# Photovoltaics for Professionals

*Solar Electric Systems*
*Marketing, Design and Installation*

Falk Antony
Christian Dürschner
Karl-Heinz Remmers

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# Foreword

This book is designed to be more than a technical manual on installing photovoltaic systems. Our priority was to provide designers and installers with practical specialist knowledge that would enable them to design and install high quality solar electric systems. However, we have also attempted to give an overview of the major photovoltaic market sectors and provide general guidance on marketing the technology and good business practice. While getting the technical side of installing solar electric systems right is essential, solar businesses also need to be commercially successful. The book has been structured with this in mind, as can be seen from the title of the opening chapter, *Marketing and promoting photovoltaics.* This is followed by *Solar cells, PV modules and the solar resource.* Subsequent chapters deal with designing, installing and maintaining systems. The bulk of the book deals with grid-tied systems, the largest market sector. A comprehensive chapter on stand-alone systems has also been included.

A knowledge of the environmental and energy security aspects of photovoltaics is important for solar business and these have also been discussed. Customers and potential customers are increasingly concerned about these issues and becoming increasing well-informed about them. Photovoltaic professionals involved in marketing the technology need to be able to discuss them knowledgeably.

The authors hope that their work will serve as a useful contribution to a change from a fossil fuel economy to one based on renewable energy.

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# 1 Marketing and Promoting Photovoltaics

## 1.1 Renewable energy

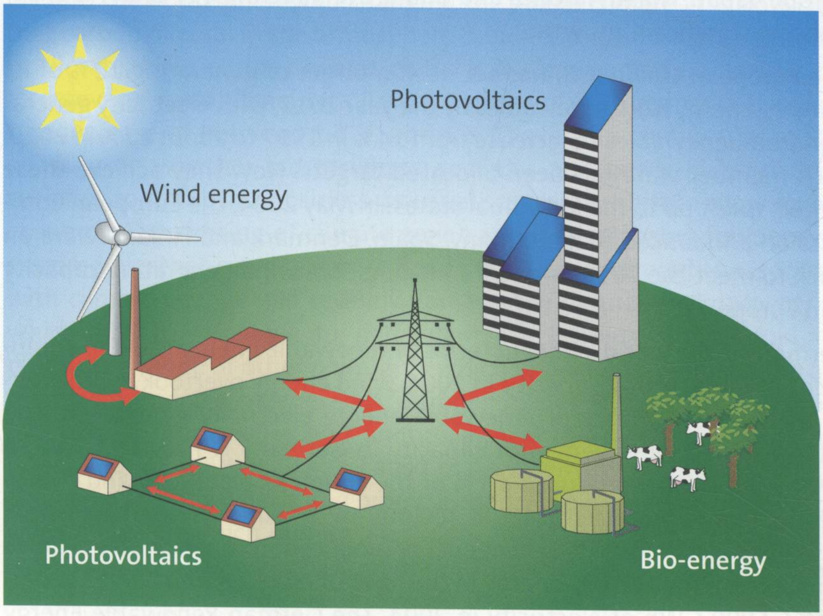


*Figure 1.1: There is no shortage of renewable energy from the sun and the wind. Hydro energy, bio-energy and geothermal resources are also considerable*

Our planet's renewable energy potential is effectively limitless when measured against humanity's needs. Solar energy, wind energy, hydro-electric, bio-energy (energy from plants) and geo-thermal energy are already being used on a large scale and in many different ways. Solar thermal technology uses solar energy directly to produce hot water. Photovoltaics (PV) produces electricity directly from sunlight. Plants harness solar energy and produce biofuels – wood, straw, vegetable oils for bio-diesel and other fuels. Wood itself is the oldest fuel. The use of water as an energy source goes back at least two thousand years and today hydro-electric power plants generate vast quantities of electricity. Most large potential hydro-electric sites are being utilized or developed but there is still enormous potential at medium and small sites. Wind turbines are the second largest generator of electricity from renewable resources. Total global installed wind power capacity (2004) is already 47.6 GW (Giga Watt = one billion watts). A 1.5 MW (MegaWatt = one million watts) wind turbine, with a rotor diameter of about 70 meters – can generate 76 GWh, gigawatt-hours, of electricity in 20 years; the amount of electricity a modern brown coal/lignite power plant would need to burn about 84,000 tonnes of fuel to produce.

