1. Introduction to *Research Handbook on Energy and Society*: why study energy and society?

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Unprecedented, climate breakdown, ecosystem collapse. These are some of the terms used to denote the risks to all life on Earth from humanity's intensive exploitation of fossil fuels for energy, and the associated degradation of nature. In affluent industrialised societies, most people take access to energy for granted; they have little knowledge of sources, production systems or related injustices and environmental impacts. The extensive and intensive technologies of electricity, gas and oil are woven into working, resting, socialising and travelling, so that they have become part of the background to life. Energy is consumed even while most people are sleeping: freezers and fridges operate; lights switch on and off; industrial processes run; data centres and networks operate, along with all of the other service infrastructures of consumer societies.

Fossil fuels have been fundamental to the development of such societies, bringing benefits from mass production of goods and services, health and welfare systems, greater scope for self-determination and increased life expectancy. But their intensive exploitation is causing major changes in the Earth's atmosphere and climate systems, as well as polluting the air, and degrading land, soils, water sources and oceans. Before the eighteenth century industrial revolution, concentrations of atmospheric greenhouse gases (GHGs), measured as carbon dioxide (CO₂) equivalent, were around 280 parts per million. Dependence on fossil fuels for energy since then is associated with rapidly increasing concentrations to over 400 parts per million. This is estimated to be the highest level in three million years (for detailed data see Ritchie and Roser, 2020; United Nations Environment Programme (UNEP), 2020). Increased concentrations of greenhouse gases produce global warming; the ten warmest years on record have occurred since 1998. The impacts on the climate system are already evident in increasing frequency and severity of droughts, heat waves, storms and crop failures, as well as sea level rise and loss of glaciers. Unchecked, the expectation is that whole regions will become barely habitable, resulting in widespread social disruptions, diseases and widening inequalities, associated with intensifying wars over food, water and all resources, major flooding and loss of coastal cities, and mass extinction of many species (UNEP, 2020). The science is clear; we need urgently to end dependence on fossil fuels and to transform ways of life in affluent countries, in order to avoid the worst climate disasters, and to have hope for future generations.

Valuable research on clean energy, mainly led by engineering sciences, has been done, and has been instrumental in significant technological innovations. But systemic change at the speed and scale needed to mitigate risks of catastrophic climate change is lacking. This *Research Handbook on Energy and Society* adopts the perspective that technological innovations are insufficient to solve societal problems. In order to transform energy systems, with the aim of avoiding the worst impacts of climate disruption, we need to understand processes of *societal* change, and the interdependencies of technology and society. In the book, international contributors analyse the interactions between energy systems and societies over time,

in different places, and with different consequences for material ways of living, inequalities and social divisions, political conflicts and environmental degradation. The *Handbook* aims to inform debate across publics, policy makers and practitioners about the future of energy and the governance of societal change. This introductory chapter describes the main themes and structure.

THE SOCIETAL CHALLENGE

Most governments of countries responsible for major GHG emissions have made commitments to radical action to avoid disastrous climate change. Signatories to the United Nations (UN) Paris Agreement (2016) are formally committed to limiting global temperature rise to 1.5 degrees Celsius, or a maximum of 2 degrees Celsius, above pre-industrial levels. The most affluent countries have also accepted an obligation to support low- and middle- income countries in mitigating and adapting to climate crises. Gaining agreement between 197 countries (189 of whom have since ratified the Agreement) is an impressive accomplishment, but it has taken too long. The work of effecting necessary societal and economic transformations is also far harder than an agreement to act. Among other things, meeting the commitments of the Paris Agreement means replacing entrenched, extensive fossil fuel energy systems with renewable and low carbon energy. Any remaining combustion of fossil fuels requires carbon capture usage and storage (CCUS) infrastructure to prevent further release of large amounts of GHGs into the atmosphere.

International frameworks intended to guide such transformations have existed for over 30 years: the Intergovernmental Panel on Climate Change (IPCC) was established in 1988, and the UN Framework Convention on Climate Change (UNFCCC) was established in 1994. Fossil fuel consumption has, however, continued to increase, almost doubling between 1980 and 2020, despite renewable energy developments. Although coal combustion is declining in many (but not all) parts of the world (see Pearson, Chapter 2, and Tyfield, Chapter 15), oil and gas extraction continues to grow, and action to decarbonise industry, transport, buildings and heating systems has been limited. There is increasing social protest over the consequences for pollution, species extinction and environmental damage. There is also considerable scientific and technical knowledge about options, as well as finance to underwrite new infrastructures. But there is no consensus on routes forward, and there are major questions about the capabilities, and willingness, of governments, businesses and citizens to manage the required transformations. Many potential solutions are contested, with hard questions about shares of responsibility for change and social justice, in an increasingly inter-connected world.

