



# COMPETITIVE, SECURE, LOW-CARBON ENERGY SUPPLY

a social sciences and humanities  
annotated bibliography



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## Executive summary

### The challenge

- European Union (EU) energy policies have three main aims: competitiveness, secure supply and sustainability. EU countries have agreed to reduce greenhouse gas emissions by 40% compared to 1990, and to increase the share of renewable energy to 27%, by 2030<sup>1</sup>.
- Transitions to low-carbon societies in Europe are challenging and require substantial change in how we produce and use energy. The Horizon 2020 energy work programme<sup>2</sup> emphasises the importance of research and innovation for supporting these transitions.

### The aim

- European energy policy has so far mainly relied on research from Science, Technology, Engineering and Mathematics (STEM) disciplines. Energy-related Social Sciences and Humanities (energy-SSH) have been significantly underrepresented. This annotated bibliography showcases the diversity of energy-SSH research of relevance to competitive, secure, low-carbon energy supply in Europe. It aims to demonstrate the policy relevance of energy-SSH to support low-carbon energy transitions in Europe.

### Coverage

- As well as providing an overview of high impact research, such as from the Economics domain, this bibliography also highlights so far underrepresented disciplines, such as Ethics and History.
- The research presented in this bibliography has a clear bias towards Western and Northern European based researchers mirroring the dominance of these regions in overall energy-SSH. However, case studies from Southern and Eastern Europe have intentionally been added.
- To ensure the representation of different SSH perspectives, the main topics of the bibliographies are politics, publics, and markets for competitive, secure, low-carbon energy. Further, it addresses the role of research on energy histories and energy futures.

### Key findings

- Economics dominate energy-SSH research, both in terms of impact in academia and influence on policymaking. Other, still underrepresented, disciplines provide valuable and policy-relevant insights on issues such as energy ethics; histories of energy; the role of visions, imaginaries and expectations for policymaking; and public engagement with low-carbon energy.
- Transitions towards low-carbon energy systems are of significant interest to energy-SSH researchers, in terms of both how transitions happen and how to manage and govern them. The 'Multi-Level Perspective' has become a dominant framework to describe transitions. Much focus is also on studying 'green niche' initiatives. SSH research emphasises the importance of better understanding politics and power in sustainability transitions. More research is also needed on the established actors involved in current energy systems and their role in changing policies and practice.
- Rather than a sole focus on specific renewable energy technologies, SSH researchers highlight the relevance of broader innovations that include the public and citizen initiatives. Such research on 'publics' often emphasises the need for a better understanding of how to engage publics in low-carbon energy transitions. Further, there is a need to discuss the actors and processes responsible for engaging citizens in both renewable energy projects and the development of new technologies. Energy justice is also an important, though understudied, topic in this context.

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1 European Commission 2014/15/EC A policy framework for climate and energy in the period from 2020 to 2030, [online] Available at: <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0015&from=EN> [Accessed 31 May 2017].

2 European Commission Decision C(2017)2468 of 24 April 2017 Horizon 2020 Work Programme 2016 -2017. 10. 'Secure, Clean and Efficient Energy', [online] Available at: [http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016\\_2017/main/h2020-wp1617-energy\\_en.pdf](http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-energy_en.pdf) [Accessed 31 May 2017].



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## Introduction

### A taste of energy-SSH

This annotated bibliography on 'competitive, secure, low-carbon energy supply' is one of four annotated bibliographies created as part of the EU Horizon 2020 Platform *Social Sciences and Humanities for Advancing Policy in European Energy* (SHAPE ENERGY)<sup>3</sup>. SHAPE ENERGY aims to develop Europe's expertise in using and applying energy-related Social Sciences and Humanities (energy-SSH)<sup>4</sup>. Compared to Science, Technology, Engineering and Mathematics (STEM) research on energy, energy-SSH has been significantly underrepresented in informing European energy policy. In funding SHAPE ENERGY, the European Commission is supporting a better integration of energy-SSH into the policy process.

The aim of the annotated bibliographies is to give non-experts (such as policymakers, practitioners, and academics from a range of disciplines) a taste of the diversity of energy-SSH research in, or of relevance to, Europe. They thereby contribute to making the capabilities of energy-SSH more visible and they provide a convincing statement of the policy relevance of perspectives from the Humanities and Social Sciences. However, it is important to note that energy-SSH represents a diversity of disciplines, and many different, sometimes contradictory, perspectives and approaches to energy-related issues.

As part of the SHAPE ENERGY scoping work package, the annotated bibliographies will also feed into other SHAPE ENERGY activities, such as 18 multi-stakeholder workshops in cities across Europe, an Early Stage Researcher programme, Horizon 2020 sandpits, and the SHAPE ENERGY 2020-2030 research and innovation agenda. The scoping work package also includes four cross-cutting theme reports with practical recommendations for how to be sensitive to gender, multi-stakeholder interests, energy justice, and active consumers, which readers may be interested in. Both the theme reports and the annotated bibliographies may be useful as teaching resources.

### The four energy topics

The annotated bibliographies cover the four main energy topics that the SHAPE ENERGY project spans:

1. Energy efficiency and using less
2. Competitive, secure, low-carbon energy supply
3. Energy system optimisation and smart technologies
4. Transport sector decarbonisation

These topics have been selected based on their relevance for EU-policy; in particular, they are inspired by the priorities set out in the Strategic Energy Technology (SET) Plan<sup>5</sup> and consequently the Horizon 2020 energy work programme priorities. Hence, the bibliographies focus on the potential contributions of energy-SSH to these particular challenges. Although these four energy topics are very broad and can incorporate much of the existing energy-SSH, it is clear that through selecting these topics, other possible topics have been left out. Further, due to the broadness of the four topics, a comprehensive presentation of all energy-SSH research of relevance for the topics was, of course, impossible. Many very interesting articles had to be omitted. The bibliographies therefore present a selection of energy-SSH literature based on criteria such as impact (citations), quality assessment, disciplinary and regional diversity.

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<sup>3</sup> [shapeenergy.eu](http://shapeenergy.eu)

<sup>4</sup> SHAPE ENERGY will work across the full range of Social Sciences and Humanities, including energy-related research (both current and potential) within: Business, Communication Studies, Development, Economics, Education, Environmental Social Science, Gender, History, Human Geography, Law, Philosophy, Planning, Politics, Psychology, Science and Technology Studies, Sociology, Social Anthropology, Social Policy, and Theology.

<sup>5</sup> Commission Communication 2015/6317/EC Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation, [online] Available at: [https://ec.europa.eu/energy/sites/ener/files/documents/1\\_EN\\_ACT\\_part1\\_v8\\_0.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v8_0.pdf) [Accessed 21 May 2017].



## How to use the annotated bibliographies

Each annotated bibliography is divided into several sections, which again contain several subsections on different sub-topics. Each subsection provides a list of references, based on published literature including books, journal articles, working papers, reports, etc. Short, accessible annotations are provided under each reference that summarise key points, such as the questions being asked by the authors, the approach taken, headline findings, and/or policy relevant recommendations. They are (of course) not a substitute for reading the original publication, but rather provide a 'window in' that the reader can then follow up, if desired. Longer, more academic abstracts are usually available online. An email request to the author(s) may be a good way to obtain to full text documents, which are not public.

Note that the four bibliographies are independent documents and one reference may feature in more than one bibliography.

