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Renewable Energies

Business Outlook 2050

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Preface

This book presents the main advances in renewable energy sources and looks into the Business Outlook of the sector until 2050. Each chapter discusses the key issues expected to influence renewable energy in the forthcoming years. This book integrates analytic principles with business practice in the renewable energy sector. It provides an interface between the main disciplines of economic/engineering/technology and the organisational, administrative and planning abilities of management applied in renewable energy. It is complementary to other subdisciplines such as economics, financial management, marketing, decision-making and risk analysis.

This book is intended for wide use among engineers, economists, strategists, managers, researchers and scientists conducting research or working on renewable energy-related disciplines. The authors of this book describe their original work in the area or provide material for case studies successfully applying engineering management in case studies.

This work provides a comprehensive overview of current renewable energy technologies and their basic principles. It also addresses the financial aspects of renewable energy projects and analyses their profitability, covering the most relevant topics for engineers, economists, managers and scientists who are actively involved in renewable energy research and management. The authors are researchers and professionals active in renewable energy, supplementing the main content with revealing case studies and best-practice examples.

Renewable energy is essential for the world economy and the current and future generations' welfare, contributing in a balanced way to the attainment of the general goal of energy security and environmental protection. However, there are also different technical, economic, societal and financial challenges and limitations for the deployment of renewable energy sources, distribution and consumption which need to be addressed. In order to understand and overcome these challenges and barriers in further promoting renewable energy growth, it is important to model, analyse and assess the cost-effectiveness and societal and environmental impact of various renewable energy solutions systemically. Chapter "Multiple Criteria Performance Modelling and Impact Assessment of Renewable Energy Systems—A

Literature Review" aims to review relevant performance modelling, impact assessment and decision analysis techniques for renewable energy systems.

Chapter "Towards Energy Self-sufficiency in Large Metropolitan Areas: Business Opportunities on Renewable Electricity in Madrid" introduces the paradigm of the large metropolitan areas that are generally associated with high energy demand but low energy production, thus acting as vast energy drains. Reducing energy import levels in this type of region may bring about relevant business opportunities. Given the increasingly significant role of green (low-carbon) energy in current and future energy policies, these opportunities are expected to be closely linked to renewable energy. In this chapter, the energy system model of the region of Madrid (Spain) is used to evaluate novel energy scenarios to 2050 based on alternative electricity import levels. As indigenous electricity supply increases, wider market horizons arise for renewable energy technologies as a plausible option. Overall, through the case study of Madrid, it is shown that the path towards clean energy self-sufficiency has the potential to act as an effective catalyst for business opportunities on renewables in large metropolitan areas.

Chapter "How Do Energy Engineers of the Future Think. Analysis of Master Students' Proposals" considers the projects on renewable energy developed by postgraduate students, as it is significant to know the vision of the new generation of energy engineers. These projects can be used as a source of creativity and innovation. The projects of 168 international students pursuing EIT KIC InnoEnergy masters, more specifically M.Sc. RENE and M.Sc. SELECT, were analysed. The students were gathered in 25 teams and worked on projects and challenges following their own ideas. The students' proposals were listed and classified according to technologies, degree of radical innovation, complexity, scope, TRL and agents that would develop the solutions. The typical proposal is based on solar energy, involves several elements, has, at least initially, a limited scope, uses commercially available technology and is adapted to the case in all other respects. This vision seems to be very promising to spread renewable energy solutions.

Concentrated solar power (CSP) systems use the thermal energy coming from the sun in the form of solar radiation for generating electricity. This renewable energy source will require the use of new technologies in the future to expand further. Chapter "Concentrated Solar Power: Present and Future" describes the main characteristics of CSP systems, their technical issues and maintenance management. The solar thermal industry employs different CSP plant types based on parabolic trough, linear Fresnel, solar towers, dish Stirling and solar chimney technologies. Each of these technologies is analysed compared with the others. The operational expenditure (OPEX) costs of CSP must be reduced further in order to increase its competitiveness in comparison with other power generation sources and increase market penetration prospects. The chapter also presents the main maintenance management approaches, including inspection strategies for ensuring structural integrity during operation.

Big Data is becoming the most powerful tool to analyse the huge amount of data that the condition monitoring and SCADA systems currently collect. Cloud processing is among the benefits offered by Big Data, allowing analysis of data in real time from different parts of the world. The technological advances in mass data processing can be exploited to treat information from thousands of sensors. Chapter "Concentrated Solar Plants Management: Big Data and Neural Network" presents a new approach for optimal condition monitoring and control of CSP Plants spread over different geographical locations. The information from condition monitoring sensors and data for the optimal control of the plants need a cloud platform for joint analysis with forecast data (meteorological, demand of other plants, etc.). The main processing tool used is based on neural networks, responsible for correlating the obtained signals in real time, to determine anomalous results and generate alarms.

