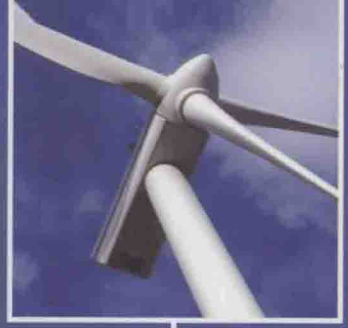

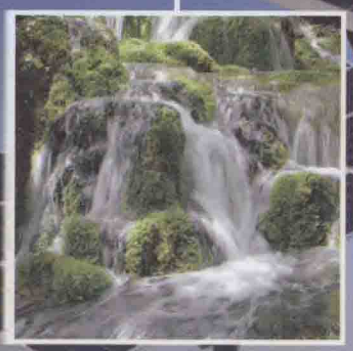

Renewable Energy and Climate Change

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Renewable Energy and Climate Change

Preface

The problems of energy and climate change have finally ended up where they belong: at the heart of public attention. Yet the connection between energy use and global warming is something we have been aware of for decades. In the late 1980s the German federal government proclaimed climate protection to be one of its main targets. At the time numerous experts were already calling for a speedy restructuring of the entire energy supply. Despite the government's declaration, the official response was, at best, half-hearted. But the climate problem can no longer remain on the back burner. There is a growing awareness that climate change has already begun. The prognosis of the researchers studying what is happening to our climate is horrendous. If we do not pull the emergency cord soon, the catastrophic consequences of climate change will far exceed even our powers of imagination. The awarding of the Nobel Peace Prize to Al Gore, the US climate activist, and the Intergovernmental Panel on Climate Change, which has been urgently warning of the consequences for years, could be seen as a sign of helplessness rather than optimism about solving the problem.

At the same time as climate change is threatening our environment, new records for rising oil and natural gas prices show that the supplies still available will not be enough to cover our requirements for much longer and that other alternatives must be exploited as soon as possible.

And yet the solution is a simple one: renewable energy. Renewable energy could completely cover all our energy supply needs within a few decades. This is the only way to end our dependence on energy sources like oil and uranium, which are so costly both in financial terms and in the havoc they wreak on our environment, and satisfy our hunger for energy in a way that is sustainable and compatible with the climate.

However, the path we need to take to get to that point is still unclear to many. Many people still do not believe renewable energy offers a viable option. Some underestimate the alternative possibilities offered to such an extent that they predict a return to the Stone Age once oil and coal supplies have been fully depleted.

The aim of this book is to eliminate these prejudices. It describes, clearly and simply, the different technologies that exist and the potential for using renewable energy.

The focus is always on the interaction between the different technologies. The example of Germany shows the forms that sustainable energy supply can take and how it can be implemented. But the book is designed to show all readers, wherever they live, how they themselves can make a contribution towards building a climate-compatible energy economy. In addition to explaining different energy measures that individuals themselves can undertake, the book provides concrete planning aids for implementing renewable energy systems.

This book has been specifically written so that it offers essential information to a broad spectrum of readers. It introduces the different technologies to readers who are new to the subject but at the same time provides interesting background information to those who already have some knowledge about the field.

This book has been translated from the German version. It is an important supplement to the technical book 'Renewable Energy Systems', written by me and published by Hanser Verlag publishers. It is clear from the high level of interest generated by this technical book, which is now in its fifth edition in German and has been translated into English and Arabic, that a real need exists for literature on the subject of renewable energy. The feedback I have received from the book and from many of my lectures indicates that readers want something that offers an overview of the subject that is easy to understand but still comprehensive. This book should fill this gap and provide support in the development of sustainable energy supply.

Berlin, 2009

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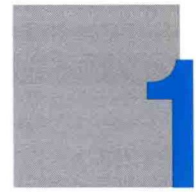

1 Our Hunger for Energy

Most people have heard of the cult TV series *Star Trek*. Thanks to this programme, we know that in the not-too-distant future man will start exploring the infinite expanses of the universe. The energy issue will have been resolved long before then. The Warp drive discovered in 2063 provides unlimited energy that Captain Kirk uses to steer the starship *Enterprise* at speeds faster than light to new adventures. Energy is available in overabundance; peace and prosperity rule on earth and environmental problems are a thing of the past. But even this type of energy supply is not totally without its risks. A warp core breach can cause as much damage as a core meltdown in an ancient nuclear power station. Warp plasma itself is not a totally safe material, as the regular viewers of *Star Trek* very well know.