## Coverage

The annotated bibliographies aimed at both disciplinary and geographical diversity (within Europe) when selecting references. However, there is a clear dominance of some disciplines, particularly Economics, in energy-SSH research. Therefore, we intentionally added other disciplines that are not so visible and cited. There was a balance to be struck between including seminal work, and yet emphasising work that is also important, but so far not so visible. In addition, it is not always possible to easily determine which discipline(s) an author sees their work as sitting within. Given that energy-SSH research operates at the intersection between SSH and technology, the bibliographies not only include work by scholars from SSH-disciplines, but also work by scholars from STEM disciplines, who used methods from the Social Sciences and Humanities to approach their particular research problem. Furthermore, although most bibliographies have authors from different disciplines, our own disciplinary bias needs to be mentioned.

Geographical diversity was similarly difficult to achieve. There is a clear Western/Northern European (and particularly UK) dominance in energy-SSH research, and English language publications may achieve a wider readership. Again, a balance needed to be found between including seminal work and highlighting research from underrepresented regions, particularly Eastern Europe, and languages other than English. Whilst doing the search work for the bibliographies, we also discovered that, for example, google scholar automatically filters results based on which country you are from. This of course contributes to geographical and language bias.

As the four energy topics both differed in span and disciplinary coverage, and the expertise of the authors differed, each merited a slightly different approach to searching and compiling of the research literature.

## The topic of this bibliography: competitive, secure, low-carbon energy supply

This topic reflects the main objectives of EU energy policy: (1) a competitive environment for energy providers, (2) security of energy supplies, and (3) sustainable sources of energy supply. The topic deals with how the share of renewable and low-carbon energy and conversion technologies for electricity, heating and cooling can be increased in the EU. A particular focus is on energy transition processes and how to manage and encourage them. Further, the topic addresses the conditions under which transitions and the diversification of the energy mix happen, particularly how they affect consumers, citizens, businesses and industries, and the role of these actors in transition processes.

## Methodology

The topic 'competitive, secure, low-carbon energy supply' is very broad. Just to demonstrate the large amount of Social Sciences and Humanities work in this area: a quick search on 'energy security' (just one small subtopic of this annotated bibliography) on scopus, the largest database for peer-reviewed literature, gave more than 2000 hits (already filtered to only include research from SSH disciplines). Hence, our approach to this bibliography was not to aim at a comprehensive overview, but to present a selection of relevant energy-SSH literature.



We used different strategies to compile the literature for this bibliography. First, we looked to previous reviews of energy-SSH research<sup>6</sup> for inspiration for which subtopics to focus on. Second, we contacted scholars from different disciplines with research interests within this topic for advice on relevant literature. The authors of this bibliography also represent different SSH disciplines. Third, we used databases, such as the above-mentioned scopus, to search for literature about specific sub-topics, and from specific disciplines. The selection of references was based on our aim of both including seminal work (including most-cited publications from top-journals) and publications that have been 'invisible' and underrepresented (in terms of disciplines, topics and regions).

## Structure

The annotated bibliography is divided into four main sections: (1) Politics, (2) Publics, (3) Markets, and (4) Pasts and Futures of competitive, secure, low-carbon energy. Each of these four sections is again divided into several subsections. Each subsection contains an introduction to the respective subtopic, including a brief description of the literature selected to represent this subtopic. The subsection introductions are followed by the lists of references with short annotations ordered according to their appearance in the introduction. Sometimes, we mention references in the introductions, which are not included in the main bibliography. The readers can find these references in the footnotes.

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<sup>6</sup> E.g., Sovacool, B. K., 2014. What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. *Energy Research and Social Science*, 1, pp. 1-29.



# 1. Politics of competitive, secure, low-carbon energy supply

Transitions to low-carbon societies need to be planned, managed and governed. This section about the politics of competitive, secure, low-carbon energy supply presents a selection of the huge amount of research that deals with the role of governments (national, regional, local, supranational), and of regulation and planning in these change processes. Many disciplines address questions related to the politics of transitions, prominent are for example, Science and Technology Studies, Politics, Geography, Anthropology, Planning, and Law. Obviously, the insights of the research presented in this section may be of particular relevance for policymakers and planners alike.

A growing strand of research within energy-related Social Sciences and Humanities (energy-SSH), Transition Studies, as presented in subsection 1.1. '[Governing low-carbon energy transitions](#)', deals explicitly with sustainability transitions with a particular focus on the introduction of new sustainable technologies in market and society and on how transitions are managed and governed. The research takes often a broad perspective and aims to understand the overall picture of transition processes. Subsection 1.2. '[Policy instruments, policy mixes and regulation](#)', by contrast, focuses on research about particular policies and regulations. This research looks at how particular policies are developed and at success and challenges related to policies and regulation. The literature in this subsection provides many concrete recommendations for policymakers. Subsection 1.3. '[Planning and land use](#)', shifts the focus to the actual planning of transitions. It presents research on regional and local planners and developers and their struggles to implement policies and regulation. The subsection has a particular focus on research about planning issues related to land use and landscapes since this is a hot issue in the context of renewable energy development. The last subsection of this section on politics, subsection 1.4. '[Energy security](#)', shifts the perspective back to the national and global level. Here, research on energy security, a main objective of EU energy policy, is presented. The subsection addresses both global geopolitical aspects of energy security and takes the perspective of consumers on the issue. Further, it presents several discussions on how we can understand and measure energy security.

## 1.1. Governing low-carbon energy transitions

Transitions to low-carbon energy systems are very complex. They involve changes in many areas of society and require that many actors, such as policymakers, citizens, researchers, technology developers and businesses contribute. A central strand of Social Sciences and Humanities (SSH) research, Transition Studies, focuses on these transitions and aims to understand better how these extensive societal changes towards more sustainability happen. Transition Studies focus particularly on the evaluation of technological developments and their entrance into society. This field of research studies the market introduction of new sustainable technologies and especially the dynamics related to whether the technologies succeed. Transition Studies highlight that society and technology (or, the social and the material) affect each other and evolve together. This reciprocal relationship between society and technology is often described with the word 'sociotechnical'.

Much of the transition literature uses Rip and Kemp's<sup>7</sup> multi-level model of innovation, which distinguishes between 'niche-innovations', 'socio-technical regimes' and 'sociotechnical landscapes', and Kemp et al.'s (1998) concept of 'Strategic Niche Management' (SNM). These concepts are the basis for the widely used (but also criticised) 'multi-level perspective' (MLP), which argues that transitions happen through interactions between the three levels: niches, regimes and landscapes. The niche represents the micro-level. This is the place where radical changes and innovation happen. The regime, the meso-level, represents the current energy system (and its technologies, practices, infrastructures, policies, application, knowledge, and symbolic meanings). Research indicates that the regime aims at stability and that change happens slowly at the regime level. The landscape, the macro-level, contains even broader factors, such as culture, environmental issues, economics and global conflicts. Using these three levels, Geels and Shot

<sup>7</sup> Rip, A. and Kemp, R. 1998. Technological change. In: S. Rayner and Malone, E.L. (Eds.). *Human choice and climate change*. Vol. II, Resources and technology. Columbus, OH: Battelle Press. pp. 327-399.