THE VALUE OF SOCIAL SCIENCE RESEARCH ON ENERGY

Where governments in affluent economies have made formal commitments to development of a clean, or ‘net zero carbon’, energy system, solutions are frequently presented as largely a matter of technological innovation for ‘green growth’. Societal questions have often been reduced to the public acceptability of new consumer technologies, such as air source heat pumps or electric vehicles; or managing public opposition to siting of renewable energy technologies; or routes to managing costs and disruption. Renewable energy technologies

have also, thus far, served largely as additions to the mix of fossil fuel systems, rather than replacements (see Bakke, Chapter 8). This fits a pattern of energy transition through stealth governance, as politicians seek to minimise business opposition and public dissent, and to delay hard decisions such as those on decarbonising heat and transport. The approach has also allowed established institutional and market frameworks, geared to fossil fuel subsidies and investment, to continue much as before (Geddes et al., 2020).

Looking beyond issues of acceptability of new technologies, social scientists have examined the government, industry and market innovation structures characteristic of the fossil fuel age, and asked whether they are fit for the purpose of addressing its consequences. The value of social science, in this sense, derives from its analytical capacities to look through the other end of the telescope, defining energy systems as embedded in institutions of government, markets and civil society. Rather than assuming that experts and industry, working with governments, will produce the best technologies for a largely passive public to accept, social scientists are more likely to begin by investigating definitions of expertise and authority, and to consider the relevant knowledge of much wider groups of people. This has resulted, among other things, in insights into the value of public engagement and deliberative democracy in decision-making about future energy systems (see for example Pidgeon et al., Chapter 22).

Nor do social scientists accept that technological innovations are independent of society. Instead, social studies of technology have shown that the trajectories and types of innovation are themselves shaped by societies and power relations, and those technologies in turn embed particular political decisions with long term societal consequences and structural inequalities (Mackenzie and Wajcman, 1999). A classic example is provided by Winner's (1980) analysis of the politics of nuclear technologies, and in this volume, Bergman and Janda, Chapter 26, discuss the interactions between contemporary energy narratives and technology trajectories.

By investigating the full cycle of energy technology innovation, production and consumption, social sciences also bring a greater focus on energy *use*, as equally significant to, and inter-dependent with, supply in a socio-technical whole systems perspective. This encompasses questions about what we use energy for (see Morley's discussion in Chapter 5), and how the often taken-for-granted idea of a fixed energy consumer is socially and historically constituted (see Shin and Chappells, Chapter 4). A focus on energy use in turn highlights the relative neglect of policies for reducing the waste of energy and related resources, and managing demand (see Chapters 17–19). In energy-intensive societies such as those of Europe and North America, zero waste, at least in the foreseeable future, is likely to be critical to transformation, because it reduces the technical, economic and political challenges of transition to a largely renewables-based system. Social research demonstrates the major, but neglected, potential of resource efficiency to reduce greenhouse gas emissions, enabling faster progress towards net zero targets, while creating sustainable livelihoods. Key areas for change are food production, waste and diet; a shift from ownership of products to shared services, and remanufacturing, repair and reuse, all associated with significant energy savings (Norman et al., 2021).

The *Handbook* has been written during the Coronavirus pandemic, and there are renewed promises from government signatories to the UN Paris Agreement, as well as business, to invest in a green economic recovery. However, current global policy commitments to cut greenhouse gas emissions are in line with temperature increases in excess of 3 degrees Celsius this century, presaging major destruction of life (UNEP, 2020). This gap between espoused political-economic objectives and material change is an overarching theme of social science research, with questions about agency, knowledge, power and authority. We know that the

history of governing radical change is mixed, and that unexpected events – such as the pandemic – have major, but indeterminate, consequences. Social research is urgently needed to inform publics, governments and business about the risks we face and to contribute to transforming energy systems for sustainable societies.

