Renewable Energy

Sources, Applications and Emerging Technologies

Viola Burton
Editor

Renewable Energy: Research, Development and Policies

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RENEWABLE ENERGY: RESEARCH, DEVELOPMENT AND POLICIES

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PREFACE

This book provides current research on the sources, applications and emerging technologies of renewable energy. Chapter One explores which policy strategies could be successful for the large-scale deployment of renewable energies. Chapter Two discusses green nanotechnology in bioenergy. Chapter Three explores the position of waste-to-energy in the UK, as one key part of the UK's response to the wide range of energy, sustainability and climate change challenges it is facing. Chapter Four proposes a methodology that includes tangible and concrete steps, customized in a region/country's specific energy profile, characteristics and objectives, towards the formulation of an optimal strategy for the promotion of renewable energy. Chapter Five explores the history and implications of the use(s) of solar power at a time of limited natural resources and the threat of climate change. Chapter Six offers a comprehensive and consistent overview of solar-assisted heat pump (SAHP) systems. Chapter Seven presents intelligent adjustable solar panel and hydrogen cars. Chapter Eight argues the case for the prioritized demonstration and implementation of low carbon technological innovations in the Pacific region.

Chapter 1 – Many countries around the world strive towards a sustainable energy system based on renewable energy technologies. The transition from a fossil-fuel dominated system with controllable thermal units to a system dominated by intermittent and diverse renewable energies is, however, not easily achieved. In this chapter, The authors explore which policy strategies could be successful for the large-scale deployment of renewable energies. They analyse which types of policy instruments are preferable when. The authors find that policy strategies must be differentiated depending on the phase in which a particular energy transition is in. In the early phase, a focus on growth and increased deployment of technologies is likely to dominate the political agenda, whereas in later phases, the integration of technologies into system and markets will become more important. Because policy objectives are evolving alongside an energy transition, policy design needs to change. At first, it may be beneficial to establish simple and protective support schemes for the still immature technologies, such as feed-in tariffs. This is, however, only economically viable up to a certain point, from which policy safeguards, such as budget and volume control, often begin to rise on the political agenda. Then, for example premium schemes and competitive bidding processes (auctions) start to play an important role. Furthermore, with market shares of renewable energies becoming more significant, certain regime shifts become necessary, including changes in infrastructure and market rules. They describe beneficial policy frameworks for the respective transition phases and argue that tailoring policies to the specific needs of different phases will increase the success likelihood of energy transitions and lead to faster and less costly development of renewable energies.

Chapter 2 – The green technologies in an urgent attempt to alleviate fossil fuel usage and CO_2 emissions, fuels, heat or electricity must be produced from biological sources by nanotechnology which is economic, energetically efficient, environmentally friendly and not competitive with food production due to unsustain of the current fossil fuel usage and its successive greenhouse gas production. Therefore, nanotechnologies in bioenergy suitable to the friendly environment are marked aim to provide the vital information about the growing field for green energy to minimize the potential environmental risks. It is pointed out that the significantly feasible world's eco-energy for the foreseeable future should not only be realized, but also methods for using the current energy and their by-products more efficiently should be found correspondingly, alongside technologies that will ensure minimal environmental impact.

Chapter 3 – The UK is subject to a range of environmental and climate change commitments, implemented at the global (for example the Kyoto Protocol), regional (European Union, EU legislation) and national levels. The UKs 2008 Climate Change Act set a binding target of an 80% reduction in greenhouse gas emissions by 2050, relative to 1990. EU legislation includes the 2009 Renewable Energy Directive (RED), which aims, for example, for the UK to source 15 per cent of its total energy from renewable sources by 2020. Other EU legislation deals directly with waste, for example the Waste Directive and Landfill Directive. The latter, for example, requires EU member states to reduce their biodegradable municipal waste disposed to landfill by 65% by 2020, comparative to 1995 levels. In responding to these legislative imperatives, UK energy policy faces three distinct and potentially contradictory challenges: security of supply, decarbonisation of the future economy and affordability. It is argued that to meet these challenges, significant investment is needed to diversify the sources of electricity generation in the UK. UK energy strategy has been built primarily around meeting the energy security objective of the country for both domestic and business uses. This vision is bounded by meeting the UK's targets on carbon emissions and renewable energy generation. Challenges to UK energy strategy can be divided into the short term and the long term. In the short term, there is the potential for distribution failures, industrial action and severe weather events as a result of more volatile weather conditions. In the longer term, challenges include changes to market structure, shifts in the geopolitics of energy production, and climate change. In meeting these challenges the UK energy security strategy is said to be designed around competitive energy markets, combined with effective regulation to deliver diversity of supply and robust infrastructure for consumers. As seen above, the context within which UK energy policy operates includes measures aimed directly at addressing energy generation and security questions, and measures reflecting wider environmental and sustainability concerns. It is thus the intention of this chapter to review the UK renewable scene currently, and to highlight the role of energy from waste, in particular Anaerobic Digestion (AD), in aiding the delivery of UK renewable energy policy objectives. A key message is that there is no magic bullet to the problems faced. In order for the UK to meet its environmental obligations and to deliver the increasing energy capacity required, significant investment will be required in every energy sector. By definition, UK strategy must involve diversifying the energy mix and reducing dependency on imported fossil fuels. The UKs energy, sustainability and climate change policies however, cannot be delivered by supply-side action alone. Improving energy efficiency, contributing to reduced energy demand, will allow consumers to save on energy waste and thus reduce their energy bills. The main purpose of this study is to explore the position of waste-to-energy in the UK, as one key part of the UKs response to the wide range of energy, sustainability and climate change challenges it is facing.