Chapter "Wind Energy Power Prospective" deals with wind energy and wind farm operation and maintenance. Wind farms, in contrast to the conventional power plants, are exposed to variable weather conditions. As a result of these variations, wind turbines are subjected to high variable mechanical loads, which require a high level of maintenance to provide cost-effective power production and ensure uninterrupted operation throughout the intended design lifetime. The demand for wind energy has been rising at an exponential rate in recent years, due to the reduction in operating and maintenance costs, as well as increasing reliability of industrial wind turbine models. Wind turbine operators employ condition monitoring systems that collect information regarding the actual condition of the main components of the turbine, enabling maintenance crews to determine anomalous operating situations in time to intervene and correct faults.

Weather conditions have a key role in the amount of energy produced by wind farms. Ice can appear in regions with cold conditions or during winter season. Ice on blades reduces the efficiency of the turbines, increases failures and downtime, causing imbalance of the rotor and resulting in power generation losses and hence reduced profitability. This makes necessary the research and development of new methods for detection, prevention and removal of ice from blades. Chapter "Managing Costs and Review for Icing Problems" presents the current state of the art in dealing with blade icing, including some techniques and methods of detection, anti-icing and de-icing. Finally, an economicotechnic study concerning commercial ice detection systems is carried out.

Chapter "Big Data and Wind Turbines Maintenance Management" focuses on the analysis of the Big Data associated with wind farm maintenance. An analysis of the data collected by Condition Monitoring and Supervisory Control and Data Acquisition Systems is carried out. This analysis is done using two methods whose objectives are to reduce the amount of data and, therefore, to facilitate the data processing. Two case studies are presented in order to clarify how these methods should be applied.

The Icelandic society is conveniently located where the Eurasian and North-American tectonic plates meet. This allows for relatively easy and cheap access to geothermal energy. Icelanders have benefited from this since settlement, first through direct use of the warm water but later on by co-producing electricity. The nation also benefits from large glacial rivers, offering potential for energy harvesting. Chapter "Societal and Environmental Impact of High Energy Return on Investment (EROI) Energy Access" explores the benefits of renewable energy in this region, using Iceland as a case study. It is demonstrated by exploring the energy return on investment (EROI) for the Nesjavellir geothermal and Fljotsdalsstod hydropower plant and the CO_2 mitigation provided by the resources as the Icelandic society no longer needs to rely on fossil fuels for electricity and heating. This chapter demonstrates systematically how societies may benefit ecologically but also energetically from access to renewable energy sources.

Chapter "Future Maintenance Management in Renewable Energies" describes the future of maintenance management in renewable energy industry. The importance of non-destructive testing (NDT) is highlighted. NDT involves the use of a variety of inspection techniques for detecting internal or surface discontinuities in structures, or determining certain properties of materials. The results of NDT processes contribute to the improvement of quality, public safety and prevention of faults. Effective NDT approaches can help reduce the corrective/preventive maintenance requirements of a renewable energy plant as well as increase the operational lifetime of certain components.

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About the Editors

Prof. Fausto Pedro García Márquez obtained his European Doctorate in 2004 at the University of Castilla-La Mancha (UCLM, Spain) with a maximum distinction. He has distinguee with the Runner Prize (2015), Advancement Prize (2013) and Silver Prize (2012) by the International Society of ManagementScience and Engineering Management, or the Advancement Prize in the Third International Conference on Management Science and Engineering Management. He is working at UCLM as senior lecturer (with tenure, accredited as full professor), Spain, Honorary Senior Research Fellow at Birmingham University, UK, lecturer at the Postgraduate European Institute, and he was senior manager in Accenture (2013–2014). Fausto has managed a great number of 253 projects: 5 Europeans as principal investigator (PI), 4 FP7 framework programme and 1 Euroliga+4, being researcher in 3 FP7; he is PI in 2 national projects, and he has participated in 2 as PI and 2 as researcher; 4 regional projects, 1 as PI and 3 as researcher; 3 university projects, 1 as PI and 2 as researcher; and more than 100 with research institutes and industrial companies (98% as director). He has been evaluator in different programs, nationals and internationals. As a result of the research work, he has published more than 150 papers (65% in ISI journals, 30% in JCR journals and 92% internationals), being the main author of 68 publications. Some of these papers have been especially recognised, e.g. by "Renewable Energy" (as "Best Paper Award 2014"); "International Society of Management Science and Engineering Management" (as "excellent"), and by the "International Journal of Automation and Computing" and “IMechE Part F: Journal of Rail and Rapid Transit” (most downloaded). He is the author of 18 books (Elsevier, Springer, Pearson, Mc-GrawHill, Intech, IGI, Marcombo, AlfaOmega, etc), and he is the author of 5 patents. He is the associate editor of the International Journals: Engineering Management Research, Open Journal of Safety Science and Technology, and International Journal of Engineering and Technologies, and he has participated as Committee Member in more than 25 International Conferences and the Director of Ingenium Research Group (www.uclm.es/profesorado/fausto).