(2007, p. 400) have described transitions as follows: “(a) *niche-innovations build up internal momentum, through learning processes, price/performance improvements, and support from powerful groups, (b) changes at the landscape level create pressure on the regime and (c) destabilization of the regime creates windows of opportunity for niche-innovations. The alignment of these processes enables the breakthrough of novelties in mainstream markets where they compete with the existing regime*”.

The core task within this line of thinking is to figure out how currently dominant socio-technical regimes, for example energy systems based on fossil fuels, can be dissolved and replaced. Shove and Walker (2007), for example, point out that Transition Studies try to understand these system dynamics through analyses of the rise and fall of selected socio-technical systems and regimes. However, the authors also summarise the critique of this literature and argue that Transition Studies, and particularly the multi-level perspective, have failed to highlight “*how individuals and organizations can, might, or should act to affect the processes in question or to steer trajectories towards predefined, normative goals*” (Shove and Walker, 2007, p. 763). They criticise a lack of attention to ways of living and transitions in practice. Normann (2015) adds to this criticism of the multi-level perspective by pointing to the absence of a focus on politics, and especially on the role of government actors and their interests and conflicts. Therefore, he suggests extending the multi-level perspective with a focus on agenda setting.

Hildingsson and Johansson (2016) confirm the need for broader thinking around transitions when they discuss potential synergies between low-carbon strategies and other wider environmental objectives. De Jong (2011) emphasises the potential of international institutions and international energy governance to contribute to low-carbon transitions. Some debate has also arisen within the Transition Studies field itself, represented here by Smith et al. (2005). They attempt at dealing with what they refer to as an overly functionalistic framework by looking at the how differences in context, agency, and availability of resources influence regime change. Having become less conceptual and perhaps more sensitive to the need for a practical focus, Geels (2014) for instance, introduces the concepts of power and politics to the multi-level perspective. Further, Verbong and Loorbach (2012) scrutinise the discrepancy of the supposed inevitability of transition processes within discourse and the actual achievements in the Netherlands. Finally, Bolton and Foxon (2015) review how the socio-technical approach can guide in redirecting policy toward more sustainable goals.

**Kemp, R, Schot, J., and Hoogma, R., 1998. Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technology Analysis and Strategic Management*, 10(2), pp. 175–196.**

This seminal paper represents the fundament on which the multi-level perspective (MLP), which is dominant today, is established. The paper introduces the concept of socio-technical regimes as a centrepiece of Strategic Niche Management (SNM) studies in the nineties. It aims to understand the successful market introduction of new sustainable technologies. SNM scholars claim that new technologies enter into competition with already-existing technologies that maintain relatively stronger footholds in the market. Thus, they advocate the creation of protective spaces, so-called niches, to facilitate transitions.

**Geels, F.W. and Schot, J.W., 2007. Typology of sociotechnical transition pathways. *Research Policy*, 36(3), pp. 399–417.**

This article introduces the conceptual framework of the multi-level perspective (MLP), a central development of transition studies. Based on a critique of MLP, the authors develop a typology of four pathways, which can be used to evaluate ongoing transition processes: transformation, reconfiguration, technological substitution, and de-alignment and re-alignment. The article uses relevant historical examples to demonstrate how these different pathways differ according to the timing and nature of the interaction between the niche, regime and landscape levels.

**Shove, E. and Walker, G., 2007. CAUTION! Transitions ahead: Politics, practice and sustainable transition management. *Environment and Planning A*, 39(4), pp. 763–770.**

This is a critique of the transitions literature, advocating the need to (1) recognise the politics of transition management, (2) question the work involved in redefining and revising the goals of transition management as the system evolves, (3) recognise the missing transitions (or unwanted or unsustainable transitions),



and (4) the lack of reference to transitions in practice. The lack of reference to the ways of living implied in “*what remain largely technological templates for the future*” (p. 768) paints a narrow picture of what is a much wider debate about social systemic change.

**Normann, H. E., 2015. The role of politics in sustainable transitions: The rise and decline of offshore wind in Norway. *Environmental Innovation and Societal Transitions*, 15, pp. 180–193.**

The paper applies Kingdon’s three streams model of agenda setting (consisting of policy stream, problem stream and political stream) together with concepts from the multi-level perspective in order to explore the role of politics in transition processes. It finds that changes in ministerial positions created favourable conditions for offshore wind. The petroleum industry is seen as a potential resource, but also as a barrier to offshore wind in Norway. The author argues that analyses of energy transitions benefit from paying attention to the interests of government actors, and conflicts inside government.

**Hildingsson, R. and Johansson, B., 2016. Governing low-carbon energy transitions in sustainable ways: Potential synergies and conflicts between climate and environmental policy objectives. *Energy Policy*, 88, pp. 245–252.**

Climate change mitigation is too often considered separately from other fields of public policies in environmental governance, this paper argues. By examining the Swedish environmental quality objective seen as a governance arrangement, the paper presents alternative ways of governing low-carbon energy transitions in line with broader sustainability goals. Low-carbon strategies can gain increased compatibility when accompanied with flanking policies and measures designed for non-climate objectives.

**De Jong, S., 2011. Vers une gouvernance mondiale de l’énergie: comment compléter le puzzle. *Revue internationale de politique de développement*, 2, pp. 29–54.**

The institutional framework responsible for global energy relations has failed to adapt to current challenges. It suffers a lack of legitimacy as well as insufficiencies in the ability to implement compliance. The author claims that the current frameworks are doomed to inefficiency and non-representativeness without institutional reforms. De Jong delivers insight from an analysis of influential international institutions and discussion platforms on energy issues, and highlights their ability in managing successful international energy relations and governance.

**Smith, A., Stirling, A., and Berkhout, F., 2005. The governance of sustainable socio-technical transitions. *Research Policy*, 34(10), pp. 1491–1510.**

This paper tackles the concept of regime transition by emphasising a nuancing according to different contexts within and surrounding regimes, as well as varying degrees of agency of actors both outside and within regimes. This can be based on availability of resources, as well as the intensity with which pressures are exerted on regimes to make them change. The authors develop the concepts of ‘endogenous renewal’, ‘reorientation of trajectories’, ‘emergent transformation’ and ‘purposive transition’ as four ideal types of transformation that unfold under different transition contexts.

**Geels, F. W., 2014. Regime resistance against low-carbon transitions: Introducing politics and power into the multi-level perspective. *Theory, Culture & Society*, 31(5), pp. 21–40.**

The paper focuses on existing regimes rather than ‘green’ niche-innovations. The author describes regime stability as the outcome of active resistance to niche technology by ‘incumbent’ – i.e. established – actors. Drawing on insights from political economy, the paper introduces politics and power into the multi-level perspective to discuss ways in which these actors resist transitions to low-carbon systems, using examples are from the UK electricity system. The article suggests change through political intervention, rather than relying too much on ‘green innovation’.

**Verbong, G. and Loorbach, D., 2012. *Governing the Energy Transition: Reality, Illusion or Necessity?* New York: Routledge.**

Despite the fact that the notion of ‘energy transition’ is deeply rooted in political discourse, the Netherlands is lagging behind in transitioning to a sustainable energy system. Incumbent actors and interests may cause this problem, but their role and position is destabilised. The authors studied four innovative practices (storylines) that influence the energy system, and argue that they lead to confusion, insecurity and tensions



amongst incumbents and provoke societal change. Longitudinal research is needed to confirm this assumption.