Chapter 4 – Climate change mitigation is high on political agenda, while efforts are currently intensified at an international level. The concern is short-term and long-term climate goals to be reached successfully and cost effectively. Renewable energy deployment is the key to contribute to the implementation of international (regional and/or country) climate goals. Therefore, the current political scenery renders as crucial the need to support energy and climate policy makers, as well as stakeholders in general, from decision makers and market actors to general society, towards the promotion of renewable energy deployment. In the above context, this chapter proposes a methodology that includes tangible and concrete steps, customized in a region/ country's specific energy profile, characteristics and objectives, towards the formulation of an optimal strategy for the promotion of renewable energy. The identification of a series of measures and actions to be adapted by policy and decision makers is also demonstrated for a successful renewable energy deployment, supporting in this way the design of solid policies and development of clear understanding on renewable energy options and their possible impacts.

Chapter 5 – Economic development and sustainability debate often centers on the question of renewable energy. Renewables include hydropower, solar thermal, solar photovoltaic, geothermal power, wind power, biogas, solid and liquid biomass, tidal power, wave power, ocean thermal gradients, as well as organic and inorganic waste material. Sometimes, nuclear energy is also classified as a renewable. Virtually all these renewable sources, with the exception of tidal power and geothermal energy, are directly or indirectly the result of solar insolation, as biomass is largely dependent on sunlight. This article will explore the history and implications of use of solar power at the time of limited natural resources and the threat of climate change.

Chapter 6 – Energy, similar to water, food and shelter, is an essential need of all human beings in the world. Fossil fuels are the prominent source for generating utilisable forms of energy. Therefore, fossil fuels are the major contributor to global warming and the greenhouse effect on the ozone. European Union (EU) energy consumption patterns reveal that buildings are the greatest energy consumer using approximately 40% of the total energy demand followed by industry and transportation, which consume approximately 30% each. Currently, heating is responsible for almost 80% of the energy demand in houses and utility buildings, used for space heating and hot water generation, whereas the energy demand for cooling is growing yearly. The awareness of global warming has intensified in recent times and has reinvigorated search for energy sources that are independent of fossil fuels and contribute less to global warming. The European strategy to decrease the energy dependence rests on two objectives: the diversification of the various sources of supply and policies to control consumption. The key to diversification is ecological and renewable energy sources (RES) because they have significant potential to contribute to sustainable development. Among the energy alternatives to fossil fuels, RES such as solar, geothermal and hidropower are more available. Key applications for solar technologies are those that require low temperature heat such as domestic water heating, space heating, pool heating, drying process and certain industrial processes. Concerning the use of high efficiency heating/cooling systems and the integration of RES, the heat pump (HP) is one of the most advantageous systems to be considered in a heating, ventilating and air conditioning plant (HVAC). During the last decades there is an increasing interest in dual source systems. The main idea in dual source systems is that the HP absorbs heat by two heat sources. Two arrangements widely studied in literature are air-source HP/solar collectors and ground-source HP/solar collectors. Solar energy has the characteristics of intermittence and low density, which largely restrict the application of solar heating. The solar-assisted heat pump (SAHP) heating system, which combines HP technology with solar heating technology, can solve the intermittent problem of solar energy. HP systems can extract low-grade thermal energy from the environment and waste heat for use in water/space heating applications. This chapter offers a comprehensive and consistent overview of SAHP systems. Initially, it presents the operation principle of an HP, discusses the vapour compression-based HP systems, and describes the thermodynamic cycle and they calculation, as well as operation regimes of a vapour compression HP with electro-compressor. The calculation of greenhouse gas (GHG) emissions of HPs and energy performance criteria that allow for implementing an HP in a heating/cooling system is considered. A detailed description of the HP types and ground-source HP (GSHP) development is presented and important information on the selection of the heat source and HP systems are discussed. Additionally, other approach is to integrate the solar thermal system on the source side of the HP so that the solar thermal energy is either the sole heat source for the HP or provides suplementary heat. The operation principle and calculation of the thermodynamic cycle for a solar-assisted absorption HP are also briefly analysed. Finally, a novel HVAC system consisting in a solar-assisted absorption ground-coupled HP is described and some of the influence parameters on its energy efficiency is analysed. A model of the experimental installation is developed using the Transient Systems Simulation (TRNSYS) software and validated with experimental results obtained in the installation for its cooling mode operation.