Throughout the *Handbook*, contributors consider how existing institutions and established interests shape change in energy systems, and distributions of costs and benefits. Contributors provide insights into future prospects by reviewing historical trajectories of innovation; policy and politics; energy justice and inequalities; and governance, regulatory and market frameworks. The chapters illustrate the diverse methodological approaches and theoretical frameworks in use, and comment on new directions of enquiry, controversies and emerging research questions. The book has four parts: Energy Services and the Making of Markets; Social Divisions in Energy and Society; Energy Governance, Policies and Politics; and Climate Consequences and Energy Futures. Their themes are summarised below.

PART I: ENERGY SERVICES AND THE MAKING OF MARKETS

This first part examines the establishment and evolution of contemporary large-scale systems of energy production and consumption through accounts of the fossil fuel age in industrialised societies. Perspectives from social history, sociology, economics and cultural studies provide foundations for understanding current dilemmas and potential routes forward. Contemporary societies and their governments are largely structured around political-economic commitments to growth, founded on exploitation of nature. Such patterns of growth were unknown prior to the first industrial revolution enabled by extraction and combustion of coal, and stimulating major transformations of the material environment (see Tyfield, Chapter 15 for discussion of China's current reliance on coal). Intensive stores of energy in coal enabled production of raw materials for mass manufacturing, including large-scale food production to serve population growth and urbanisation (Mitchell, 2009). In this way, coal was instrumental in the demise of traditional agrarian social orders based on kinship and status. Oil and gas, alongside coal, have further intensified the process, fuelling mass production of most goods and services from housing, food and travel to plastics, pharmaceuticals and digital communications.

In Chapter 2, Peter Pearson provides a wide-ranging appraisal of the societal transformations wrought through successive periods of fossil fuel development. He uses the idea of energy transitions to analyse the inter-relations between fossil fuels and political economies, societies, cultures and geographies in different parts of the world. His analysis shows that there is nothing inevitable or pre-given about transition from one energy source, and its technical infrastructures, to another. Instead technical systems for producing and consuming coal, oil and gas are bound up in societal interests and power struggles. These co-evolve over long periods as new technical infrastructures are used in producing increasingly diverse goods and services. The chapter provides both a vivid, data-rich picture of the globally varying patterns of energy transitions, and a snapshot of their cultural significance through the story of the American automobile. The exploitation of coal, oil and gas has always proved both progressive and destructive, supporting higher material standards for many, but also underpinning wars, conflicts and injustices. The implication is that breaking with fossil fuels will need an unprecedented accord across states, markets and civil societies.

David McCrone (Chapter 3) develops the perspective on energy politics with an analysis of the closely coupled interactions of nationalism with oil and gas exploitation. Fossil fuels are not, as often assumed, ready-formed with inherent economic value, but must be socially and technically manufactured into ‘resources’ which both serve, and reshape, political-economic interests. Using the examples of Iranian and North Sea oil, McCrone shows how the oil and gas industries are instrumental in distinctive formations of society and economy. This includes the symbolic use of oil in constituting national identities, where ideas of nature and nation are bound together. The science of oil and gas itself is not separate from, but is an integral component of, such nationalisms, posing questions about the use of scientific knowledge in transforming our energy systems.

Mainstream thinking often treats the energy consumer as a self-evident category with fixed ‘needs’, rather than as a societal construct situated in particular social and material arrangements. Chapters 4 and 5 overturn this model through detailed investigation of energy uses. Hiroki Shin and Heather Chappells (Chapter 4) explore the making of the energy consumer, while Janine Morley (Chapter 5) focuses on norms of energy use, shaped by the services derived from energy consumption. Viewed in societal terms, the malleability and diversity of consumer identities are evident throughout history, from periods of mutual provisioning, to mass consumption, and now potentially to more decentralised co-provision or ‘prosumption’. Insights from sociology about the cultural and historical specificity of ‘needs’ (Morley, Chapter 5) similarly show that taken-for-granted habits of energy consumption are governed by social norms and values, which are translated into the ‘hardware’ of energy networks and appliances. These two chapters rescue the idea of the consumer, or energy user, from an economic model of self-interested individualism, and offer new insights into options for sustainable energy practices. The analyses invert the common approach to policy making, which takes current consumption patterns as the necessary standard to be reproduced. Instead, they challenge understandings of what is necessary, providing a foundation for innovative policies to reduce dependence on energy, and for active, and more equitable, civic engagement.