**Bolton, R. and Foxon, T., 2015. A socio-technical perspective on low carbon investment challenges – Insights for UK energy policy. *Environmental Innovation and Societal Transitions*, 14, pp. 165–181.**

Considering large technical systems regarding the long term and large-scale transition that align with ambitions of current energy governance is what this paper is about, and it does it with the help of the socio-technical systems approach. This kind of approach systematically reveals the dynamics of intervention into these systems, and can aid in redirecting them towards sustainability goals. This paper deals with uncertainty, avoiding lock-ins, and accelerating diffusion of low-carbon technology from within protective 'niches'.

## 1.2. Policy instruments, policy mixes and regulation

The field of Transitions Studies presented in the previous subsection is dominated by conceptual, rather than practical, approaches to transitions and many studies may appear inaccessible for non-experts. This subsection, in contrast, deals with Social Sciences and Humanities (SSH) research about particular policy instruments and policy mixes, and their role in contributing to increasing the share of low-carbon energy in Europe. The literature often presents evaluations of existing policies and recommendations for future policies. Hence, it may be highly relevant for policymakers on all levels.

Clearly, the Economics discipline dominates this research. However, this subsection intentionally presents a selection of non-Economics research on policies in order to showcase insights from other SSH disciplines, such as Law, Politics, or Science and Technology Studies. This also emphasises the point made by Del Rio (2014), that we should not only evaluate policies according to economic criteria, but also criteria such as equity, acceptability and local impact. Insights on energy policy from the Economics discipline related to, for example, energy markets and energy prices, are presented later in this bibliography (see section 3. '[Markets for competitive, secure, low-carbon energy supply](#)').

The first contribution on the list below (Kanellakis, Martinopoulos and Zachariadis, 2013) provides a review of European energy policy, on which basis it makes recommendations for future policy development. A large amount of studies in this field focuses on particular policy instruments. Jacobs (2013) studies the emergence of feed-in-tariffs in a long-term analysis, while Gullberg and Bang (2015) analyse how Norway adopted the Swedish green certificate scheme. The authors also emphasise the importance to look at the politics of decision-making processes. While most research on energy policies is about the national level, some research addresses, for example, how national energy policy instruments affect local communities (Dóci and Gotchev, 2016) or explicitly the policies of local governments themselves (Rygg, 2014).

An increasing number of scholars emphasises the importance of studying policy mixes instead of only focusing on single policy instruments. This provides valuable insights, since it takes into account that successful change processes are often an effect of different policies, rather than only one single policy instrument, under real-world conditions. Lehmann and Gawel (2013), for example, examine the policy mix of the EU emissions trading scheme, while Reichard and Rogge (2016) look at how the policy mix affects innovation in the case of offshore wind power in Germany. Clearly, evaluating policy mixes represents a challenging task. Nonetheless, Del Rio (2014) stresses that policy evaluation should move from specific policy instruments to policy mixes and he proposes a framework for assessing the success of policy mixes.

The last two contributions represent perspectives from legal scholarship on renewable energy regulation. While Johnston and Van Der Marel (2016) discuss the challenges of enforcing the EUs binding renewable energy targets, Abad Castelos (2014) looks at International Law related to marine renewable energy.

**Kanellakis, M., Martinopoulos, G. and Zachariadis, T., 2013. European energy policy - A review. *Energy Policy*, 62, pp. 1020–1030.**

This paper presents an overview of European energy policy. After a short history of the European Union's energy policy from 1951 to 2012, the authors discuss a diversity of policies from the following categories:



Renewable energy, energy efficiency and savings, internal energy markets, security of energy supply, environmental protection, nuclear energy and research and development. Based on their review, they argue for a reassessment of European energy policy in the light of the financial crisis, climate policy negotiations and recent technology development.

**Jacobs, D., 2013. Policy invention as evolutionary tinkering and codification: the emergence of feed-in tariffs for renewable electricity. *Environmental Politics*, 23(5), pp. 755-773.**

Building on literature about innovation and invention, Jacobs analyses the invention of feed-in tariffs to support renewable energy. This analysis is particularly interesting because it takes a long-term perspective. It looks at how this policy instrument was modified from its start as support for cogeneration power plants in the 1970s to its codification in 2000. Jacobs shows how policymakers modified the feed-in-tariffs gradually over time and how they adjusted them to the investment needs of renewable energy producers. This adjustment of the feed-in-tariffs was based on learning by trial and error. Jacobs argues, therefore, that policymakers should give new policy instruments time and space so that these learning processes can occur. The effectiveness of the policy instrument increased with the adjustments made.

**Gullberg, A.T. and Bang, G., 2015. Look to Sweden: The making of a new renewable energy support scheme in Norway. *Scandinavian Political Studies*, 38(1), pp. 96-114.**

This paper looks at the process by which Norway decided to adopt a green certificate scheme (GCS), which already existed in the neighbouring Sweden, and to set up a common Norwegian-Swedish GCS. To analyse this policy transfer, the authors analysed how Norway learned from Sweden, and how competition and domestic factors influenced the decision. They explore how policymakers made decisions in the decade leading up to the final decision for a GCS in 2011. Contrary to earlier literature, this study finds that competition did not play a big role as driver for the policy transfer. Policy learning seemed unsystematic and influenced by Sweden, rather than by information provided by Norwegian bureaucrats. Domestic politics, however, played an important role, in particular the need to ensure support from stakeholders. Hence, the authors argue that it is essential to look at politics in addition to policy to understand policy transfer processes.

**Dóci, G. and Gotchev, B., 2016. When energy policy meets community: Rethinking risk perceptions of renewable energy in Germany and the Netherlands. *Energy Research and Social Science*, 22, pp. 26-35.**

While a growing number of studies analyses the effectiveness of energy policy instruments to support renewable energy, little is known about the effectiveness related to specific groups of investors. This paper addresses renewable energy communities and how national policy instruments in Germany and the Netherlands support community-based renewable energy projects. The authors are particularly interested in how policy instruments can reduce the risks for investments in community energy projects. Policies in both countries were designed to achieve the same goals. However, results show that renewable energy communities viewed Germany's support scheme much more favourable than the Dutch one because it addressed all risks that could endanger investment. Policymakers should therefore consider the specific characteristics of renewable energy communities and address several types of risks when designing policies.

**Rygg, B.J., 2014. Paving the way for heat. Local government policies for developing bioenergy in Norway. *International Journal of Sustainable Energy Planning and Management*, 4, pp. 57-70.**

Analyses of policy instruments focus often on the national level. This paper takes a different approach by looking at how local governments in Norway stimulate the development of sustainable bioenergy. It looks particularly at their technology policy. The author finds that the main strategy of local governments is to increase local demand for heat and hence create a market for sustainable bioenergy. This is done by using instruments in four areas of technology policy: innovation support, infrastructure development, regulation and public engagement.

**Lehmann, P. and Gawel, E., 2013. Why should support schemes for renewable electricity complement the EU emissions trading scheme? *Energy Policy*, 52, pp. 597-607.**

The common policy mix of EU Emissions Trading Scheme (EU ETS) and support schemes for electricity generation from renewable energy sources (RES-E) has been widely criticised. RES-E schemes would not



lead to lower emissions and more cost-effectiveness. This article discusses the rationale for this policy mix. The authors argue that under real-world conditions a carefully designed RES-E scheme in combination with EU ETS has its benefits, e.g., for the development of technologies.