Chapter 7 – This chapter presents application of renewable energy in two folds. The first deals with the penetration of integrated or hybrid renewable energy sources in a micro grid system. The analysis of a hybrid power generation model suitable for serving an off grid micro power system consisting of diesel generation, biogas, solar PV, wind turbine, micro-hydro plants and dc generator of fuel cell type was presented. The concept of hybridizing renewable energy sources help in augmenting expensive constantly run diesel generator in providing power. This fold is based on the modeling, simulation, optimization and sensitivity analysis considering the net present cost, levelized cost of electricity, operating cost and performance of a renewable energy system having load of 20.6 kW under rural electricity supply. The hybrid optimization model for electric renewable software is used in the course of the study to design and optimize the proposed hybrid system. The reported load is used by the community, Al- Zahia-Musandam area of Oman. The second fold of this chapter concentrates on the solar PV-hydrogen system in the first fold in which an electrolyzer converts excess PV power into hydrogen gas. The closed operating condition output of hydrogen tank is fed to a fuel cell, which is used to power hydrogen cars. The hydrogen gas produced via electrolysis process in an intelligent adjustable solar panel configuration was compared to the volume of hydrogen gas obtained using the conventional fixed solar panel. Furthermore, the produced hydrogen gas in both cases was thereby used to power fuel cell cars employing either compressed or liquefied technologies. The performance of the hydrogen cars were then compared to the performance of a direct connected electric car. The proposed arrangement leads to dual way of producing electricity at a lower cost and also provides opportunity for future energy storage which acts as fuel for the transportation sector.

Chapter 8 – The global maritime industry today faces some of the most demanding and novel challenges that it has ever known. Most pressing of these is the challenge of climate change, a defining issue of our era which calls for innovative technological solutions to meet strict emissions reductions targets. Pacific Island Countries (PICs) face this challenge hampered by extreme imported fuel dependency and the highest transport costs, both detrimental to most aspects of sustainable development and climate change adaption measures. Despite transport being a dominant energy user and emitter, a range of complex barriers have prevented priority being given to this sector both locally and internationally. Progress in developing and implementing low carbon maritime transition has lagged dramatically behind land transport and electricity generation innovation. Previous work details the irrationality of this for the Pacific region given sea transport's centrality to the development and climate change adaption discourse. This paper makes the case that PICs offer as an ideal demonstration field for existing and emerging low carbon maritime technologies. A transition pathway is proposed anchored on proactive knowledge and technology transfer partnerships between leading innovation fields in Europe, Korea and the Pacific. Trialing these emerging low-carbon technologies in frontline regions facing climate change will promote a localized climate change adaptation agenda, whilst advancing options for renewable energy solutions at the global level. Scalable, low-cost 'proof of concept' modeling is urgently required to pave the way for the future market demand of low-emission maritime technology. A range of existing and emerging technologies is discussed in this paper, and their suitability to remote island settings is examined. It is argued that field-testing these technologies in PICs is a valid and viable development approach to supporting both the Pacific region and the broader maritime industry through the evaluation of small-scale demonstration models for their scalability. Four specific mature technologies are examined that have received investment and ongoing research attention from leading European and Korean research agencies to bring these technologies to a 'proof of concept' stage for which market uptake within a P-SIDS setting is justifiable and realistic. These technologies are: (i) Flettner rotors; (ii) soft sail cargo carriers; (iii) Wing In Ground vessels; and (iv) biofuel. The paper concludes with an open invitation to all willing partners to join a 'coalition of higher ambition' to practically advance this agenda of climate change in the maritime industry.

