broader study made by Palmer Putnam in July 1951 for the US Atomic Energy Commission, in which he had reviewed all the methods for collecting solar energy and converting it into commonly used forms of energy: natural photosynthesis, heat pumps, thermal solar collectors, solar-heated homes (13 million were expected to be built in the United States by the end of 1975), water desalination, electricity generation with solar concentration systems, the exploitation of solar energy through wind and the thermal gradients of tropical waters, controlled biological photosynthesis, non-biological photosynthesis and photovoltaic.

The Paley Report concluded that up till then only tiny steps had been taken to promote solar energy, and emphasized the importance of adopting an aggressive policy to develop the entire solar-energy sector, a sector in which the United States would be able to make a huge contribution toward the well-being of the free world.

Under the Truman administration, this prospect was one of many considerations, including the idea that the development of nuclear energy to generate electricity would contribute significantly to increase the risk of proliferation of nuclear arsenals and the threat of atomic war. These fears explain Truman's decision to keep all information on nuclear energy secret. But this policy soon proved pointless, because the Soviet Union was quickly equipping itself with nuclear weapons. Truman's approach was overturned when Eisenhower won the 1952 election and entered the White House.

In a speech delivered at the United Nations General Assembly on December 8, 1953, Eisenhower announced the "Atoms for Peace" program that, according to solar energy historian John Perlin, became the ace in America's hand to win the Cold War (Perlin, 2000). With international political commitment and economic support, nuclear power took off while Paley’s report was forgotten and solar energy left behind.

We wanted to recall the nuclear or solar debate in the 1950s, because nuclear energy, in spite of its technological and economic limits, which clearly emerged with great evidence during the Chernobyl and Fukushima accidents, continues to be considered a valid option to fight climate change because it does not produce greenhouse gases as do fossil fuels. Too often, nuclear energy is inappropriately considered, along with solar energy, as a solution to the issue of climate change.

Today, unfortunately, this idea is widespread. In order to counter this misconception, in my view, we should consider Prof. Giovanni Francia's research on the Earth's thermal equilibrium, illustrated in a paper he wrote in the early 1970s titled "The Sun and the Limits of Energy on the Earth" (Francia, 1973).

Francia, a mathematician and physicist, teaching at the University of Genoa, devoted more than 20 years of his life to studying and experimenting with solar energy systems and concepts from the early sixties up to his death in 1980. He is considered by GSES the foremost Italian solar energy pioneer of the 1900s (Silvi, 2005).

In February 2005, I discovered Prof. Francia's undated paper on the Earth's thermal balance in his personal archive, donated by his heirs to the Museum of Industry and Work in Brescia (www.musilbrescia.it).

To my knowledge, the complete Italian version of Francia's paper has remained unpublished until today. We can be reasonably sure that he wrote it between late 1973 and early 1974, because a summarized French version appeared in the second half of 1974 in the Revue international d'héliotechnique, a journal published by COMPLES (Coopération Méditerranée pour l'Énergie Solaire), of which a one of a kind collection is kept at the Italian Archive and Museum on the History of Solar Energy in Brescia (Italy).

I outlined Francia's views about the thermal equilibrium of Earth in a paper about his pioneering activities that I presented in August 2005 at the World Congress organized by the International Solar Energy Society in the United States (Silvi, 2005). The interest aroused by his approach encouraged me to try to broaden knowledge of his paper.

As it was partly typewritten and partly written in longhand, it was not easy to read it. Accordingly, I transcribed it in electronic format and made a short summary of its contents that follows.

In this study, Francia focuses on the Earth's surface temperature, the point of equilibrium between the energy radiated by the Earth into space and the energy that the Earth receives from the sun. Throughout historical time, he says, the amount of thermal energy generated on Earth by natural phenomena has remained practically constant, except for changes caused by the fluctuations in solar power that occur in eleven-year cycles.

Over the last two centuries, though, energy generated artificially by human beings, above all by burning fossil fuels, has been added to the amount of naturally generated thermal energy.

Since the amount of thermal solar energy that reaches the Earth is thousands of times greater than the sum of non-solar energies, and since the uncertainties regarding its estimation are on the same order of magnitude as the latter, according to Francia the modest amount of thermal energy generated artificially by humans might seem at first sight to lead one to conclude that it has no effect at all on the Earth's thermal equilibrium.

But this is not so, as Francia explains in a few pages with a series of observations regarding the ways in which our planet's various surfaces (water, snow, soil) absorb and reflect solar radiation in different seasons and at different latitudes.