**Reichardt, K. and Rogge, K., 2016. How the policy mix impacts innovation: Findings from company case studies on offshore wind in Germany. *Environmental Innovation and Societal Transitions*, 18, pp. 62–81.**

While policy mixes are of great importance for low-carbon energy transitions, little is known about how they affect technological innovation. This paper studies the role of the German offshore wind policy mix for innovation within offshore wind technology. The authors find that the policy mix has been very significant for innovation. Stability, consistency and a long-term perspective were important for research, development and demonstration. A comprehensive policy mix seemed vital for adaptation. The authors provide the following recommendations to policymakers: (1) Establish ambitious, credible and stable long-term targets for the specific technology early on, (2) Create a comprehensive mix of policies, (3) Demonstrate credibility – trust is essential!

**Del Río, P., 2014. On evaluating success in complex policy mixes: The case of renewable energy support schemes. *Policy Sciences*, 47(3), pp. 267–287.**

The evaluation of policy mixes is a difficult task. Energy policies do often have several aims and there are diverse criteria for success. This paper proposes a framework for how to assess policy mixes and their success. Other than much of the literature on policy evaluation, the author emphasises a broad definition of success. Not only economic criteria, such as cost-effectiveness, but also criteria like equity, acceptability, and local impacts should be reflected in evaluations of success. In order to find out where different policies are in conflict, it is important to consider both different administrative levels (local, national, European) and different instruments in the policy mix. To avoid these conflicts, the author proposes better administrative coordination between the administrative levels and different instruments. Policy evaluation should move its focus from specific policy instruments to policy mixes.

**Johnston, A. and Van Der Marel, E., 2016. How Binding are the EU's 'Binding' Renewables Targets? *Cambridge Yearbook of European Legal Studies*, 18, pp. 176–214.**

This paper deals with EU's legislation on renewable energy and particularly with the binding targets for the share of renewables of total energy consumption. However, what are the implication of having such supposedly mandatory targets? In order to discuss this question, the authors look into the history of such binding targets. They also address the challenges for enforcing such targets.

**Abad Castelos, M., 2014. Marine Renewable Energies: Opportunities, Law, and Management. *Ocean Development and International Law*, 45(2), pp. 221–237.**

The prospects of developing marine renewable energies appear promising, both in terms of environmental, social and economic gains. However, also here controversies exist, for example, related to the protection of the biodiversity at sea. This paper looks at regulatory issues related to marine renewable energy. International law of the sea provides a framework, however it has significant gaps. Most notably, the author mentions that it lacks institutions or mechanisms for international governance. That means that it is unclear who has the responsibility for implementing the law, for example, related to the protection of biodiversity in international waters. The author emphasises that it is important to take into account issues related the marine renewable energy in international oceans governance.

### 1.3. Planning and land use

Planning and land use link closely to energy issues along three dimensions. The first dimension is physical, related to the shape of the various types of rural and urban land use and to architectural and urban design. The second dimension is more intangible. It concerns the relationship between energy and regulatory frames, for example incentives for sustainable neighbourhoods or community energy projects. The third dimension looks at the places and the technologies for energy production and how to take advantage of existing renewable energy sources (wind, sun, waste) for electricity, district heating and others things.



The localisation of renewable energy appears crucial for building an entirely new low-carbon energy system. Six elements play a part in the decision-making about localisations: landscape, location, territoriality, spatial differentiation, scaling, and spatial embeddedness. These elements should be included in a complex, and geographically differentiated analysis of the interactions between direct and indirect land-use changes. Here, planners could be the great engagers, promoting community-municipality owned energy and make decentralised energy a core requirement for new places. However, land-use planning sometimes poses a significant barrier for the use of public participation in the planning process in order to address concerns of local residents and ease conflicts.

Obviously, this subsection may be of special relevance to local policymakers and planners. Many of the studies presented in the list below provide specific recommendations for planning processes. The research addresses the important role of planners in low-carbon energy transitions. Cajot et al. (2017) focus on the obstacles in urban energy planning and emphasise the need for multi-faceted solutions to the complex issue of low-carbon energy transition. Similarly, Chanard et al. (2011) look at local authorities and their role in transitions. They study the policy and planning choices that local authorities have. Based on insight from planning, Balta-Ozkan et al. (2015) provide recommendations for policymakers for how to deal with low-carbon transitions.

A large number of studies emphasises the importance of citizen participation in planning. Papaza (2016) looks at change processes related to new renewable energy projects in Samsø in Denmark. She shows how a management style that was guided by citizen interests was successful. Particularly in wind power planning, a high level of citizen participation seems essential for project success (Mc Laren Loring, 2007). Lee (2017) addresses the integration of knowledge claims from different societal actors in the planning processes. As mentioned above, planning for renewable energy is related to questions of land use and thereby to issues of landscapes and seascapes. Leibenath and Otto (2013) research the views on landscape and the role of landscape in regional planning and local debates related to renewable energy projects. Spatial planning and how sustainability principles can be integrated into it, is the topic of Demazière's (2014) contribution.

Whether urban planning, land use planning, regional planning or marine spatial planning, usually planning processes involve professionals from several disciplines. The particular role of landscape architects is addressed in the paper by de Waal and Stremke (2014). The authors emphasise the potential to involve landscape architects to a much higher degree in low-carbon transitions. However, this would require a broader planning focus, from renewable energy to sustainable land use. The emergence of marine renewable energy, mostly offshore wind power, but increasingly also other energy technologies, brought attention to issues of marine spatial planning. Christie et al. (2014) explore the collocation of different activities (renewable energy, fishing, and aquaculture) as a solution for area conflicts at sea. Kerr (2014) stresses the importance of coordination between land use planning and marine spatial planning in the context of marine renewable energy.

**Cajot, S., Peter, M., Bahu, J-M., Guignet, F., Koch, A. and Maréchal, F., 2017. Obstacles in energy planning at the urban scale. *Sustainable Cities and Society*, 30, pp. 223-236.**

Among all urban actors, planners have the most accurate and comprehensive understanding of the problems, and their experience, creativity and intuition will remain central in handling the more qualitative and wicked aspects of low-carbon energy planning. The authors' main hypothesis is that a better understanding of the multi-faceted problem should foster a multi-faceted solution approach, instead of adopting fragmented or incomplete solutions. Energy planning in cities depends on different highly time-bound and volatile parameters, such as fuel prices and operational costs, investment costs for energy conversion technology, improving and emerging technologies, population growth and high urbanization rates, changing political actors and agendas, unstable international and national policy frameworks, etc.



**Chanard, C., Sède-Marceau, M.-H. de and Robert, M., 2011. Politique énergétique et facteur 4 : instruments et outils de régulation à disposition des collectivités. *Développement durable et territoires*, 2(1), [online] Available at: <https://doi.org/10.4000/developpementdurable.8776> [Accessed on 25 May 2017].**

Local public authorities play an important role for the reduction of greenhouse gas emission. Their responsibilities in the energy field involve, for example, the energy consumption in public buildings, their energy supply networks, their energy production technologies and their employees' practices and choices related to energy. Moreover, the land planning of local public authorities also exert a substantial influence on space, society and environment on a local level. This article considers the variety of instruments and means of action available to local authorities in France for defining and organizing the public policies and planning choices, which are expected to structure their local policies for energy transition and climate.