CONTENTS

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Chapter 1

THE TRANSITION TO A RENEWABLE ENERGY SYSTEM

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ABSTRACT

Many countries around the world strive towards a sustainable energy system based on renewable energy technologies. The transition from a fossil-fuel dominated system with controllable thermal units to a system dominated by intermittent and diverse renewable energies is, however, not easily achieved. In this chapter, we explore which policy strategies could be successful for the large-scale deployment of renewable energies. We analyse which types of policy instruments are preferable when. We find that policy strategies must be differentiated depending on the phase in which a particular energy transition is in. In the early phase, a focus on growth and increased deployment of technologies is likely to dominate the political agenda, whereas in later phases, the integration of technologies into system and markets will become more important. Because policy objectives are evolving alongside an energy transition, policy design needs to change. At first, it may be beneficial to establish simple and protective support schemes for the still immature technologies, such as feed-in tariffs. This is, however, only economically viable up to a certain point, from which policy safeguards, such as budget and volume control, often begin to rise on the political agenda. Then, for example premium schemes and competitive bidding processes (auctions) start to play an important role. Furthermore, with market shares of renewable energies becoming more significant, certain regime shifts become necessary, including changes in infrastructure and market rules. We describe beneficial policy frameworks for the respective transition phases and argue that tailoring policies to the specific needs of different phases will increase the success likelihood of energy transitions and lead to faster and less costly development of renewable energies.

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Keywords: economic policy analysis, support instruments, feed-in tariffs, effectiveness, efficiency, risk reduction, auctions

INTRODUCTION

Energy systems today are still largely based on fossil fuels. Policy makers and members of society in many countries around the world target the transition towards sustainability and energy systems based on renewable energy sources (RES). The technologies and services that are to form the basis of a new, sustainable energy system including RES technologies, energy efficiency measures and demand management appliances face, however, various barriers to implementation. Therefore, the transition to a renewable energy system requires policy intervention and dedicated policies for the development of desired technologies and services.

It has long been popular in economic energy policy analysis to investigate which policy instrument is superior to achieve deployment in the most efficient way (for an overview see Kitzing, 2014). Acknowledging the dynamic nature of energy transitions, we update the research question and analyse which specifications and combinations of policy instruments are superior to achieve which targets at what times. Answering this research question is crucial for the design of effective policies that can trigger fundamental change at the least long-term cost possible. The insight to focus on long-term normative goals for systemic change has recently entered innovation systems thinking and policy making on a broader basis (Weber & Rohracher, 2012). Some recent studies have started to adopt this broader perspective. For example Miller et al., (2013) describe how policies will evolve during a transition from being focused on maximum deployment ('first-generation' drivers) towards having more nuanced objectives including the reduction of investment risk, minimisation of policy costs and market integration ('next-generation' drivers). Kitzing & Mitchell (2014) provide an evaluation framework for economic policy analysis drawing from transition theory and the multi-level perspective that explores the effects of reducing risks and creating an enabling environment for RES technologies. This chapter is primarily based on this work and further explores some implications for policy making in energy transitions.

ENERGY TRANSITIONS IN TWO POLICY MAKING PHASES

Transitions in general are gradual, continuous processes in which society or a sub-system of society (like the energy system) changes fundamentally over several decades (Rip & Kemp, 1998; Rotmans et al., 2001). In a transition, changes appear at different levels which are typically denoted niches, regime and landscape (Geels, 2004). These changes may happen spontaneously or systematic. They can be induced and triggered by dedicated policy making. In this, policy making can influence but never entirely control the direction, scale and speed of transitions.

We describe two separate phases of an energy transition because of their distinct implications for policy making: An early phase with focus on growth of technologies in protected niches and a later phase with focus on efficient integration and stabilisation of the technologies at regime level. In the early phase of an energy transition, most focus is on growth and fast deployment of new technologies. A dynamic transition process must be initiated. Often, policy makers create protected spaces for the still immature technologies. Protection can for example be achieved by reducing risks, stabilising revenue streams and providing technology-specific price guarantees to enhance investment incentives for new technologies (Finon & Perez, 2007). At some point in time, the niches have grown so much that the new technologies become significant at regime level. Then, the focus of policy making in energy transitions must shift and thus a second distinct phase begins. In this phase, growth cannot be the sole focus of policy making anymore: integration at regime level must play a larger role. Generally, technologies can become part of the regime in two ways. Either they merge into the existing regime by becoming competitive under the existing selection environment and rules ('fit and conform') or they challenge the existing regime and trigger an adaptation of its selecting criteria, rules, and institutions ('stretch and transform') (Smith & Raven, 2012). In energy transitions, the latter development is more likely due to the very different technical and economic characteristics of RES technologies as compared to conventional thermal power plants (Verbong & Geels, 2007). The adaptation of the regime in areas that are directly or indirectly related to the new technologies is thus a crucial characteristic of the second phase in an energy transition. A more holistic and coordinated approach not only targeted towards niches but also towards regime and landscape level becomes crucial. The failure to coordinate policies sufficiently can lead to inefficiencies in transition processes (Weber & Rohracher, 2012).