Dr. Alexander Karyotakis after graduating in Mechanical Engineering and completing a Ph.D. on the optimisation of offshore wind farm O&M strategies and reliability of wind turbines at University College London (UCL) has been working as a coordinator and business developer on renewable energy projects, while involved as a technical consultant in several international research and development programs in renewables including NIMO, Optimus and SolarFox, having published highly cited journal and conference papers in renewables.

In 2010, he joined TERNA ENERGY (Member of GEK-TERNA Group), where he got involved and coordinated the development, engineering, construction and operation of large onshore wind projects in Europe and the USA, while supervising the first-stage technical design and conceptual development of several offshore wind farms (conventional and floating) in southern Europe.

Dr. Mayorkinos Papaelias (Ph.D. in Metallurgy, Chartered Engineer—Greece) is a senior lecturer in NDT and Condition Monitoring at the School of Metallurgy and Materials at the University of Birmingham. Dr. Papaelias is an expert in NDT and condition monitoring technology. He has been involved as technical coordinator or scientific consultant in several FP6 and FP7 collaborative research projects. He is the author or co-author of more than 70 journal and conference papers in NDT and condition monitoring. He is also a member of the International Society for Condition Monitoring. Dr. Papaelias regularly authors articles for industrial magazines.

Multiple Criteria Performance Modelling and Impact Assessment of Renewable Energy Systems—A Literature Review

Ting Wu, Dong-Ling Xu and Jian-Bo Yang

Renewable energy is essential for the world economy and the current and future generations' welfare, and it contributes in a balanced way to attain the general goal of energy security and environmental protection. However, there are also challenges and barriers to the deployment of renewable energy generation, distribution and consumption, including technical, economic, cultural and financial challenges. In order to understand and overcome the challenges and barriers of promoting the growth of renewable energy, it is important to model, analyse and assess the cost-effectiveness, and societal and environmental impact of various renewable energy solutions systemically. This chapter aims to review relevant performance modelling, impact assessment and decision analysis techniques for renewable energy systems.

1 Introduction

In 2003, the energy white paper released by the British government sets a target of carbon emissions reduced to 60% of 1990 levels by 2050. At the same time, current resources are forecast to be limited in the coming years with apparent destructive consequence to the environment [4]. In order to achieve the objective and solve the energy shortage problem in long term, renewable energy alternatives are widely selected to replace the conventional sources and there is an increase to use electricity which is generated from renewable energy, such as small hydro, solar power, wind power, biomass, biogas, geothermal power, etc. [43]. The major advantages of renewable energy include little pollution and emission, unlimited supply, better energy structure and security. However, relatively low efficiency, high costs for

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power generation and research and development, scattered energy sources and energy acquisition difficulty become the disadvantages of green energy, which hamper their deployment [27, 45].

Therefore, how to evaluate the performance and impact of different sources of renewable energy is a key problem in energy policy making and involves different factors. In order to stride over the challenges and barriers and to support making informed and insightful decisions, there is a great necessity to model and assess the performance, cost-effectiveness, societal and environmental impact of alternative renewable energy system systemically. Renewable energy decision-making problems cannot be analysed by traditional single criteria decision-making approach. It needs to handle various complex issues of current and future energy systems and can be considered as a multiple criteria decision-making problem with correlating criteria.

The next section will introduce the recent development in renewable energy and its related policies. The third section will review criteria, techniques and models for impact assessment of renewable energy systems. The fourth section will focus on the applications of impact assessment of renewable energy systems in policy making. The chapter is concluded in the fifth section.

2 Policy Making Related to Renewable Energy Systems

The development of renewable energy can potentially tackle the climate change, prevent serious environmental pollution and slow down the exhaustion of fossil fuel reserve problem [45, 55]. REN21 report [63] provided an overview on the global renewable energy market and industry across both developed and developing countries. In Europe, the use of renewable energy is seen as a key element in energy policy. Directive 2009/28/EC was issued to promote the use of energy from renewable sources and it established criteria accounting for the 2020 targets on renewable energy sources. As a result, it is observed in the past decade that the use of renewable energy sources has increased significantly. For example, Fig. 1 shows the continuing increase on the share of energy from renewable sources for electricity, and the renewable energy sources account for 27.5% of European energy generation in 2014 [27]. In China, RE100 [62] analysis showed that the government and also private sectors increased investment to renewable energy in 2015 by 32% from the previous year, and a series of policies and regulations were put into effect to encourage domestic renewable energy deployment.

