Introduction and overview of the chapters

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Opening remarks

This book aims to explore aspects of the future demand for electricity in the light of the challenges posed by climate change. In the UK we have a formal target for the reduction of carbon dioxide equivalent emissions of 80 per cent by 2050 (on 1990 levels). Official publications regularly suggest that reducing overall energy demand is an important part of meeting that target. Indeed, in a recent report of the UK Committee on Climate Change (CCC, 2009, p. 22), it was suggested that residential energy efficiency measures could reduce carbon dioxide emissions by 50 million tonnes per annum (or around 10 per cent of the UK's current total emissions) by 2022. The UK is not alone: many other countries have targets and aspirations for the reduction of energy consumption. Meanwhile, the future of energy demand will increasingly be synonymous with the future of electricity demand if the heat and transport sectors are electrified over the coming decades.

Decarbonization of the energy sector is not just about reducing energy demand. Emissions from direct combustion of heat and direct combustion of liquid fuel in vehicles are roughly equal to emissions from power stations. Reducing emissions from electricity production is technically feasible via a combination of renewables, nuclear power and carbon-capture-and-storage equipment. This implies that switching heating and transportation demand for energy from combustion of fossil fuels to heat from electricity (or combined heat and power) and to electric vehicles is important in reducing emissions.

The scale of the decarbonization challenge will depend in large part on the drivers of energy demand. If underlying demand for energy increases due to population growth and increasing wealth then more low-carbon energy production will be required. Projections of energy demand by 2050 vary widely and consequently give rise to large variations in the required amounts of electricity generation. Working out how to delink future energy demand growth from traditional upward drivers of demand will be important for energy regulators and policy makers.

While aggregate demand for energy is made up of industrial, commercial and residential (or household) demand, we focus significantly in this book on domestic demand for electricity. The reason for this is that this is the portion of energy demand (and energy-related carbon emissions) where there are significant untapped possibilities for improvements in efficiency and where much of the recent research interest and effort has been focused. In particular, the emergence of smart metering of electricity (and gas) combined with smarter domestic appliances capable of responding to price and stability signals coming from the electricity grid implies a level of consciousness and responsiveness in energy demand previously seen only in larger industrial and commercial users.

The book focuses on the UK, while drawing substantially on evidence from elsewhere. The UK is an interesting case study globally for a number of reasons. It is a mature economy with slow-growing energy demand where efforts to improve energy efficiency are likely to be an important and noticeable part of any successful decarbonization. The UK has also led the world in terms of policy development. It was one of the first countries to liberalize its electricity and gas markets, to independently regulate its energy networks and to implement targets for substantial long-term carbon emissions reduction. The UK will be an interesting case study for other countries to learn from (positively or negatively) in terms of how (and indeed if) demand-side measures can be combined with and integrated into a competitive energy market environment.

Structure of the book

This chapter presents the motivation of this book and an introduction to the wider context of economics of energy demand and efficiency. The rest of the book is organized in the following four parts. Part I examines some specific economic aspects of future electricity demand. In Chapter 1, Platchkov and Pollitt provide an introduction to the economics of energy demand and efficiency, laying down some economic fundamentals of energy demand. In Chapter 2, Ault *et al.* outline four rather different scenarios along which demand and its effects on the system can unfold towards 2050. A smart grid requires participation of active customers. Chapter 3 by Torriti *et al.* explores the customer participation options. Given the potential for major changes in the level and pattern of demand, the importance of modelling and forecasting demand is likely to increase. A review of recent trends in modelling energy and electricity demand is presented in Chapter 4 by Steinbuks.