While policies most certainly should be adapted to the changing needs of the different transition phases, it is crucial that policy changes are made in a well-prepared and predictable way. Creating additional risks related to (potential) regulatory and policy changes can be detrimental for energy transitions, as their dynamic processes are dependent on investor trust and stable frameworks (Agnolucci, 2008). This chapter shall contribute to adopting a long-term perspective in policy making for energy transitions. By laying out the different policy needs and potentially successful strategies over the lifetime of an energy transition, we help to enable the development of long-term strategic policy making frameworks.

Policy Instruments for Energy Transitions

Policy makers can support the transition to a renewable energy system in many ways. Measures range from indirect support, e.g., through carbon pricing, over direct financial support payments to creating enabling environments. In this chapter, we focus mostly on direct support instruments and more specifically the most common production-based support instruments: feed-in tariffs (FIT) and feed-in premiums (FIP), as well as quota schemes with tradable green certificates (TGC). Kitzing et al., (2012) describe traditional FIT schemes as technology-specific mechanisms that offer a guaranteed price to eligible producers, traditionally in combination with priority dispatch and exemption from participation in balancing markets. FIP schemes typically provide fixed, guaranteed add-ons to market prices. Recent feed-in implementations feature sliding premiums, incorporating both the characteristics of an add-on to market price and a guaranteed price level. Traditional TGC schemes are technology-neutral mechanisms that oblige energy suppliers to having a certain amount of RES in their portfolio, which can be acquired in form of green certificates from eligible producers at a dedicated certificates market. FIT and FIP are considered price-control instruments, as traditionally it is the policy makers who are determining the level of support. TGC schemes are considered quantity-control instruments, as here the policy makers define a volume quota and the price is determined on a dedicated market through trading. More recently, auction schemes are being implemented for FIT and FIP, in which policy makers determine a certain target volume, which is then called for in an auction where the price level is found in competition. These new FIT auction implementations have the characteristics of a volume-control instrument while still upholding the stability and security stemming from the price guarantee.

Risk aspects of energy policy receive increasing attention in the choice of support instrument and their design specifications (see e.g., Gross et al., 2010; Klessmann et al., 2008). One of the main areas where risk aspects should be considered is the creation of protected spaces for new technologies. In the energy market, RES producers can be protected from market price risks with a price guarantee, as provided in FIT schemes. Traditional FIT schemes also exempt RES producers from participating in balancing markets. Hence, several market risks are transferred from individual RES producers to a pooling agent, mostly the system operator, who in turn transfers the costs of these risks to electricity consumers or taxpayers. Traditional FIT schemes thus protect RES producers from substantial energy market risks, whereas in FIP and TGC schemes they remain exposed to most risks. Therefore, the literature describes FIT schemes often as low-risk approach, and TGC schemes as high-risk approach (see e.g., Klessmann et al., 2008). These inherent characteristics can, however, be substantially altered by design specifications, so each instrument can also be implemented in a low-risk or high-risk way. In fact, Ragwitz et al., (2011) observe a gradual convergence of key properties in FIT and TGC implementations in Europe, with trends to provide differentiated technology-specific support, to enact quantity controls, and to introduce elements of market exposure.

Furthermore, a number of non-market risks affect private investment decisions and thus need to be considered in policy making. Most risks are common to many investors in a country (e.g., regime stability, regulatory conditions, etc.) and will not be changed in light of an energy transition. A number of risks can, however, be addressed to increase the success likelihood of an energy transition. Typical non-market risks are related to policy stability and predictability, permitting procedures, public acceptance issues, etc. Reducing non-market risks should be considered an important part of policy making as it can decrease costs for private investors without transferring much risk to other parts of society.

POLICY MAKING APPROACHES IN TWO PHASES

In this section, we discuss different policy making approaches depending on the current phase of an energy transition. We go through five separate elements, which all can be seen as part of the overall objectives of policy making for energy transitions. First, we explore effectiveness, i.e., how policy making can help initiating and controlling the dynamic process of an energy transition. Then, we explore efficiency, both in the short term and the long term. Next, we look at the systems perspective and explore policies that support the integration of RES technologies in the energy system. Finally, we touch upon the important area of