### 1.1.1 Renewable energy around the world

Renewable energy presents business opportunities for manufacturers, distributors, system designers and installers. A whole range of technologies are already being produced, marketed, installed and creating jobs in Europe, Japan, North America and China. Every technology sector is experiencing significant growth.

The European Union (EU) has set itself a target of generating 12 % of its primary energy from renewables by the year 2012, with electricity generation from renewables to increase from 14 % in 1997 to about 22 % in 2010. Each member state has been allocated targets. How they achieve these targets is left up to the individual states. In May 2004, the European Commission announced that Germany, Spain, Denmark and Finland were on track to meet the 2012 target. 72.7 % of global wind generating capacity is in Europe.

Germany is the world leader in terms of renewable energy use and equipment manufacturing capacity. In 2004, wind energy overtook hydro energy as the main source of renewable energy electricity generation. The total installed wind generator capacity in Germany is now 16.6 GW. In 2004 wind energy produced 4.1 % of the country's electricity and hydroelectric plants produced 3.4 %. 6,300,000 $m^2$ of solar thermal collectors have been installed. 90 % of heat energy produced from renewables comes from bio-energy and bio-energy in the form of biomass and biogas generated 53,000 GWh of electricity in 2004. The German Renewable Energy Law, which offers guaranteed prices for PV-generated electricity has led to dramatic growth in this market sector – 360 MWp was installed in 2004 – making Germany the world's largest market for PV.

In the USA, about 6 % of total energy is produced from renewable sources, mainly hydro-electric and geothermal. There is over 7.2 GW of wind energy installed, 86 MW of PV and 52,000 $m^2$ of solar thermal collectors (2004). The USA is the world's third largest PV market. Japan is the second largest – 280 MWp was installed there in 2004. In the same year China installed 14,000,000 $m^2$ of solar thermal collectors.

One third of the world's population has no access to electricity at all – this is over 1,700 million people. Most of them live in rural areas and require relatively small amounts of electricity, too small to justify the expense of extending the grid. Small stand-alone PV systems are in reality the only practical way to supply many of these people with power. There is a large market for small stand-alone PV home systems in Asia, Africa and Latin America.



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## 1.2 Climate change and dwindling fossil fuel reserves

Environmental problems associated with the burning of fossil fuel and the medium and long-term supply of fossil fuel itself, particularly oil and gas, make the move towards a global renewable energy economy both desirable and necessary. At the end of the 21st century, in only 400 years of industrial activity, humanity will have used up much of the fossil fuels which have been deposited in the earth's crust over the last 400 million years. Burning coal, oil and gas is releasing vast quantities of carbon dioxide into the atmosphere and changing the global climate. It is now clear that carbon dioxide in the atmosphere is increasing, and that the change in climate, both regionally and globally, is clearly measurable. The UN Intergovernmental Panel on Climate Change (IPCC) predicts a temperature increase of between 1.4 °C and 5.8 °C over the next 100 years, depending on whether industrialized societies and newly industrializing societies continue in a business-as-usual scenario or shift to a low carbon economy. The shifting of climate zones and the increasing frequency of extreme weather events such as floods, storms and droughts associated with climate change will severely damage the natural environments on which millions of people are dependant. The burning of fossil fuel also produces a range of other pollutants which impact on human health and the environment: benzene, soot, nitrogen oxides, hydro-carbons, carbon monoxide, sulfur oxides and ammonia. Acid rain destroys forests and lakes, and oil spills regularly cause massive environmental damage. A change in the way we use and produce energy is necessary to preserve the eco-spheres on which human life is dependant. Only a radical shift from fossil fuels to a low carbon economy will achieve this. The use of renewable energy will reduce carbon dioxide and other greenhouse gas emissions and help avoid a possible environmental catastrophe.