**Balta-Ozkan, N., Watson, T. and Mocca, E., 2015. Spatially uneven development and low carbon transitions: Insights from urban and regional planning. *Energy Policy*, 85, pp. 500–510.**

The paper highlights five key issues that are relevant for policy makers dealing with low carbon transition: (1) The need for a radical, system-wide change raises questions around how such a transition can be managed effectively and potential risks avoided or mitigated. (2) The development and use of consistent indicators can also help with the development of policies that take into account wider socio-economic and infrastructure differences. (3) Policies could be tailored to local areas to take local issues into account or be designed centrally to include flexibility in implementation. Further, the economic potential of regional hubs as a way of revitalising poorer regions could be promoted. (4) No matter what the shape of the future energy system will be (a centralised, upstream decarbonised or more decentralised and local), green jobs would be affected. (5) Finally, rather than deterministic approaches, the use of scenarios can help facilitate the alignment of policy goals at different scales and across different actors, as well as analysing the impacts of policies as a whole more systematically.

**Papaza, I., 2016. Management through hope: an ethnography of Denmark's Renewable Energy Island. *Journal of Organizational Ethnography*, 5(2), pp. 184–200.**

The island of Samsø in Denmark is known for being a Renewable Energy Island. This paper addresses how project developers in Samsø managed change processes related to new renewable energy projects. The authors observe two different methods for approaching these processes of change, which seemed to have great influence for whether citizens supported or rejected new projects. The method first is 'change management', which involves a focus on outcomes and solutions and on building a 'sense of urgency' in order to legitimate new renewable energy projects. The second method is 'hope management' where project developers focus on taking the citizens' interests and worries, such as job security, training, innovation, need for legal assistance etc., as starting point for negotiations. While 'change management' failed to get the support of citizens', 'hope management' was more successful partly because it made sure that the proposed project matched with the culture of the island community.

**McLaren Loring, J., 2007. Wind energy planning in England, Wales and Denmark: Factors influencing project success. *Energy policy*, 35(4), pp. 2648–2660.**

When planning the use of land for wind energy, it is not uncommon for resistance to build and pose a barrier to development. In order to understand the dynamics of such processes, this paper presents findings from 18 in-depth case studies of land-use planning in England, Wales and Denmark. It examines the role of local community participation and how networks of individuals and organisations ultimately determine levels of acceptance. Results indicate high levels of participation is conducive to success.

**Lee, M., 2017. Knowledge and landscape in wind energy planning. *Legal Studies*, 37(1), pp. 3–24.**

From a legal scholarship perspective, this paper looks at how planning receives knowledge claims about the impacts of wind energy projects on landscapes and seascapes. Landscape issues are understudied in legal studies despite its centrality for legal processes and decisions, particular related to wind energy. The author discusses how different knowledge claims shape legal processes. She differentiates between: (1) expert and technical knowledge claims, (2) lay and local knowledge claims, (3) prior institutional knowledge claims, and (4) professional knowledge claims.



**Leibenath, M. and Otto, A. 2013. Local debates about 'landscape' as viewed by German regional planners: Results of a representative survey in a discourse-analytical framework. *Land Use Policy*, 32, pp. 366-374.**

This paper looks at local debates about 'landscape' in Germany and at how regional planners perceive these debates. The authors find that the majority of debates where landscape plays a role is related to renewable energy. This emphasises the point that renewable energy development draws attention to landscapes and affects how people perceive landscape and space. Interestingly, the relation of landscape debates to renewable energy issues was particularly prevalent in Southern Germany with much less renewable energy facilities installed than in Northern Germany. Hence, the authors conclude that local landscape debates are not consequences of large numbers or concentrations of existing renewable energy facilities. Rather it is expected change processes, such as discussion of regional plans for renewable energy, which trigger local debates on landscape.

**Demazière, C., 2014. Localisation des activités économiques et planification spatiale en Angleterre et en France : vers un développement territorial durable? SHS Web of Conferences, 9, 04003, [online] Available at: [https://www.shs-conferences.org/articles/shsconf/pdf/2014/06/shsconf\\_trans2013\\_04003.pdf](https://www.shs-conferences.org/articles/shsconf/pdf/2014/06/shsconf_trans2013_04003.pdf) [Accessed on 25 May 2017]**

This article studies the comparative impacts of the introduction of sustainability principles into spatial planning practices for eight large conurbation areas located in France and in England. New objectives, processes and spatial scales are now required, regardless of the nation's specificities, such as the degree of (de)centralization. The article analyses the side effects of such a paradigmatic shift and tries to grasp to which extent the 'greening' of the planning documents confronts and affects the institutional systems and their long-term evolution. The author also looks at the implications of such new practices on the consumption of the lands necessary to the development of economic sites. The results show that France stands out as being highly decentralised in the planning decision making processes, which explains numerous territorial discrepancies in the search for coherence and sustainability. On the other hand, the English national guidelines have been more faithfully transcribed into the localities' plans. Thus, the author concludes that the local communities' heteronomy is a key element to consider when thinking the (im) permeability of territorial and sustainable developments.

**de Waal, R.M. and Stremke, S., 2014. Energy transition: Missed opportunities and emerging challenges for landscape planning and designing. *Sustainability (Switzerland)*, 6(7), pp. 4386-4415.**

This paper deals with the role of landscape architects in the transition from fossil fuels to renewable energy. The authors look at three successful cases of energy transitions in Güssing, Jühnde and Samsø to get insights into how landscape architects were involved. Citizen participation, enthusiastic frontrunners and adjustments to local context as well as institutionalised considerations of landscape impact, siting and design were found to be success factors in these transitions. However, landscape architects were not that much involved in these transitions. The authors suggest that a broadening of the focus from 'renewable energy provision' to 'sustainable energy landscapes' could get landscape architects involved to a higher degree.

**Christie, N., Smyth, K., Barnes, R. and Elliott, M., 2014. Co-location of activities and designations: A means of solving or creating problems in marine spatial planning? *Marine Policy*, 43, pp. 254-261.**

This paper takes as its departure point the pressures which arise from wind power taking ever more space in the marine areas around UK, creating conflict with others users of these areas. The authors thus take a closer look at the idea of co-locating several activities as a means to deal with such conflict, especially activities like protected areas, aquaculture and commercial fishing. Looking at UK and EU policy the study finds that with the aid of a criteria-based system, co-location can be feasible.

**Kerr, S., Johnson, K. and Side, J.C., 2014. Planning at the edge: Integrating across the land sea divide. *Marine Policy*, 47, pp. 118-125.**

This paper bases its inquiry on Scotland's marine renewable energy (MRE) development in the Penland Firth and Orkney Waters, a world centre for MRE. However, marine area use increases, this has consequences for land activity. Thus, marine spatial planning and land planning, two sectors, which have developed independently of each other, now intersect. The paper consider the two planning areas and highlight



differences. Results indicate an integration of the areas is not achievable, but that interactions between them remain crucial for coordination.

## 1.4. Energy security

Energy security has recently become a policy priority for the European Union (EU) due to growing concern about environmental challenges (in particular climate change) and the fact that the EU imports about half of the energy it needs. However, the concept of energy security still lacks a clear definition. Social Sciences and Humanities (SSH) research addresses this issue by discussing and proposing different definitions of the concept and their implication for the assessment of energy security. Winzer (2012), for example, reviews different definitions of energy security. Based on this review, he proposes to differentiate between 'security of supply' and other energy security objectives in order to simplify the evaluation of energy security.