Unfortunately – or sometimes fortunately – most science fiction is far removed from the real world. From our perspective the discovery of a warp drive seems highly unlikely, even if dyed-in-the-wool *Star Trek* fans would like to think otherwise. We are currently not even close to mastering comparatively simple nuclear fusion. Consequently, we must rely on known technology, whatever its drawbacks, to solve our energy problems.

In reality, energy use has always had a noticeable impact on the environment. Looking back today, it is obvious that burning wood was less than ideal and that the harmful noxious fumes created by such fires considerably reduced the life expectancy of our ancestors. A fast-growing world population, increasing prosperity and the hunger for fuel that has developed as a consequence have led to a rapid rise in the need for energy. Although the resulting environmental problems may only have affected certain regions, the effects of our hunger for energy can now be felt around the world. Overconsumption of energy is the main trigger for the global warming that is now threatening to cause devastation in many areas of the world. However, resignation and fear are the wrong responses to this ever-growing problem. There are alternative energy sources to be tapped. It is possible to develop a long-term safe and affordable energy supply that will have only a minimal and

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manageable impact on the environment. This book describes the form this energy supply must take and how each individual can contribute towards a collective effort to halt climate change. But first it is important to take a close look at the causes of today's problems.

1.1 Energy Supply – Yesterday and Today

1.1.1 From the French Revolution to the Early 20th Century

At the time of the French Revolution in 1789 animal muscle power was the most important source of energy. Around 14 million horses and 24 million cattle with an overall output of around 7.5 billion watts were being used as work animals (König, 1999). This corresponds to the power of more than 100 000 mid-range cars.

Power and Energy or the Other Way Around

The terms 'power' and 'energy' are closely linked, and for this reason they are often confused with one another and used incorrectly.

Energy is stored work; thus the possibility to perform work. It is identified by the symbol E. The symbol for *work* is W.

Power (symbol: P) indicates the time during which the work is to be performed or the energy used.

$$P = \frac{W}{t} \quad \left(\text{power} = \frac{\text{work}}{\text{time}}\right)$$

For example, if a person lifts a bucket of water, this is considered work. The work that is performed increases the potential energy of the bucket of water. If the bucket is lifted up twice as quickly, less time is used and the power is doubled, even if the work is the same.

The unit for power is the watt (abbreviation: W). (The fact that the abbreviation for watt is the same as the symbol for work does not simplify matters.)

The unit for energy is watt second (Ws) or joule (J). Other units are also used for energy. Appendix A.1 provides the conversion factors between the different units of energy.

As the required powers and energies are often very high, prefixes such as mega (M), giga (G), tera (T), peta (P) and exa (E) are frequently used (see Appendix A.1).

The second staple energy source in those days was firewood, which was so important that it probably changed the political face of Europe. It is believed today that the transfer of the Continent's centre of power from the Mediterranean to north of the Alps came about because of the abundance of forests and associated energy potential there. Although the Islamic world was able to maintain its position of power on the Iberian peninsula well into the 15th century, one of the reasons why it lost its influence was the lack of wood. The problem was that there was not enough

firewood that could be used to melt down metal to produce cannons and other weapons. This goes to show that energy crises are not just a modern phenomenon (Figure 1.1).

Figure 1.1 Firewood, draught animals, wind and water power supplied most of the energy needed in the world as late as the 18th century.

In addition to muscle power and firewood, other renewable energies were used intensively until the beginning of the 20th century. Between 500 000 and 600 000 watermills were in operation in Europe at the end of the 18th century. The use of wind power was also widespread, particularly in flat areas with a lot of wind. For example, the United Netherlands had around 8000 working windmills at the end of the 17th century.

For a long time fossil energy sources were only of secondary importance. Although coal from underground deposits was known to be a source of energy, it was largely avoided. It was not until a lack of wood in certain areas of Europe led to energy shortages that coal deposits began to be exploited. In addition, the higher energy density of coal proved to be an advantage in the production of steel. There was no stopping the development of this resource once the industrial revolution dawned. In 1800 60% of coal was used to provide domestic heat, but 40 years later far more coal was used in ironworks and other factories than in homes.

Fossil Energy Sources – Stored Solar Energy

Fossil energy sources are concentrated energy sources that evolved from animal and plant remains over very long periods of time. These sources include oil, gas, hard coal, brown coal and turf. The base materials for fossil energy sources could only develop because of their conversion through solar radiation over millions of years. In this sense, fossil energy sources are a form of stored solar energy.

From a chemical point of view, fossil energy sources are based on organic carbon compounds. Burnt in conjunction with oxygen, they not only generate energy in the form of heat but also always produce the greenhouse gas carbon dioxide as well as other exhaust gases.