Turning back to supply-side questions, the next two chapters compare European strategies for governing systemic change in the context of large-scale, incumbent, network infrastructures and different market designs. Innovations in technological systems for heating buildings and water in Denmark, Germany and the UK are evaluated by Richard Hanna and Robert Gross in Chapter 6. They compare the interactions of innovation policies and governance structures under state-ownership vs liberalised markets. In all cases, it is clear that replacing incumbent fossil-fuel heating systems is likely to be a drawn-out process, but innovation appears more straightforward where there is political willingness to apply historical lessons about governing systemic change.

In Chapter 7, Thomas Reverdy, Frédéric Marty and Ronan Bolton consider innovation in electricity systems in the liberalised markets of France and the UK. The authors focus on contemporary policy support for incorporating intermittent wind and solar power into electricity supply, alongside large-scale fossil fuel and nuclear power stations. The analysis examines the consequences of European decisions to govern supply through markets, rather than state planning. With concerns about ‘keeping the lights on’, both French and British governments have devised political rationales to justify public subsidies to assure private investment in electricity generating capacity. It follows that electricity markets are not governed by universal economic laws of supply and demand, but are designed to accommodate varying political objectives.

Both chapters show the centrality of political will and reflexivity in devising systemic innovations needed to meet carbon targets.

Gretchen Bakke (Chapter 8) concludes the part by looking to the future, with an appraisal of prospects for a new kind of energy transition. In the past, 'transition' has often been understood in terms of one fossil fuel source displacing another. All of the material in this first part has shown that a linear depiction of the history of energy systems is far from accurate. Oil and gas have not superseded coal, which continues to be intensively exploited around the world, including in countries with strong commitments to climate protection.

The addition of renewable energy sources to the mix is, however, resulting in new, and distinctive, forms and patterns of transition. Among other things, Transition 2.0, Bakke argues, is likely to feature the integration of diversity in more differentiated systems. This may seem complex and unwieldy, at least from the current standpoint where fossil fuel systems are fundamental to, and often invisible in, life in economically affluent societies. If societies can, however, solve problems of governing shared resources, more diverse and differentiated energy provisions can sustain long-term resilience, marginalising fossil fuels and creating more equitable access to energy and its benefits.

PART II: SOCIAL DIVISIONS IN ENERGY AND SOCIETY

The second part examines social divisions and inequalities directly. Access to, and the affordability of, energy is a concern in high- as well as low- and middle-income countries. Such inequalities structure opportunities for personal and domestic security, including decent homes, education, increased life expectancy, and ability to work, participate and invest in a changing energy system.

Niall Kerr's appraisal (Chapter 9) of the potentially unequal impacts of the different rationales underlying energy and climate policy frames the part. Policy to support home energy retrofit, for example, is typically presented in terms of co-benefits for carbon emissions, fuel poverty and public health. The relative prioritisation of these goals can result in different types of policies, with varying distributions of costs and benefits. The primary purpose of policy for heat decarbonisation, for example, is to mitigate climate change, but where there is political concern to make decarbonisation more palatable this rationale may become clouded by claims of cost-saving or other welfare benefits. Kerr argues that this risks undermining public trust in the purpose of policies, ultimately jeopardising low carbon energy transition.

The next two chapters, by Julia Tomei and Long Seng To (Chapter 10), and Karina Standal and Mariëlle Feenstra (Chapter 11), turn directly to the inequalities in access to energy around the world. In 2020, around one billion people lacked access to electricity and around three billion relied on traditional cooking fuels such as firewood, predominantly in low- and middle-income countries. Using case studies and ethnographic research methods, each chapter investigates material expressions of equity and justice in different aspects of energy systems.

Tomei and To use case studies of a technology (biofuels); a specific political context (displacement), and a fundamental societal challenge (gender equity). Standal and Feenstra analyse the situation of women and solar energy in India, in the context of global energy transition. Gender relations frame women's and men's participation, decision-making and shares of benefits in implementing solar energy at household and community level. Both chapters demonstrate the value of social science research methods in revealing the processes

of social differentiation (producing intersecting inequalities such as gender, ethnicity, class, caste) which govern the roles and opportunities of different groups. They also demonstrate the contributions of social science to energy justice. Tomei and To review the prospects for global governance to support principles of equity and to enable people to engage on an equitable basis. Standal and Feenstra use their analysis to identify means to design and implement gender-sensitive policies and interventions.