Gracceva and Zeniewski (2012) refer to a definition of an energy secure system as a system that evolves over time with an adequate capacity to absorb adverse uncertain events, so that it is able to continue satisfying the energy service needs of its intended users with acceptable change in amount and price. The problem with this definition is that it does not necessarily imply a reduction of emissions and an increase in the use of sustainable energy sources, issues that lay at the heart of the low-carbon energy transition. Therefore, the authors propose a systemic approach to energy security. They identify five properties of energy security, which may aid the assessment of energy security in a low-carbon EU energy system. Related to this, McCollum et al. (2013) argue that climate policies can improve energy security. Nepal and Jamasb (2013) focus on indicators for evaluating energy security. Further, Parag (2013) suggests changing the focus from energy security to the security of energy services, which implies a more user-oriented perspective.

Another focus of SSH research is on energy consumers' attitudes and perceptions of energy security (Knox-Hayes et al. 2013; Sovacool and Tambo, 2016). This research supports the above-mentioned efforts to include environmental and climate considerations into our understandings of energy security. Furthermore, SSH research addresses energy security from a global perspective. Bradshaw (2010), for example, emphasises the importance of a geographical perspective to understand the interplay between energy security, globalisation and climate change. While Umbach (2010) looks at the geopolitical dimensions of energy security and its implications for the EU, Hayashi and Hughes (2013) study the effects of the Fukushima accident on global energy security.

### **Winzer, C., 2012. Conceptualizing energy security. *Energy Policy*, 46, pp. 36-48.**

This paper looks at different definitions of the concept of energy security, which so far has no clear definition. The widest of the definitions the author reviews include all risks that are caused by or have an impact on the energy supply chain. The author then narrows this concept down by identifying different sources of risk, impact measures and subjective severity filters in these definitions. The concept of 'energy supply continuity' is introduced by the author to reduce the ambiguity connected with the concept of energy security. In order to make it easier to evaluate energy security, the paper suggests to separate between security of supply and other energy security policy objectives and to define energy security as "*the continuity of energy supplies relative to demand*" (p. 36).

### **Gracceva, F. and Zeniewski, P. 2014. A systemic approach to assessing energy security in a low-carbon EU energy system. *Applied Energy*, 123, pp. 335-348.**

This paper proposes a new theoretical approach to energy security to get a better understanding of the complex relationship between energy security and climate change policies. This approach takes into account the multi-dimensional characteristics of energy security. To do this, it identifies five properties of energy security: Stability, flexibility, adequacy, resilience and robustness. The authors introduce a new framework for assessing energy security and provide suggestions for further research.



**McCollum, D.L., Krey, V., Riahi, K., Kolp, P., Grubler, A., Makowski, M. and Nakicenovic, N., 2013. Climate policies can help resolve energy security and air pollution challenges. *Climatic Change*, 119(2), pp. 479–494.**

Energy security, climate change, human health impacts due to air pollution are identified as key element of energy sustainability. The authors argue that it is important to move to a holistic approach to policymaking, which takes into account all three above-mentioned elements. They analyse different energy-climate futures with an integrated assessment model and find that stringent climate policies can lead to improved energy security in terms of diversifying the energy mix and increasing the use of domestically available renewable energy sources. Stringent climate policies would also lead to improved human health due to a decarbonisation and hence, improved air quality. Hence, this paper highlights these climate policy synergies and particularly the cost savings in terms of reduced pollution control and expenses for energy security.

**Nepal, R. and Jamasb, T., 2013. Security of European electricity systems: Conceptualizing the assessment criteria and core indicators. *International Journal of Critical Infrastructure Protection*, 6(3–4), pp. 182–196.**

The paper exposes the possible risks connected to unforeseeable events and threats regarding the European electricity systems. Economic risks due to underinvestment and rising electricity demand are major concerns along with the risks of natural calamities and severe weather conditions. The increasing digitalisation of the grid and the transition toward a smart grid are increasing the scope and the magnitude of cyber security threats facing European electricity networks. The protection of networks against exceptional events and other threats will require upgrades to the aging electricity infrastructure and the adoption of sophisticated technologies. The penetration of renewables across the European grid will require detailed planning coupled with accurate resource and load forecasting as the transition is made towards a low carbon economy. The future security, stability and resilience of European electricity networks are linked to flexible and innovative regulatory mechanisms that incorporate local, regional, continental as well as international considerations.

**Parag, Y., 2014. From energy security to the security of energy services: Shortcomings of traditional supply-oriented approaches and the contribution of a socio-technical and user-oriented perspectives. *Science and Technology Studies*, 27(1), pp. 97–108.**

Drawing on insight from Science and Technology Studies, this paper proposes to shift the focus from energy security to the security of energy services. The author criticises approaches to energy security, which merely focus on supply, for overlooking energy users. For energy users, the essential issue related to energy security is the provision of energy services. Hence, the author argues that we should add user-oriented and socio-technical perspectives to broaden our understanding of energy security.

**Knox-Hayes, J., Brown, M.A., Sovacool, B.K., and Wand, Y., 2013. Understanding attitudes towards energy security. Results of a cross-national survey. *Global Environmental Change*, 23(3), pp. 609–622.**

This paper studies attitudes towards energy security of energy consumers in Brazil, China, Germany, India, Kazakhstan, Japan, Papua New Guinea, Saudi Arabia, Singapore, and the United States. The authors use mixed methods – multivariate regression analysis and case studies. In addition to attitudes towards energy security, the paper also focuses on each country's energy resources, consumption characteristics and energy policies. They find that both socio-demographic factors, particularly gender and age, and the different regional contexts play a role for people's attitudes towards energy security. Hence, the results imply that no 'one-size fits all' mentality of energy security exists and that we need a nuanced and multi-dimensional understanding of the highly context-dependent issue of energy security.

**Sovacool, B.K. and Tambo, T., 2016. Comparing consumer perceptions of energy security, policy, and low-carbon technology: Insights from Denmark. *Energy Research and Social Science*, 11, pp. 79–91.**

Based on the survey study mentioned in the previous paper, this article digs deeper into the energy users' perceptions of energy security in Denmark. Results contravene a number of logical propositions and assumptions rooted in some of the academic literature on energy security and policy. This study strongly suggests that energy security analysis in particular must extend beyond traditional themes such as analysing security of fossil fuel supplies and the efficacy of energy markets and incorporate emergent areas



of importance including the development of new and innovative energy systems, ensuring equitable access to energy services, and minimizing damage to environmental endowments.

**Bradshaw, M.J., 2010. Global energy dilemmas: A geographical perspective. *Geographical Journal*, 176(4), pp. 275-290.**

This paper claims that the world currently faces a global energy dilemma: How can we satisfy ever-growing demand for energy without doing irreparable damage to the planet's ecosystem? This global energy dilemma is shaped through the interplay of energy security concerns (both security of supply and security of demand), the processes of economic globalisation (and the associated drivers of economic and population growth, industrialisation and urbanisation) and climate change policy. The author emphasises the importance of a geographical perspective in order to understand the socio-economic processes that underlie energy security, economic globalisation and climate change policy combine in different ways in different parts of the world. He calls upon all kinds of geographers (human, development, urban, economic, political and cultural geographers) to develop an agenda for studying the geographies of energy security, climate change and low carbon transitions.