To the contrary: if in a hundred years' time this small amount of thermal energy generated continuously by humans were to reach amounts tens of times higher than those of 1974, according to Francia, it would produce phenomena of thermal instability on the Earth, triggering a chain of events with positive retrospective effects that could shift our planet into an equilibrium very far from the initial one, and at speeds much faster than living beings can adapt to.

Prof. Francia concludes that, ***"It would seem that the production of even small quantities of energy on the surface of the Earth alters the climate dramatically, and that henceforth it will be necessary to use solar energy, the only kind that does not generate thermal pollution."***

From Francia's research, which did not include the effects of greenhouse gases, one can conclude that climate change seems also to be connected to the production of artificial heat on Earth, which is added to natural thermal heat from solar radiation, by burning fossil and nuclear fuels, and by extracting the Earth's internal heat. What has not been studied, is the combined effect of the two.

6. Habitat and Agriculture

The importance of sun's energy use and human life on Earth is deeply inscribed in the history of human habitats and surrounding farmlands. Since prehistoric civilizations, habitat and farming were always based on the same energy principles. As energy historian Vaclav Smil points out, “all agriculture was based on the conversion of solar radiation through the process of photosynthesis. Photosynthesis produced food for humans and livestock, recycled waste to fertilize the soil, and provided the fuel needed to melt the metals with which primitive farming tools were made. Traditional farming methods were thus based entirely on solar energy. Except for cutting down old forests, they did not impoverish energy stocks. The whole process was based on a virtually immediate capacity to convert solar energy flows.” (Smil 1999).

Then came fossil fuels – first coal, then oil, then natural gas – and later nuclear energy. In less than a hundred years, we’ve built huge and efficient energy infrastructure – coal and oil shipping terminals, oil and gas pipelines, power plants and power lines, and so on – that have assured abundant energy, development and well-being, but have also had ever more obvious effects on the environment and led to profound changes in the socioeconomic geography, habitats, farming and lifestyles of whole civilizations that had grown over the centuries with the use of solar energy alone.

Mega-cities grew rapidly, as well as rural depopulated areas, altering relationships among the different functions of cities and their surroundings.

A thesis presented in Genoa in 2006 by GSES was that in order to bring the modern solar city into being we must intelligently combine and integrate the experience gained by the ancient cities – not only in terms of technical know-how, but also of art, culture, relations and communication – with the many solutions made available by the scientific discoveries and extraordinary technological developments of the past two hundred years, especially in the most recent decades (Silvi et al., 2006).

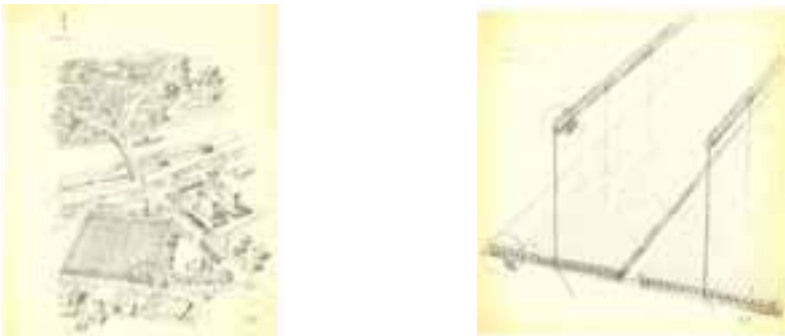

Fig. 5: **Drawings of large Linear Fresnel Reflector Solar Power Plants integrated in a city designed by Francia in 1965 circa (Francia Archive donated to the Museum of Industry and Work in Brescia by his heirs in 2005)**

In the “Solar City Project – Ideas for an Urban Structure”, Prof. Giovanni Francia and his collaborators (Francia, 1971 et al.) discussed whether and how the discoveries, suggestions and results that solar energy science has produced in the past few decades are compatible with the new directions that architecture is taking.

They were convinced – and they believed many other people were as well – **“that in the near future scientists, architects, economists and sociologists will have to study the large-scale use of solar energy, and that (as far as they could tell at the time) for the most part their studies will focus on electricity generation and the heating and cooling of cities.”**

Fig.6: Francia, right, showing a model of the solar city project, Genoa (Italy), 1978.

The Solar city exhibition held in Genoa by GSES in 2006, to honour Francia’s vision of a Solar city, recounted the vicissitudes of cities, of architecture, energy and food-supply infrastructures, and the scientific discoveries and technological developments that marked the major stages in their history, with special focus on day lighting, heating and cooling of buildings.