In around 1530, coal mines in Great Britain were producing about 200 000 tons of coal annually. By 1750 it was about 5 million tons and in 1854 an astonishing 64 million tons. By 1900 three countries, Britain, the USA and Germany, had an 80% share of world production (König, 1999).

Renewable Energies – Not That New

The supplies of fossil energies, such as oil, natural gas and coal, are limited. They will be depleted within a few decades and then cease to exist. Renewable energy sources, on the other hand, 'renew' themselves on their own. For example, if a hydropower plant takes the power of the water from a river, the river will not stop flowing. The energy content of the river renews itself on its own because the sun evaporates the water and the rain feeds the river again.

Renewable energies are also referred to as 'regenerative' or 'alternative' energies. Other renewable energies include wind power, biomass, the natural heat of the earth and solar energy. Even the sun will eventually disappear in around four billion years. Compared to the few decades that fossil energy sources will still be available to us, this time period seems infinitely long.

Incidentally, renewable energies have been used by mankind for considerably longer than fossil fuels, although the current systems for using these fuels are vastly more advanced than in the past. Therefore, it is not renewable energies that are new but rather the knowledge that in the long term renewable energies are the only option for a safe and environmentally compatible energy supply.

At the end of the 20th century worldwide coal production reached almost 4 billion tons. With an overall share of less than 3% of the world market, Germany and Britain had lost their former position of supremacy in the coal industry. Today power stations use most of the available coal. China and the USA are currently the main coal-producing countries by a considerable margin.

1.1.2 The Era of Black Gold

Like coal, oil consists of conversion products from animal and plant substances, the biomass of primeval times. Over millions of years plankton and other single-celled

organisms were deposited in sea basins. Due to the lack of oxygen, they were unable to decompose. Chemical processes of transformation eventually turned these substances into oil and gas. On the other hand, the biomass that was originally deposited originated from the sun, which means that fossil energy sources like coal, oil and gas are nothing more than long-term conservers of solar energy. The oldest oil deposits are around 350 million years old. The area around the Persian Gulf where most oil is exploited today was completely below sea level ten to fifteen million years ago.

The oil deposits were developed much later than coal, because for a long time there were no practical uses for the liquid energy source. Oil was used in small quantities for thousands of years for medicinal and lighting purposes, but its high flammability compared to coal and charcoal gave it the reputation of being a very dangerous fuel. Petroleum lamps and later the invention of internal combustion engines finally provided a breakthrough at the end of the 19th century.

Industrial oil production began in August 1859. While drilling at a depth of 20 m near Titusville in the US state of Pennsylvania, the American Edwin L. Drake struck oil. One name in particular is linked with further oil exploitation in America: John Davison Rockefeller. In 1862 at the age of 23 he founded an oil company that became Standard Oil and later the Exxon Corporation and incorporated large sections of the American oil industry.

However, it was still well into the 20th century before fossil energy supplies, and specifically oil, dominated the energy market. In 1860 about 100 000 tons of oil were produced worldwide; by 1895 it was already 14 million tons. German government figures reveal that in 1895 there were 18 362 wind engines, 54 529 water engines, 58 530 steam engines and 21 350 internal combustion engines in use in the country (Gasch and Twele, 2004). Half the drive units even then were themselves still being operated using renewable energy sources.

There was a huge rise in oil production in the 20th century. In 1929 output had already risen to over 200 million tons and in the 1970s it shot up to over three billion tons (Figure 1.2). Today oil is the most important energy source of most industrialized countries. An average UK citizen, including small children and pensioners, uses around 1600 litres of oil per year. An average German citizen uses 2000 litres and an US citizen an astonishing 4000 litres. This amounts to 40 well-filled bathtubs.

Being too dependent on a single energy source can become a serious problem for a society, as history shows. In 1960 OPEC (Organization of Petroleum Exporting Countries) was founded with headquarters in Vienna. The goal of OPEC is to coordinate and standardize the oil policies of its member states. These include Algeria, Ecuador, Gabon, Indonesia, Iraq, Qatar, Kuwait, Libya, Nigeria, Saudi Arabia, Venezuela and the United Arab Emirates, which at the end of the 20th century together controlled 40% of oil production worldwide. As a result of the Yom Kippur war between Israel, Syria and Egypt, the OPEC states cut back on production in 1973. This led to the first oil crisis and a drastic rise in oil prices. Triggered by shortfalls in production and uncertainty after the revolution in Iran and the subsequent first Gulf war, the second oil crisis occurred in 1979 with oil prices rising to US$38 per barrel.