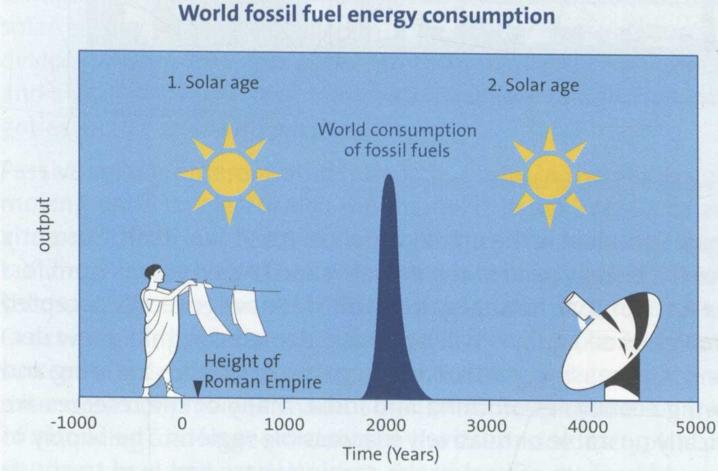


*Figure 1.2: In a period of 400 years a large part of the fossil fuels which have been deposited in the earth over a period of 400 million years will have been used up*

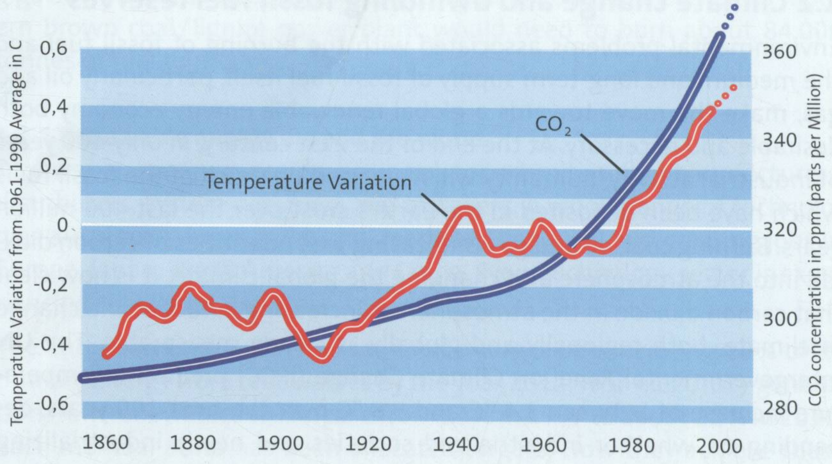


*Figure 1.3: The increase of carbon dioxide in the atmosphere and the increase in temperature have been measurable for many years*

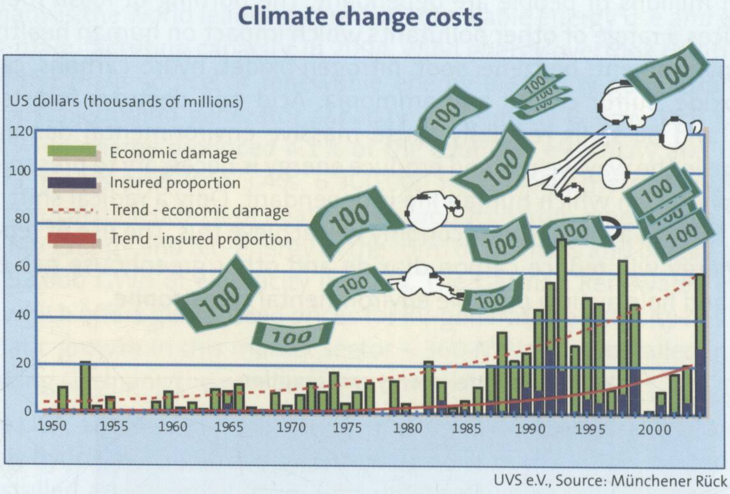


*Figure 1.4: The economic costs of climate change*

The other major problem is the actual supply of fossil fuel itself. Currently about 80 % of the energy used in the industrialized world comes from fossil fuel in the form of coal, natural gas and oil. It is now generally accepted that the reserves of oil and gas will be largely depleted within a few decades. Demand is increasing, particularly from the new industrializing and rapidly growing economies of China and India. Many of the reserves are also in politically unstable or relatively inaccessible regions. The supply of oil and gas could become critical in the coming years and lead to shortages. This is reflected in steadily rising prices.