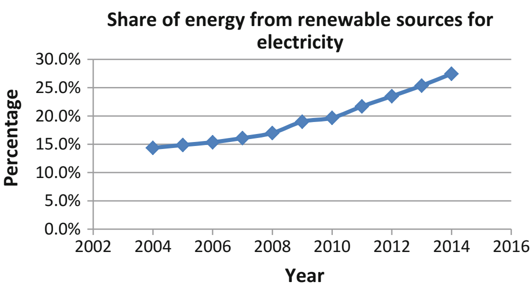

Fig. 1 Share of renewable energy sources for electricity (*Data source* [27])

There are different forms of renewable energy, as complements to traditional energy resources (e.g., oil, coal and natural gas) and nuclear power. The mainstream forms of renewable energy are very briefly introduced below in order to further review relevant criteria, techniques and models for their performance modelling and impact assessment.

(1) Hydropower

Hydropower is derived from the energy or force of fast moving water, and it is regarded as the most flexible and consistent of renewable energy resources. There are different ways of harnessing the waterpower, and hydroelectricity is the most widely used form of renewable energy. According to the key world energy statistics by the international energy agency [35], hydroelectricity contributes 20% of global electricity generation in 2013. However, it is extremely expensive to construct dams for hydropower, which must be operated for decades to be profitable. The natural environment could be changed dramatically from the flooding of large areas of land.

(2) Wind power

Wind power is extracted from airflows, through which wind turbines are run to produce mechanical or electrical power. Wind turbines have been widely installed to offshore and high altitude areas globally where winds are usually strong and constant. Wind power produces an increasing percentage of the global electricity. The wind energy technology is relatively mature and advanced compared with other renewable energy technologies [21], but it also requires a large-scale land use to build wind farms, and noises and visual effect are also obstacles for the wide installation of windmills.

(3) Solar power

A range of ever-evolving technologies have been used to gather solar energy in the forms of radiant light and heat from the sun. Different technologies, such as solar heating, photovoltaics, concentrated solar power (CSP) and solar architecture [34], can be used to capture and convert solar energy in a either active or passive way. However, solar energy is dispersed unevenly around the world and there is no solar energy at night, which makes energy collection discontinuous and unstable, especially with the seasonal and weather effects [55].

(4) Biomass

Biomass uses biological materials usually derived from plants or plant-derived materials. As an alternative renewable energy source, biomass can be used in two different forms: direct combustion to produce heat or indirect conversion to various forms of biofuel, such as methane gas and biodiesel. There is potentially side pollution from the waste processing of biomass energy.

Apart from the mainstream renewable energy sources, there are also some other sources of renewable energy, such as geothermal energy and ocean energy. There are advantages and disadvantages of harvesting each type of renewable energy.

Instead of taking a close look at the various forms of renewable energy, this chapter is mainly concerned with criteria, techniques and models for impact assessment of renewable energy systems, in particular, renewable or decentralised green energy (DGE) systems. In contrast to centralised energy systems, a decentralised energy system relies to a large extent on small-scale and sometimes intermittent generation from the above renewable energy sources [23]. Developing decentralized energy systems can increase the use of renewable energy, so as to reduce carbon emissions, improve energy efficiency, explore new energy generation capacity and improve the security of generation supply [3, 23, 20]. Furthermore, decentralised green energy systems are regarded to be central to the world's future energy and economic strategies. However, there are also barriers and challenges to deploy decentralised renewable energy systems. In addition, the development of the systems is also dependent on national energy legislation and policies. For example, small-scale DGE systems may not as competitive as centralised energy systems without financial subsidies or support. In order to support the decision making process, the performance, cost-effectiveness, social and environmental impact of alternative DGE solutions are reviewed systematically in Sect. 3.

3 Criteria, Techniques and Models for Impact Assessment of DGE Systems

Many researchers have developed a spectrum of different criteria, techniques and models for impact assessment of renewable energy systems [22, 28, 39]. For example, Evans et al. [28] assessed renewable energy technologies in the context of sustainability. The critical sustainability indicators include price of generated electricity, greenhouse gas emission, availability of renewable sources, efficiency of energy conversion, land requirements, water consumption and social impacts, and they are assumed to have equal importance. The most sustainable energy was ranked as wind power, hydropower and photovoltaics. Elliott [22] looked at the institutional and social obstacles to the development and deployment of renewable energy in the context of sustainable development. Painuly [57] emphasized the importance of providing energy with sustainability to the vast populations in developing countries, and also pointed out the barriers to renewable energy penetration.

3.1 Criteria of Impact Assessment

In the context of impact assessment of renewable energy systems, multiple criteria can be identified and weighted in order to provide a structured way to produce informative assessment results. Multiple criteria performance modelling and impact assessment can provide in-depth understanding of key advantages and inherent impact, and facilitate an informed decision making process. Papadopoulos and