The future of electricity demand will undoubtedly be influenced by technological change and innovative solutions in different areas. In Part II the book turns to technological solutions for achieving the active future

demand. In Chapter 5, Hong *et al.* present intelligent demand-side management and control systems at homes and building level, which aim to maximize comfort and convenience for the consumers. They make clear that much of the future development and promise of smart grid and active demand hinges upon the roll-out of smart meters. This is explored in Chapter 6 by Haney *et al.*, who review different functionalities of smart meters and the international experience with these so far, focusing on cost–benefit analysis of roll-outs. In Chapter 7, Silva *et al.* take a different approach and focus on the role of smart domestic appliances that can shift load and use scenario simulations to estimate their value to the system. There is a growing anticipation that electric cars will link energy demand from road transport to household demand for energy. We therefore conclude this part with Chapter 8 by Marsden and Hess presenting a review of the main technological options for electric cars and assessment of the effect of their large-scale adoption on electricity use as well as the peak demand.

The social and behavioural aspects of energy demand complement and interact with the economic and technical features of the electricity system. With regards to active demand this role is likely to grow in importance and is studied in Part III. Chapter 9 begins this part with Haney *et al.* presenting the result of two public opinion surveys on consumer attitudes and actions revealing differences between the roles of the individual as consumer versus citizen and its relevance for the political economy of energy policy. This is followed by a discussion of the local dimension of energy demand (for both electricity and heat) in Chapter 10 by Kelly and Pollitt. Achieving the ambitious climate policy objectives is likely to lead to significant price increases for all customers, and this is likely to be a serious problem for those millions of households (in the UK) already in energy poverty. In Chapter 11, Devine-Wright and Watson explore the centralization versus decentralization options for the UK electricity sector. We examine energy poverty in Chapter 12, where Waddams Price revisits the concept of fuel poverty and distinguishes between households officially characterized as fuel poor and those who consider themselves as such. Chapter 13, by Meier and Jamasb, emphasizes the case of potentially vulnerable groups of households, such as single-mother headed, pensioners and those on benefits.

As mentioned earlier, achieving flexible networks and active demand will require strong policy commitment and implementation. In Part IV we shed light on some relevant policy aspects and areas that can facilitate development of a flexible electricity demand. Chapter 14 by Haney *et al.* reviews the lessons from international experience from *demand-side strategies* towards the residential sector adopted in leading countries. The configuration of electricity networks will be important in facilitating a

more active demand side. The implications for *regulatory policy towards networks* are therefore analyzed in Chapter 15 by Jamasb and Marantes. They present a detailed and disaggregated distribution network investment model, the results of which can feed into investment planning and strategies for active networks and demand. Given the myriad possibilities that can be identified on the demand side for electricity, a coherent *research policy* will be essential for the development and implementation of new technologies As an example of a move in this direction, Bouffard *et al.*, in Chapter 17, describe the results of a large-scale European collaborative research initiative for the development of active demand. *Building regulations* can also play a role in facilitating the active demand future. Chapter 16, by Clarke *et al.*, reviews a selection of the EU and UK legislative approaches to energy performance of buildings. Low hanging fruit still exists on the demand side of policies which are cost effective in saving energy (and carbon). As a rather precise example of this, Chong *et al.*, in Chapter 18, describe how a *change in the daylight saving time* in the UK can contribute to electricity demand and emissions reductions. Finally, in Chapter 19, the editors offer some closing reflections on how to create a smarter, more efficient demand side for electricity.

Overview of the main chapters

Part I: The economics

Chapter 1: *The economics of energy (and electricity) demand*, by Platchkov and Pollitt, lays out some of the important economics foundations of energy demand in general, and electricity in particular. The authors first look at the macroeconomic context. The examination of the different drivers of energy and electricity consumption over time reveals how both are subject to the same drivers – income and price. Taking the example of demand for electric light over the last centuries in the UK, they point out that relative energy prices matter for long-run economic transitions. Long-run demand trends are mirrored in long-run price trends. However, the authors caution against the risk of taking energy demand (and carbon emissions) falls in isolation, as raising the price of energy – and hence reducing consumption – in one country may have little effect at the world level. The authors then examine some of the features of energy service expenditures over time. The share of income spent on energy services is fairly constant over time (around 8 per cent of GDP in the UK since the 1970s), transport fuel is the most significant component, and taxes on energy consumption are an important revenue to the government (around 7 per cent of total tax revenues in the UK). However, the

different sectors are very distinct from one another in terms of consumption profiles, and new sources of electricity demand may substantially change total demand and the way electricity is consumed.

