Solar Energy Now

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Solar Energy, Why?

- Exhaustion of fossil fuels
  - Price uncertainty, Geopolitical problems: Iraq, Russia, etc.
- Mitigation of Climate Change.
- Concerns about nuclear energy
  - Plant Safety, Proliferation, Nuclear waste.

<table>
<thead>
<tr>
<th>Fossil energy source</th>
<th>Annual Production/consumption 1000 TWh</th>
<th>Proven Reserve (expected additional Resources) 1000 TWh</th>
<th>Equivalent Solar delivery time in deserts days</th>
<th>Static depletion time of reserves years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>45</td>
<td>1,900 960</td>
<td>8.5 4.3</td>
<td>42</td>
</tr>
<tr>
<td>Natural gas</td>
<td>24</td>
<td>1,600 1,900</td>
<td>7.2 8.4</td>
<td>65</td>
</tr>
<tr>
<td>Coal</td>
<td>33</td>
<td>5,700 29,000</td>
<td>25 129</td>
<td>170</td>
</tr>
<tr>
<td>Uranium, Thorium</td>
<td>4</td>
<td>460 1,740</td>
<td>2.0 7.8</td>
<td>101</td>
</tr>
</tbody>
</table>
Climate Change

The mitigation of climate change effects requires the rapid phase-out of the use of fossil fuels.

Nuclear will not help!

Solar irradiation is thousands of times larger than present energy consumption.
Archimedes’ burning mirrors — III Century BC.

Myth or reality?
The Roman glass pane — 11 century CE.

Possibly the first “modern” solar technology in architecture.
The Progeny of Solar Energy

Big vs. small.
An unknown precursor: Alessandro Battaglia

Patent for a “Multiple Solar Collector”, Genova 1886.

I am grateful to Cesare Silvi of the GSES (Gruppo per la Storia dell’Energia Solare) for communicating this discovery before publication!
Giovanni Francia (1911-1980)

Mathematician, Engineer, Solar Pioneer

(1,2) Prototype of Fresnel Concentrator — Marseille 1964
Giovanni Francia (1911-1980)

Thinking big.

Ideas for a Fresnel Concentrator Solar Plant.
The 1 MW plant is now decommissioned.
The largest solar complex — SEGS, Mojave Desert 1984-1990

A total of 384 MW in nine plants. SEGS VIII and IX at Harper Lake.
The largest solar complex — SEGS, Mojave Desert
1984-1990

A total of 384 MW, in continuous use since completion. Real milestone!
The central problem: Price reduction

Present cost of solar electricity is \( \approx \) three times that of fossil fuels. How to reach parity?

- R&D — Improved or simpler Technology.
- Economies of scale, learning ramp.
- Price of fossils and nuclear is increasing.
- Take into account the real cost of fossils:
  - Climate Change
  - National Security

Taking the last factors into account we are probably not far from parity.
Today’s technology of CSP systems is implemented in the cost range of 15 - 20 cents€/kWh. In the conventional power market, it competes with mid-load power in the range of 3 – 4 cents€/kWh. Sustainable market integration as predicted different scenarios can only be achieved, if the cost will be reduced in the next 10 to 15 years to a competitive cost level. Competitiveness is not only impacted by the cost of the technology itself but also by a potential rise of the price of fossil energy and by the internalization of associated social costs such as carbon emissions.

From the Ecostar study commissioned by the European Union to the Deutsches Zentrum für Luft und Raumfahrt (DLR, the German NASA)

The European Commission Finances R&D activities and contributes to the financing of power plants, such as PS10, Andasol-1, and Solar-Tres.
Ausra employs linear fresnel and direct steam generation. A few medium-size systems under construction, large systems projected.
Competing Technologies — Molten salts as working fluid.

Developed by ENEA, Italy.
A 5MW prototype, the Archimedes project, under construction near Syracuse.
Competing Technologies — Tower systems.

PS10: a 10MW plant in Spain. Scaling to larger plants is foreseen.
Feed-in tariffs for reaching critical mass.

<table>
<thead>
<tr>
<th>Feed-In Tariff</th>
<th>Capacity</th>
<th>Tariff</th>
<th>Duration Years</th>
<th>Inflation Adjustment</th>
<th>Restrictions</th>
<th>Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>max 12MW</td>
<td>0.30€/kWh</td>
<td>20+</td>
<td>no</td>
<td>max 12MW, max 1500h/a</td>
<td>no</td>
</tr>
<tr>
<td>Germany</td>
<td></td>
<td>0.46€/kWh</td>
<td>lifetime</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Greece</td>
<td>up to 5MW</td>
<td>0.23-0.25€/kWh</td>
<td>10+10</td>
<td>no</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>over 5MW</td>
<td>0.25-0.27€/kWh</td>
<td>10+10</td>
<td>no</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Israel</td>
<td>up to 20MW</td>
<td>0.20USD/kWh</td>
<td>20+10</td>
<td>yes</td>
<td>max 30%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>over 20MW</td>
<td>0.16USD/kWh</td>
<td>20+10</td>
<td>yes</td>
<td>max 30%</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>up to 10MW</td>
<td>0.21€/kWh</td>
<td>15</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>over 10MW</td>
<td>0.16€/kWh</td>
<td>15</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Spain</td>
<td>up to 50MW</td>
<td>0.27€/kWh</td>
<td>25+</td>
<td>yes</td>
<td>max 50MW, max 15%</td>
<td></td>
</tr>
</tbody>
</table>

Feed-in tariffs for concentrated solar plants in European countries. Similar tariffs exist for photovoltaic installations.
Andasol-1.

The first of the new generation of Spanish Solar Thermal Plants. Andasol-1 is the first to adopt heat storage for extending operation by 7 hours.
Spain the center of European Solar Thermal Plants.

At the end of 2007 more than 50 CSP projects with about 2150 MW have been registered by the Ministry of Industry.

Generous feed-in tariffs attracted the European industries and kick-started a flourishing Spanish solar industry.
Desertec: a possible future?

Linking together Europe, North Africa and Middle East. Not only electricity, but also water desalination, a major need of many countries. This map underestimates the weight of Photovoltaic!
The Photovoltaic advantage

- Technical advances and scale economies lead to falling prices.
  - Thin Film, Carbon Nanotubes, ...
  - Solar Concentrators promise high efficiency.
- Can employ unused spaces such as roofs, building walls, on the side of highways, etc.
- Large-scale installations not necessary: installations of a few kW make sense. Rapid installation.
- Can be installed close to final user and grid connected there.
- Can be integrated into buildings.

Photovoltaic technologies will reach parity in a few years.
An example of technological progress: concentrating PV

Concentrating solar radiation allows the use of small — high efficiency — solar cells. A 5MW plant based on this technology is being built in Portellana, Spain.
Photovoltaic is booming in Europe.

In 2007 Europe accounted for \( \approx 50\% \) of world’s PV installation, driven by generous feed-in tariffs in many EU countries. Germany leads the way, followed by Spain, Italy and others.

Source: EPIA
Small vs. Big

- **User-end side**
  - Provide for day-time peak consumption
  - Needs grid for storage and night/cloudy time

- **Utility side**
  - Provides grid backbone
  - In 10-20 years PV will become competitive also for large plants.

The two tender to different corners of the energy market. Together they represent a formidable alternative to the fossil and nuclear-based technologies.
For a Bright Future!

The End