The development of policies to advance equity and justice in access to energy are directly examined by Karla Ricalde, Karla Cedano, Harriet Thomson and Tiare Robles (Chapter 12) in their analysis of the nascent stage of policy framings and measurement of energy poverty in Mexico. The increasing policy attention to energy poverty across regional and national institutions has been accompanied by the launch of a monitoring observatory. The authors develop a new Capabilities-driven Energy Satisfactors Index (CESI), based on and underpinned by community workshops. They conclude that overly-simplistic metrics flatten the diversity and cultural specificity of experiences, and advocate multidisciplinary collaboration between physical and social scientists to avoid such reductionism.

The energy sector is a major source of employment around the globe, but knowledge about occupational stratification between men and women is limited. Bipasha Baruah and Sandra Biskupski-Mujanovic (Chapter 13) address this significant gap in research with an analysis showing that women are particularly underrepresented in jobs requiring science, technology, engineering and maths (STEM) qualifications and training. Plans to transform the energy sector from one reliant on fossil fuels to clean energy are dependent on new skills, training and an increasing labour supply. This presents major opportunities to recruit and promote women, indigenous peoples, new immigrants and historically marginalised groups. The authors suggest a significant new research agenda, with major social and economic benefits.

Part II concludes with Karen Lucas, Noel Cass and Muhammed Adeel's (Chapter 14) analysis of social divisions in personal energy consumption arising from car ownership and driving. Echoing Peter Pearson's account (Chapter 2) of the role of the car in the American Dream, the authors argue that cars and driving reveal the habitual or even compulsive symbolic, as well as material, value placed on cars, road trips and associated activities. Those in higher income groups are sometimes hyper-mobile, and account for a disproportionate share of emissions from private transport. Changing the status of the car is an emotive area for policy, with little progress on reducing emissions. Given unequal access to car ownership, the authors are critical of policy assuming that a shift to electric vehicles is sufficient to solve emissions from personal travel. In line with other authors, they advocate equity as a key policy principle, but recommend that tackling high-end travel consumption is as important to improving energy equity as reducing energy poverty. This approach would prioritise walking, cycling and collective transport, while making private car use less attractive through measures such as congestion charges, and mileage rationing or bans on the largest private vehicles.

PART III: ENERGY GOVERNANCE, POLICIES AND POLITICS

In this part authors examine variation in energy policies, and effectiveness, in the context of governance structures, asset ownership and control, politics and market institutions. Governance arrangements have implications for types of energy innovations, pace and scale of changes, and the distribution of costs and benefits across society.

Actions in China are enormously consequential for the achievement of global climate protection goals, and the section commences with David Tyfield's dissection (Chapter 15) of Chinese innovation governance. Treating innovation as politics, Tyfield highlights the dynamism of Chinese innovation, which marries major socio-technical with socio-political change, increasingly at global scale. He argues that the significance of such innovations resides not in direct technical impacts, but in the resulting social upheavals, which are disrupting incumbent socio-technical systems. Using the case of urban mobility, Tyfield concludes that China may be leading the world towards 'ecological civilisation', but most probably by stumbling backwards, rather than by surging decisively ahead. In related discussion, with reference to electric vehicles (EVs), Kerr (Chapter 9) also notes that the Chinese Government have promoted EV development and sales as much for economic growth as for climate protection reasons. This reinforces the continuing political tensions, if not contradictions, between economic and climate policies.

In the European context, the next two chapters consider interactions between devolved government in the United Kingdom (UK) and diverging policy and investments. Richard Cowell (Chapter 16) analyses interactions between UK devolution and the development of renewable electricity. In Chapter 17, Faye Wade, Janette Webb and Margaret Tingey compare diverging policies for low-energy buildings in Scotland and England. Cowell shows that the devolved governments of Northern Ireland, Scotland and Wales have made differential use of their particular powers in relation to energy. Tensions over who controls energy decision-making create pressures on devolution settlements, but resulting renewable electricity developments are not simply determined by formal powers. Instead, they depend on the alignment of actors with the available powers in each territory, as well as on opportunities created by central government financial support mechanisms. The dynamics of devolved government are in turn shaped by the materiality of energy infrastructures and markets, configuring the scope for 'sovereignty'. Cowell's analysis makes clear the fragmentary nature of democratic control over energy, as well as the inevitable imperfections of any attempt to define a single 'best scale' for governing energy systems or their transformation.