Turning to the microeconomic context of energy demand, the authors review some of the physics of energy demand, highlighting the energy efficiency of electric power. Theoretically, large savings are possible; however, the economics is unlikely to support achievement of all the technical potential. A number of challenges need to be taken into account, including how consumers actually behave (rather than should behave). The authors conclude by highlighting the various unknowns that characterize the future of energy demand, such as the scale and shape of the IT changes required, the kinds of innovations that might appear in the heat and transport sectors, who will be the future actors in the energy market, and the uncertainty as to how consumers may react to new technological opportunities.

Chapter 2: *Energy scenarios and implications for future electricity demand*, by Ault *et al.*, explores the possible paths along which the UK future electricity system can develop in the long run-up until 2050, with a particular focus on the demand side. These futures are explored through four scenarios: big distribution and transmission, energy services companies (ESCOs), distribution system operators (DSOs) and microgrids. The scenarios build on the insights from a major research project on the future of the UK electricity networks, sponsored by the energy regulator Ofgem. The differences in the scenarios developed are primarily driven by customer participation, environmental concern and institutional governance. The findings highlight the long-term effect of different demand trajectories which are in the rather wide range of 290 and 450 TWh by 2050 as against around 330 TWh in 2000.

Chapter 3: *Demand-side participation: price constraints, technical limits and behavioural risks*, by Torriti *et al.*, disentangles some of the drivers of and constraints to demand-side participation in liberalized energy markets, which can bring about significant reductions in electricity prices. Shifts of demand which reduce system peaks could reduce the need for higher marginal cost of generation, offer lower-cost system balancing, decrease grid reinforcement investment and play a key role in achieving ambitious environmental policy objectives, through facilitating greater connection of intermittent renewable generation. However, there are significant constraints associated with the extent to which consumers can manage electricity loads. Those constraints are categorized into (1) price constraints – including price structures and signalling, (2) technical limits in terms of the availability of metering technologies and their cost effectiveness as well as communication technologies, and (3) the behavioural

types of constraint, particularly issues of psychological motivation and social acceptance. Those are then illustrated with demand-side participation experience in European countries. The authors then propose and discuss key aspects and mechanisms of an incentive/payment scheme for end-users, taking into account wider economics and behavioural issues.

Chapter 4: *Review of recent developments in economic modelling of energy demand*, by Steinbuks, revisits recent developments in the literature on econometric modelling of demand for energy and electricity. The chapter discusses the diverse and complex factors that are in play in accurately modelling the demand for electricity (within the context of the overall demand for energy), such as energy intensity, own and cross elasticities, and the rebound effect associated with energy efficiency. The chapter covers demand for energy in the residential, industrial and transportation sectors. Energy demand modelling can also potentially play a role in better understanding of the factors that influence active demand. The main themes being traced in the chapter include the scope for fuel input substitution, trends in energy efficiency, the impact of changing industrial structure of the economy as a whole, and the nature of technological change.

Part II: Technology

Chapter 5: *Demand-side management and control in buildings*, by Hong *et al.*, examines the application of demand-side management and control, or DSM+c, in buildings. The subject of this chapter differs from the conventional view of DSM in that an advanced control system responds to potentially intermittent supply signals and manages the different loads in a building in subtle ways and without compromising the comfort of the users. The DSM+c concept presented in this chapter is based on utilization of the flexibilities that exist in the constituent components of the loads within a building. The control systems are a vital part of the systems and utilize the latest advances in information and communication technologies, including the use of Internet to activate the demand side. Power demand and supply and environmental variables are monitored using sensors connection to Internet-based communication systems.