Gaetano Vinaccia (1889-1971), an Italian architect of the early 1900’s and solar pioneer, author of more than 200 publications, most of which devoted to solar energy, in his book “The City of Tomorrow” wrote: **“To reach the city of tomorrow, we need first of all – to save time and effort – to retrieve old paths considered useless by people who think the past is a ball and chain bound to humanity's feet so as to prevent our triumphant march toward progress. The fruit of thousands of years of intelligent work, the selection that centuries of experience has contributed to, cannot be bypassed, cannot be modified, cannot be refuted except through centuries of hard and serious work. And there are absolute truths that no one can modify, much less destroy" (Vinaccia, 1939).**

Fig. 7: Front cover of Vinaccia’s book “Il corso del Sole in urbanistica ed edilizia.” The Course of the Sun in Urban Planning and Construction (Vinaccia, 1939).

In Genoa GSES’s solar city exhibition drew inspiration from the pioneering works of two Italian important solar scientists, Francia and Vinaccia, intelligently combining our millennia experiences and principles in solar energy use with the most advanced technologies from the extraordinary scientific advancements of the last 500 years. In other words, as put by Norbert Lechner, “Use the best of the old and the best of the new” (Lechner, 2000).

Is Urbanization an irreversible phenomena? Will 75% of 10 billion people, as we are expected to become in 2015, live in cities? We do not know. For certain we might reconsider historically and scientifically what options we had in the past and what we can have in the future.

A key aspect of solar energy use is its intermittency. Until 200 years ago we knew how to use solar energy stored by nature through photosynthesis in a common fuel: fire wood.

Today there are many scientists who are working to store solar energy in a fuel that can become as commonly available as fire wood has been for centuries.

Among scientists that conquered global media attention on this possibility is Daniel Nocera. During the impact of the Arab oil embargo and other oil crises of the 70s and 80s, Nocera envisioned his scientific career as one of a humanitarian activity focused on the discovery of the "guarded secret of plants", a concept which was introduced into the scientific debate in 1912 by Italian chemist Ciamician in his paper The photochemistry of the future (Ciamician 1912, Venturi et al. 2005, Nebbia and Kauffman 2007, Nocera, 2011).

In 2011 Nocera presented a cheap coated-silicon sheet, referred to as an artificial leaf, which, when placed in a glass of tap water and exposed to sunlight, was able to split water into hydrogen and oxygen. "If there is one thing that's unique to this technological development," said Nocera, "it is that it was done with the very poor in mind."

Fig. 8: A slide by Daniel Nocera in which power lines are no longer needed. Electricity and fuel will be provided by the artificial leaf, which when placed in a glass of tap water and exposed to sunlight, is able to split water into hydrogen and oxygen

If in the last century millions moved from villages to cities, is it possible that in the future might millions move back from cities to villages? Is a modern new solar colonization of Earth thinkable and possible?

7. Italian Archive and Museum on the History of Solar Energy

The idea of Italy's Archive and Museum on the History of Solar Energy started to take shape within GSES in 2003, with the main purpose being to preserve and make widely available the Italian heritage of solar energy use in our country (Silvi, 2008).

The Archive and Museum, whose initial core has been taking shape in the past few years in Brescia, in northern Italy, at the Luigi Micheletti Foundation and the Eugenio Battisti Museum of Industry and Work (www.musilbrescia.it), is being organized around the following topics: solar pioneers and devices starting in the early years of industrialization; solar architecture and city planning; the use of solar energy in agriculture.

In this paper we have provided examples of the kind of contributions that can come from knowing the work of great Italian pioneers such as: Giovanni Francia, mathematician and physicist; Giacomo Ciamician, chemist; Gaetano Vinaccia, architect. Their stories and work are documented at the web site of GSES www.gses.it, mainly in Italian.

8. Conclusions

The "easy" and "abundant" energy provided by fossil fuels permitted architects and engineers to ignore the fundamental rules of solar architecture and city planning which had been used as guides for thirty-five hundred years – proper insolation, building orientation – and led to major changes in our society that will not be easily reversed. Perhaps, still more important, this "easy" energy resulted in the loss of the ancient culture that was necessarily sophisticated and frugal in the use of natural resources.

Today it would probably be much easier to continue, as we are doing, along the same path, continuing to build energy infrastructures based on fossil and nuclear fuels, than it would be to create an entirely new energy infrastructure that enables widespread use of solar energy.

However, human societies progress when they face difficult challenges and manage to come up with new solutions, rather than falling back on easier and conventional ones. The solar challenge is indeed a difficult one, but that's exactly why it ought to interest us and why we should work harder at advancing it.

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