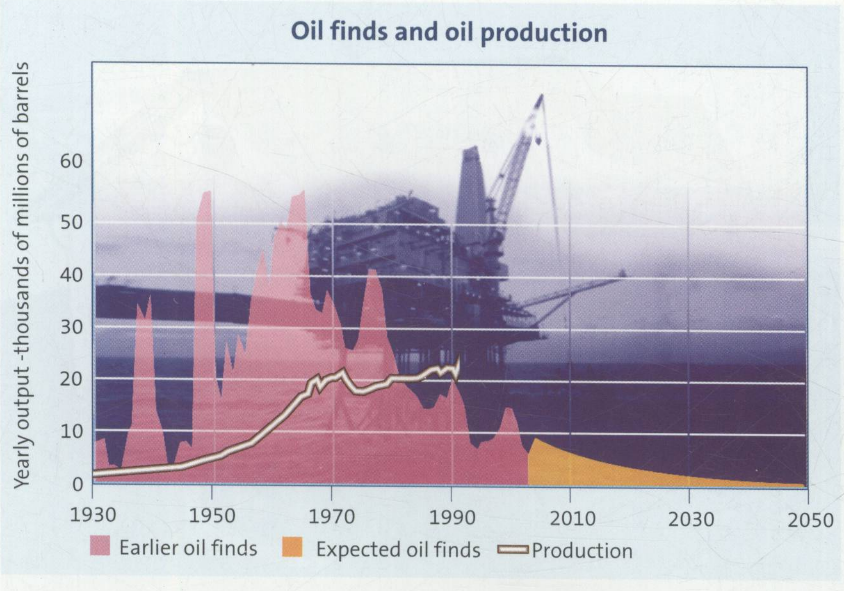


*Figure 1.5: The world's major oil reserves have all been found. Production will not keep up with demand*

## 1.3 Overview of renewable energy, solar energy and the solar resource

Most renewable energies are in effect solar energy – directly or indirectly. The wind is the result of the heating effect of the sun on the earth's atmosphere, as is hydropower. Plants (biomass) need sunlight to grow. Geothermal energy is an exception, it uses the heat of the earth's core. Although hydro turbines, biomass power stations and wind turbines utilize solar energy indirectly, the term *solar energy* is usually used to refer to devices which utilize the energy of the sun directly to produce both heat and electricity. These technologies are broadly categorized into two categories: *active solar* and *passive solar.*

Passive solar is differentiated from active solar in that it does not have any moving parts or electrical components. It usually refers to architectural and constructional features which reduce the overall energy needs of buildings by keeping them warm in winter and cool in summer. Passive solar architecture has a tradition of several thousand years. In ancient Greece buildings were constructed so that during the cold winters the low sun contributed to the heating of the building and during the summer the extended roof provided shade. Small windows (or none) on the north side of a building and large windows on the south side are typical passive solar features in northern latitudes. Passive solar technology is very site-specific – a passive solar house in Alaska will look very different from one in Florida.

*Figure 1.6: Design for a house in Central Europe with several passive solar features, such as conservatories and small windows on the north side. The central heating system is solar thermal assisted (Source: http://www.elco.net)*

Active solar systems are categorized into solar thermal, which usually produce hot water, but can also be used for cooling and producing steam which drives electricity-generating turbines – and photovoltaics (PV), which produces electricity directly from solar radiation.