Drawing on institutional theories, Wade et al. further explore the scope for flexibility in use of devolved powers to create distinctive policy for energy efficiency retrofit of buildings. The perspectives of officials in Scottish and UK governments suggest greater emphasis on market solutions in England, and a more planned and coordinated approach in Scotland. In England, greater ambivalence over strategy includes uncertainty over the feasibility of local authority sharing of responsibility. Ultimately, however, the authors conclude that neither the Scottish nor UK government has policies fit for the scale or urgency of action required.

Tina Fawcett and Marina Topouzi (Chapter 18) consider what kinds of policies are needed to accelerate action in line with carbon budgets, when all rates of retrofit are currently far below those required. They assess multi-level governance and policy initiatives for retrofitting existing buildings to high standards, and supplying remaining need for heating and hot water with clean energy. Fawcett and Topouzi propose ways of raising ambitions within current policy frames, such as setting detailed targets and higher building standards, as well as creating incentives for fuel switching and developing institutions to support coordination across scales of government. They go beyond this, however, with a more challenging call to reconsider the purpose and limits of building-related policies, echoing Janine Morley's discussion of sufficiency in energy use (Chapter 5).

This perspective is developed by Sarah Royston and Jan Selby (Chapter 19) in their examination of the ways in which energy demand is affected not only by energy policies, but by policies relating to other sectors, such as industry, transport, farming, health and education. These ‘non-energy policies’ have impacts on all spheres of society, hence influencing the timing, location and scale of energy consumed. Using the key example of marketisation as a non-energy policy, they reveal its often invisible effects on energy demand in one sector: UK higher education. Policy and practical implications are significant, and Royston and Selby identify ways that social scientists can contribute to greater understanding of this critical, but neglected, aspect of energy governance.

The section concludes with a distinctive empirical study of such governance implications in the rural setting of the Hebridean Isle of Lewis, off the north-west coast of Scotland. Annabel Pinker (Chapter 20) uses ethnographic research methods to analyse the governance of mega-developments at local scale. She examines the issues at stake in crafting new energy futures – with potential to redistribute resources, expertise and socio-economic power – in the context of both the established centralised electricity grids and systems governing land use. The population of Lewis is accustomed to the practices of resource extraction and exploitation, with significant local employment from offshore contracts in the North Sea. Given its location at the north-east edge of the Atlantic, Lewis is increasingly envisaged as a potential renewable energy hub, offering reliable wind and wave power. But questions over who should own and install such energy infrastructures, what land is for, and who should control it in an era of transition, are highly contested.

PART IV: CLIMATE CONSEQUENCES AND ENERGY FUTURES

The final part of the *Handbook* considers ways of understanding possible futures for energy systems, with a focus on different kinds of knowledge and its uses, and public engagement in producing and accessing knowledge. This ranges from research and development, and systems engineering models, to local knowledge about energy, and perceptions of how places and ways of life may change. Digital innovation is considered in relation to knowledge systems for potential peer-to-peer electricity trading, and customisation of energy systems to community objectives.

This part commences with an examination of localised structures of knowledge in use in Scottish marine energies, and their implications for energy transitions. Shana Hirsch (Chapter 21) uses concepts from science and technology studies to examine the processes and practices of structuring knowledge about marine energy, through networked and nested testing and demonstration centres; standards for instrumentation and testing; and university–industry collaborations. The resulting localised knowledge infrastructures enabled innovation by facilitating the work of engineers and scientists in training experts, in turn improving knowledge exchange, capacity building and standard setting between academia and industry. Understanding the interactions between such local knowledge infrastructures and central support mechanisms is critical to facilitating research and development not just in marine energy, but in numerous other contexts.

In Chapter 22, Nick Pidgeon, Christopher Groves, Catherine Cherry, Gareth Thomas, Fiona Shirani and Karen Henwood address the question of how social scientists can engage with publics in exploring benefits, uncertainties and drawbacks of different ways to decarbonise

energy. Pidgeon et al. use a novel methodology, situating public deliberation in locally realistic energy scenarios, to explore interactions between local knowledge and perceptions of energy futures in the steel town of Port Talbot, Wales. The research reveals participants' ambivalent views of their industrialised environment, and shows the potential for locally specific injustices and inequalities to result from centralised, pre-fixed scenarios. Engaging with residents' relationships to place and understandings of local histories hence provides a valuable route to improving the evaluation of energy policy options, and avoiding such injustices.

