1 ASSESSING RENEWABLE POWER

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It is fair to say that nowadays electricity, more than oil, is the lifeblood of industrial society. Electricity drives the machines of industrial enterprises, heats and cools the spaces where we live and work, enables computing and communication over vast distances and powers an almost infinite set of tools and toys. Soon, also a large share of the transport of goods and people could come to rely on electricity.[1]

World electricity consumption has increased by three per cent annually, almost doubling over the last twenty years. Measures to improve energy efficiency might curb growth of demand but with a growing world population, increased economic activity and a shift from other energy carriers to electricity, demand for electrical power will likely continue to grow in decades to come.

While electricity in itself is a convenient energy carrier that can be used without emissions of pollutants and greenhouse gases, its production is laden with environmental, social and political problems. Two thirds of the electricity consumed globally is still produced from fossil fuels and eighty per cent is produced from non-renewable energy sources. This calls for a radical transformation of electricity supply in the coming decades. Climate, pollution, safety, security and cost issues related to fossil fuels and nuclear power constitute strong drivers to harness renewable flows of energy for power production all over the world (Chapter 2).

Electrical power produced from biomass is gaining increasing interest and recently surpassed one per cent of world supply. While being renewable if managed properly, bioenergy is, like fossil fuels, a chemically stored form of energy with unique benefits and drawbacks. Therefore, bio power and the use of biomass in general, is not included in this book but is dealt with in detail in another book in the same ebook series.[2] The focus of this book is instead the potential and implications of converting naturally occurring energy flows directly into electricity.

1 See for example *Systems Perspectives on Electromobility.* (2014) 2nd edition. Chalmers Univeristy of Technology, Göteborg, Sweden
2 See *Systems Perspectives on Biorefineries.* (2014) 3rd edition. Chalmers Univeristy of Technology, Göteborg, Sweden.

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Hydro power has been around since the dawn of electricity production in the 19th century and currently supplies a sixth of world electricity demand. While hydro power production continues to grow (Chapter 4), its ultimate technical potential is fairly limited (Chapter 3) and social and environmental concerns may further constrain its expansion (Chapters 3 and 6). Also geothermal power has increased steadily over many decades, although on a smaller scale. In contrast, most of the many forms of ocean power technology are still in an experimental phase, but with an increasing number of demonstrations initiated all over the world (Chapter 4). The most important development, however, is the rapid growth of wind and solar power over the last two decades. Although their shares of world electricity supply at the end of 2013 were only about three per cent and a half per cent, respectively, the exponential growth, rapid price drops and huge potential which vastly exceeds current electricity supply, signal the entry of a possible game changer (Chapters 2-3).

The inclusion of renewable power that varies over the day and year and with shifting weather conditions, so called intermittent power, presents a challenge to the current power system which was developed around fuel combustion and controllable hydro power. The challenges cover a wide spectrum of time constants: from the milliseconds and seconds relevant for power quality and grid stability to energy balances over days and seasons (Chapters 5 and 9). There is a demand for new solutions to transmit and store electricity, but also new ways of aligning demand and supply as well as combining different forms of power production (Chapters 5, 9-12).

A perhaps even greater challenge for the incumbent industry is the possible shift from centralised to decentralised power production. Modular technologies, such as solar photovoltaics (PV), open up for radically different system configurations, with millions of small producers linked in networks or forming numerous independent systems with local storage. This threat is met by industrial actors and the political system in different ways, but as in all profound societal transformations, there is bound to be battles over institutions, i.e. fight over the laws, regulations and norms that frame what is considered viable, affordable, profitable and desirable (Chapters 2, 13-14).

While in most cases profoundly less harmful and risky than fossil fuels and nuclear power, renewable power systems will not be without environmental impacts (Chapter 6). The energy use and associated greenhouse gas emissions in the production of renewable power plants is, in general, small and may decrease even further in the future, but can under certain circumstances be of relevance for specific installations (Chapter 7). More importantly, considerations of the local environment in the selection of sites and design of installations is a critical issue for most renewable power technologies (Chapters 6 and 8).

The renewable power technologies have different characteristics. Solar power has such a large potential, and even global distribution of that potential, that it can replace all non-renewable energy (not only electricity). It can even allow for a sustainable global industrial society where ten billion people use as much energy as people in present industrial societies (Chapter 3). Also wind energy has a large

potential and is available in most geographical settings. The other energy forms are locally concentrated, and while they can never contribute with a very high share of electricity supply, they can be of local importance and, in addition, help balancing demand and supply. The Nordic hydro power resource is an example of this (Chapter 11).

Despite the large potential and many benefits, development and diffusion of renewable power will require policy support. Different technologies will require different types of support, and typically one type of policy intervention is not enough. Here we provide one example: what is required for a large scale diffusion of off-shore wind power in Sweden and in the Baltic Sea (Chapter 15)? The case of off-shore wind power is also used to illustrate the need for financial and human resources in the very large scale transformation processes that will be required to develop electricity and energy systems based on renewable power (Chapter 16).

In summary, there are great opportunities to transform the electricity system and eventually the complete energy system. The natural energy flow resources are immense, there are technologies available and their economics is steadily improving. We might be on the verge of a new industrial revolution,[3] but as in all revolutions, there will be mistakes made, hurdles to pass and conflicts to solve. It is our hope that books like this might help out in the process.

3 Sandén, B.A. (2008) Solar solution: the next industrial revolution. Materials Today 11:22-24.