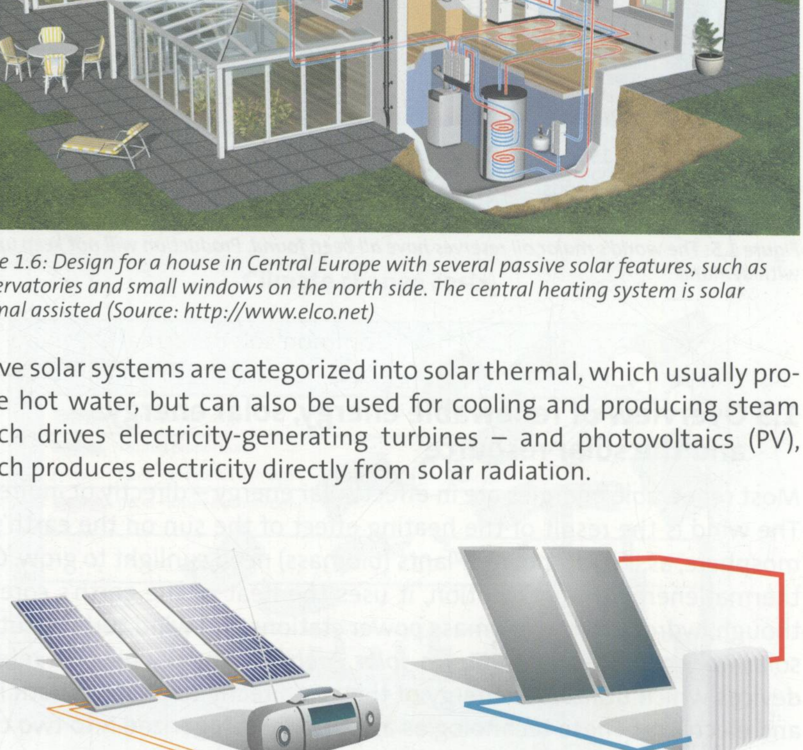

*Figure 1.7: Active solar technology: PV (left) producing electricity, and (right) a solar thermal system producing heat energy*

*Figure 1.8: Solar thermal power station in California. The parabolic mirrors concentrate the sun's rays on the pipe to produce steam to generate electricity (Source: Solar Millennium AG, Erlangen, D)*

Solar hot water heating is the most common solar thermal technology. It produces hot water in homes, hotels and hospitals. It is also used to heat swimming pools even in sunny regions, thus extending their period of use. And it can also be used to produce hot water for industrial purposes. Solar water heating is particularly efficient at converting solar energy into heat energy. This gives it a relatively short energy pay-back period – 1 to 2 years. In many situations the hot water is usually used at the end of the day when it is available and it is easily combined with other water heating technologies such as electricity, gas and oil.

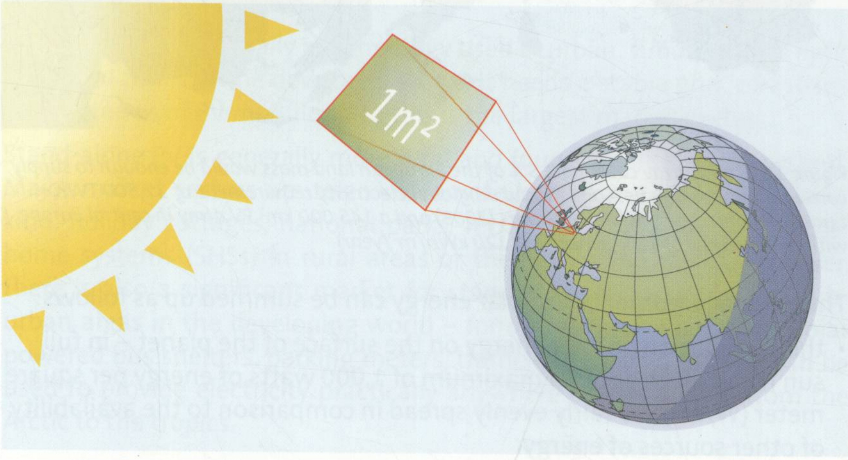


*Figure 1.9: Solar is the most democratic of energy sources, falling fairly evenly on all the world's surfaces. A full midday sun averages about 1,000 watts per square meter*

The amount of sunlight falling on the earth contains far more energy than we can ever use – 10,000 times more than the whole of humanity's current consumption. And with a life expectancy of billions of years, the sun is a source of energy which will effectively never run out. Even in northern latitudes, in regions not generally thought of as sunny, solar energy can be harnessed effectively. To supply current global electricity needs using PV, the land area needed would be only 1.5% of the European landmass, about 145.000 square kilometers (380 km by 380 km) or 56,000 square miles (237 miles by 237 miles), an area about the size of the US state of Iowa. And that is at solar radiation levels found in the northern latitudes. It would be even less at the equator.


*Figure 1.10: A PV array covering 1.5 % of the European land mass would be enough to supply current global energy demand (based on global electricity requirement of 17,300 TWh – tera-watthours, one trillion watthours (2005) and a 145,000 km² PV array in central Europe with an efficiency of 12 % generating 120 kWh/m²/year)*

The general arguments for solar energy can be summed up as follows:

- the distribution of solar energy on the surface of the planet – in full sun it can reach about a maximum of 1,000 watts of energy per square meter (W/m²) – is fairly evenly spread in comparison to the availability of other sources of energy
- solar energy is accessible to everyone after the initial investment, running costs are extremely low



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