Chapter 6: *Smart metering: technology, economics and international experience*, by Brophy Haney *et al.*, looks at technologies that can enable small users to become active participants in energy markets. The recent emergence of smart meters acts as a platform for both more sophisticated and transparent pricing structures as well as automated demand response, in

combination with smart appliances, for instance. The authors start with a discussion of the policy context for smart metering. Metering is a central part in the relationship between energy consumers and suppliers, and different models have been applied worldwide, subject to different drivers. There is still much confusion on what makes a smart meter 'smart', so the chapter clarifies the object of the debate with a presentation of the range of available technologies and their functionalities. It follows on with an economic assessment of smart metering, which is a delicate question due to the sensitivity of different costs and benefits, among others to the chosen roll-out strategy. The subsequent review of the international experiences uncovers various drivers which have shaped different regulatory approaches and technology choices. In Italy, for instance, the initial push came from industry, whereas in Sweden it was the requirement for more accurate customer bills. The authors conclude that technology choice is important, but difficult, and deployment depends on the existing market structure; however, smart meters could add significant value to electricity systems.

Chapter 7: *Smart domestic appliances as enabling technology for demand-side integration: modelling, value and drivers*, by Silva *et al.*, describes the role that smart domestic appliances can play in increasing the flexibility of the demand side and contributing to the balancing and security of the wider demand–supply system as well as the network operation. Such appliances account for a considerable share of total domestic electricity consumption, but this fact can also potentially offer benefits to the system. The chapter presents a framework for assessing the economic value of the flexibility of demand and new ancillary services provided by smart appliances through automatic and intelligent modification of their operations. The methodology employed consists of a simulation model of an annual system operation which schedules generation sources and smart domestic appliances, taking into account system security and operational constrains. The model is used to explore case studies of demand shifting and dynamic demand and quantify their effects under different scenarios.

Chapter 8: *The scope for and potential impacts of the adoption of electric vehicles in UK surface transport*, by Marsden and Hess, examines some of the key issues associated with large-scale adoption of the main types of electric vehicle, with a particular focus on their potential impact on the electricity system and especially the networks. The electric cars can shift a considerable demand for transport fossil fuels over to the electricity system, a development which poses both possibilities as well as concerns. Among other significant points presented in the chapter, it argues that the effect of large-scale adoption of electric cars will probably not have

a major impact on the total electricity demand. At the same time, the load effect of such a trend on the system can be more significant. This in turn implies that the challenges and implications of electric cars for the electricity networks can be more important than their potential impact on the generation segment of the electricity sector.

Part III: Social dimensions

Chapter 9: *From citizen to consumer: energy policy and public attitudes in the UK*, by Akcura *et al.*, presents the results from two public opinion surveys conducted in the UK in 2006 and 2008 to draw insights into factors affecting customer attitudes and behaviours. Public support is particularly important in energy policy, where the public is expected to actively contribute by changing lifestyle. Hence, understanding the determinants of customer attitudes and actions will be increasingly important in considering how feasible demand-targeting electricity policies are, and successful policies will heavily depend on how they can influence existing behaviours. The surveys reveal the dichotomy between consumer and citizen, in other words between attitudes/intentions and behaviour/action. The many dimensions involved in individual decision making, which go beyond the very availability of information to encompass social, demographic and exogenous factors, are also highlighted. Policy preferences and attitudes to energy and the environment are found to be very sensitive to the broader economic climate, for instance. This is evidenced by a dramatic shift in energy policy preferences between 2006 and 2008, with the authors finding that in 2006, respectively 26 per cent and 20 per cent of the respondents considered 'increasing the use of renewable energy' and 'reducing the impacts of climate change' as a top priority, a percentage that reduced to respectively 9 per cent and 6 per cent in 2008. Over the last years, concerns dramatically shifted towards fuel poverty, with 41 per cent of respondents considering 'keeping price low' of utmost importance in 2008.

Chapter 10: *The local dimension of energy*, by Kelly and Pollitt, argues that some of the best opportunities for reducing energy demand and carbon emission would require a stronger involvement and leadership from local governments. The contrast is drawn between community energy versus local energy, where the former is typically developed from grassroots (bottom-up), whereas local energy projects are typically undertaken by institutions such as local government (top-down). There is now a growing emphasis on local energy governance. Local governments can and do have a significant impact on both energy production and consumption and will be key stakeholders in the solutions to future energy

systems, as they play a vital role in educating, mobilizing and responding to challenges of sustainable development, and are responsible for large areas of policy. Kelly and Pollitt argue that one of the reasons explaining lower energy intensities of some countries, such as Denmark, Sweden or Japan, is the devolved power to local authorities. The evidence suggests the importance of energy services companies as a vehicle for delivering those strategies. The chapter highlights three key success factors for local governments: the recognition of the co-benefits of local energy, a strong political leadership and the use of partnerships.