A direct form of public engagement in energy transactions is explored by Alexandra Schneiders, Anna Gorbacheva, Michael Fell and David Shipworth in Chapter 23. The increasing volume of small-scale renewable electricity sources connected to local distribution networks opens up the potential for bottom-up peer-to-peer trading. This could reshape top-down markets, potentially providing co-benefits for consumers, communities and the electricity grid. In a decentralised trading model, participants act as both consumers and sellers/traders, rather than being passive 'end users'. An agreed local goal, such as financial savings, climate protection or reducing demand on the network, could be met by peer-to-peer trading networks. There are, however, questions about fair access to participation, and about the potential for some communities to avoid paying a fair share of costs of maintaining the established electricity distribution networks. The authors conclude that social science research on distributional and societal impacts is needed to inform policy and regulation for such local electricity trading.

Digital or 'smart' energy systems are typically regarded as the key to resolving some of these issues, by providing real time visibility of energy flows, and shares of costs, across networks. The term 'Smart Cities' is increasingly used to position urban centres as the basis for digital innovation. Drawing on new empirical research from the island state of Tasmania in Australia, Heather Lovell (Chapter 24) instead examines the potential for smart grid innovations in *rural* communities. Using insights from the case study, she discusses the distinctive social science contributions to understanding processes of energy transition, in particular the increasing socio-technical diversity between urban and rural areas. Rural areas may be able to adapt existing energy grids to local community visions, with opportunities for innovation in the whole cycle of generation, supply and use.

The concept of smart grids is also a significant component of proposals for integrating power, heat, transport and gas systems at varying scales in order to secure improvements in the reliability, cost effectiveness and sustainability of the whole energy system. In Chapter 25, Antti Silvast uses empirical material collected while working with engineers and natural scientists at a major UK research centre concerned with developing an Energy Systems Integration (ESI) model. The author examines the ways that systems-thinking, computer-based modelling and disciplinary divides shape knowledge. The analysis reveals a particular gap in knowledge about how users and citizens might engage with integrated energy systems. Silvast shows how science and technology studies helps to make explicit the assumptions used in engineering models, providing a route to dialogue about the correspondence between the model and the materiality of socio-technical systems, markets and participants. Such dialogue is instrumental to the development of useful modelling tools for the future.

Part IV concludes with an appraisal of narratives and stories about such futures, and their impacts on energy and climate policy, and technology development in the present. Noam Bergman and Kathryn Janda (Chapter 26) draw on innovation studies, environmental history and ecological economics to examine competing narratives of past, present and future. They use a typology of future visions to help test responses to optimistic and pessimistic scenarios.

They argue that the dominant ‘modern economic growth’ narrative narrowly defines sustainability as the need to reduce emissions and centres on technological solutions. This marginalises the possibility of deeper social change and leaves us underprepared for energy and climate change challenges. Their conclusions explain the value of multiple stories, or a ‘system of stories’, to support understanding of the scale of changes entailed, and to incorporate diverse solutions in orienting to the future.

THE CHALLENGES WE FACE

A concluding editorial contribution briefly reviews the key themes, and disciplinary and theoretical perspectives in the *Handbook*. It considers the implications for teaching energy and society, and suggests new directions in energy and society research, in the context of the very small share of energy research funding received until now (Overland and Sovacool, 2020).

Overall, the *Handbook* aims to contribute to a firm footing for social studies of energy, bringing diverse theories, research methods and data to understanding the ‘history of the present’, the embedding of carbon- and energy-intensive infrastructures in how we live and who we are, and how to move on. The authors demonstrate the value of social sciences in identifying the inter-locking societal and technical changes needed to limit climate disruption. Contributors examine socio-technical dynamics of energy systems from macro to micro scales, identifying ways to live within environmental limits, and to manage the consequences of massive combustion of fossil fuels. Such insights are critical to informing changes in governance institutions, production and consumption systems, and public infrastructures, while minimising perverse consequences and injustices. From business and industry, through governance and policy, to personal action, social sciences are needed to face the unthinkable, to speak truth to power, and to help create sustainable futures for life on Earth.

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