Chapter 11: *Centralization, decentralization and the scales in between: what role might they play in the UK*, by Watson and Devine-Wright, explores the scope for the UK energy system to develop at a range of different scales – from continued large-scale, centralized power plants to small-scale, decentralized heating systems that are integrated into buildings. There has been extensive debate on the potential advantages of decentralized energy for meeting current and future challenges, but there have been only marginal changes until now. The authors ask whether the strongly centralized approach to energy provision that developed in the post-war period can continue to meet the needs of society over the coming decades. They argue that it may be sufficiently flexible to meet the dual challenges of energy security and climate change, but this is by no means certain. They start with some definitions of decentralized energy, which can involve different technologies, institutions, policies and stakeholders. Then they explore and compare the range of scales and actors that distinguishes decentralized from centralized energy systems. The authors highlight the importance of retrofitting the building stock, which has an important social dimension, and hence will partly depend on public acceptance and levels of trust. The barriers imposed by the regulatory framework are also stressed. They conclude that the choice of future energy options is not straightforward, and the extent to which decentralization leads to a more secure or sustainable system depends on the kind of decentralization that is pursued.

Chapter 12: *Equity, fuel poverty and demand (maintaining affordability with sustainability and security of supply)*, by Waddams Price, introduces the current debate on fuel poverty, which leads the author to unwrap one of the key dilemmas of the energy policy agenda: the tension between climate change and energy security targets versus affordability. This implies a contradiction at the very heart of the energy agenda, due to the opposite pressures towards energy prices that each of these challenges implies. Waddams Price argues that higher energy prices are crucial for both energy security and the realization of the environmental agenda; and in the UK liberalized context, whether competitive

markets remain the best vehicle to deliver affordability is challenged. The very nature of energy demand poses important dilemmas, where most responsive demand comes from low-income households. In parallel, regulators' duties are expanding and being enhanced by new obligations. There is a discussion of a UK household survey of low-income households conducted in 2000 which reveals some striking differences between the official and a more subjective definition of fuel poverty. Half of the 16 per cent of people feeling unable to afford sufficient heating were spending less than 10 per cent of their income on energy expenditure, the official criteria used to classify people as fuel poor.

Chapter 13: *Energy spending and vulnerable households*, by Jamasb and Meier, focuses on fuel poverty in Great Britain, in particular on energy spending among households on very low incomes, including pensioners, female single-parent households and benefit recipients. Three factors play a major role in fuel poverty: income, energy prices and energy efficiency. The authors describe how energy spending has changed over time and they shed light on a broader picture of energy spending. The chapter explores the determinants of energy spending of vulnerable groups of households. Using the British Household Panel survey (BHPS), they analyze the number of vulnerable households over time and the drivers of fuel poverty. They find that vulnerable household groups have on average higher levels of energy spending of their incomes than the average household in the sample. They explain this difference by lower levels of insulation, less energy-efficient appliances and less access to different fuels, and different payments methods. Lower-income households may also spend more time at home. The authors conclude that next to financial support, smart metering and social tariffs can play an important part in eradicating fuel poverty. However, their possible impacts need to be carefully examined, including any possible accompanying measures and issues of equity.

Part IV: Policy and regulation

Chapter 14: *Demand-side management strategies and the residential sector: lessons from international experience*, by Brophy Haney *et al.*, explores demand-side management (DSM) strategies, including both demand response and energy-efficiency policies. The aim is to uncover what features might strengthen DSM effectiveness. The authors start with a presentation of key features of residential energy demand, in which they discuss the limits to energy indicators and, consequently, cross-country comparisons. Despite the challenges this poses, the importance of residential energy demand within the broader energy demand and its large