**Umbach, F., 2010. Global energy security and the implications for the EU. *Energy Policy*, 38(3), pp. 1229-1240.**

The article analyses the global and geopolitical dimensions of international energy security and its implications for Europe from 2010 onwards. It focuses particularly on the 'Energy Action Plan' of the EU Spring summit of 2007. The author observes that the Russian cutbacks in gas deliveries affected the Ukraine and EU member states, and that this has questioned long-standing assumptions underlying Germany's and Europe's energy (foreign) policies. In the age of globalization, any policies that ignore detailed analyses of various domestic and regional stability factors could be proved as extremely short-sighted and being paid with high financial, economic and political. The '3 A's' strategy for achieving the three criteria of accessible, available and acceptable energy is seeking a closer cooperation and deep integration of the public and private sectors, both domestically and internationally.

**Hayashi, M. and Hughes, L. 2013. The Fukushima nuclear accident and its effect on global energy security. *EnergyPolicy*, 59, pp. 102-111.**

This analysis focuses on the short-term effects of the Fukushima nuclear accident in terms of the replacement of fossil fuels and the consequences on global energy security. The authors show that the effects of Fukushima were not limited to Japan. Germany, is an example, of a country where low public acceptability led to the decision for a nuclear phase-out. Today, it is difficult to ignore climate change when considering energy policy; therefore, when taking into account electricity costs from fossil fuels and the need to reduce greenhouse gas emissions, a radical shift either way in global civilian nuclear policy as a result of the accident appears unrealistic despite the severity of the Fukushima accident. In this context, even though the cost of electricity from nuclear power is rising and Fukushima has resulted in a public backlash against nuclear, the accident has not changed the fundamental dynamics of global energy policy and the need to improve energy security. Nuclear power, as well as fossil fuels, will continue to be used while jurisdictions continue to make efforts to improve and incorporate new renewable energy technologies.



## 2. Publics of competitive, secure, low-carbon energy supply

Transitions towards low-carbon societies require that we fundamentally change how we produce and use energy. Such demanding changes in European societies can only be achieved with broad public support and participation. Energy-related research in the Social Sciences and Humanities (energy-SSH) focuses on a diversity of aspects of the publics' relations to energy. 'Publics' is here deliberately put in the plural to demonstrate that SSH research not only deals with the 'general public' and their relation to low-carbon energy, but with a diversity of different publics, that is different groups of citizens, communities, stakeholders, individuals, and civil society organisations and their role in low-carbon energy transitions. The insights gained from this large and diverse strand of research is relevant for European, national, regional and local policymakers and for developers of energy projects and technologies.

Subsection 2.1. '[Attitudes and acceptability](#)' deals with public attitudes to and acceptability of low-carbon energy. It focuses on people's perceptions and responses, particularly on the factors contributing to support or opposition to energy projects. Subsection 2.2. '[Energy citizenship](#)' is about people's active engagement and participation. It also includes research on community energy projects. Subsection 2.3. '[Consumers and prosumers](#)' focuses on energy use in households and everyday life setting. Here, we address people as consumers and prosumers of low-carbon energy. Subsection 2.4. '[Ethics and religion](#)' is about the role of people's ethical and religious considerations in low-carbon energy transitions. This is an underrepresented area of research and gets therefore particular attention here. Finally, subsection 2.5. '[Energy justice](#)' deals with the three dimensions of energy justice (distributional, procedural and recognition justice) which have become a focus for work in this area, and how they affect transitions to low-carbon energy.

### 2.1. Attitudes and acceptability

Public attitudes, acceptance and acceptability of low-carbon energy technologies and particular energy projects has been addressed by a large number of studies from different disciplines within the Social Sciences and Humanities (SSH), among others, Psychology, Sociology, Science and Technology Studies and Human Geography. This field of inquiry is dominated by quantitative research in the form of survey studies about people's perceptions of different technologies and projects. The aim of much of this research is to understand the factors that explain public support or opposition. Increasingly, however, qualitative methods gain importance to obtain a better understanding of the underlying reasons for and mechanisms behind people's attitudes.

The first article (Wüstenhagen et al., 2007) in this subsection is a widely known theoretical contribution, which introduces the concept of social acceptance and its different dimensions. While the terms 'acceptance' and 'acceptability' often are used interchangeably, some scholars emphasise the difference between acceptance (of *ex-post* outcomes) and acceptability (of *ex-ante* processes)<sup>8</sup>. A large amount of studies addresses the factors that explain the acceptance or acceptability of renewable energy. These studies find a diversity of explanatory factors: economic aspects and the degree of people's involvement in planning and decision-making (Zoellner et al., 2008), people's political party preferences (Karlstrøm and Ryghaug, 2014), a lack of knowledge, fairness and trust (L'Orange Seigo et al., 2014) or community benefits (Walker et al. 2014). Many studies only address a limited numbers of explanatory factors, for example, whether the number and visibility of wind turbines influences their acceptability (Ladenburg et al., 2013). However, Perlaviciute and Steg (2014) argue that it is important to pay attention to both psychological and contextual factors in order to understand acceptability. An interesting note comes from Delicado et al. (2014), who observe that wind power in Portugal has been very successful despite a non-favourable public attitude.

<sup>8</sup> Cowell, R., Bristow, G. and Munday, M., 2011. Acceptance, acceptability and environmental justice: the role of community benefits in wind energy development. *Journal of Environmental Planning and Management*, 54(4), pp. 539-557.  
Fournis, Y., and Fortin, M., 2017. From social 'acceptance' to social 'acceptability' of wind energy projects: towards a territorial perspective. *Journal of Environmental Planning and Management*, 60(1), pp. 1-21.



Finally, a large number of studies engages critically with NIMBYism as explanation for public opposition (Devine-Wright, 2009). Other research takes this further by changing the focus from public opposition to the way experts and developers view and imagine publics and which consequences these views may have for the development of renewable energy (Burningham et al., 2015; Heidenreich, 2015).

**Wüstenhagen, R., Wolsink, M. and Bürer, M.J., 2007. Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy*, 35(5), pp. 2683–2691.**

This widely recognised paper introduces three dimensions of the concept of social acceptance related to renewable energy: (1) socio-political acceptance, (2) community acceptance, and (3) market acceptance. Socio-political acceptance is about acceptance of technologies and policy by the public, policymakers and key stakeholders. Community acceptance relates to local acceptance of particular renewable energy projects and factors such as procedural and distributional justice and trust. Market acceptance is about market adaptation of, for example, small-scale renewable energy technologies and focuses on consumers, investors and intra-firm acceptance. The authors argue that social acceptance needs to be taken seriously so that policies for renewable energy development can be successful.

**Zoellner, J., Schweizer-Ries, P. and Wemheuer, C., 2008. Public acceptance of renewable energies: Results from case studies in Germany. *Energy Policy*, 36(11), pp. 4146–4141.**

Using an environmental-psychological approach, this paper focuses on the public acceptance of photovoltaic (PV) solar, biomass and wind power plants. The study combines a quantitative survey and qualitative interviews to investigate the factors that shape public acceptance. Economics aspects, in terms of cost-benefit calculations made by people, were the strongest indicator for people's acceptance of renewable energies. However, public acceptance was also affected by the way people were involved in decision-making and whether they thought the planning process was fair. Therefore, the authors argue that economic benefits of renewable energy developments need to be better communicated. Further, people should be involved more in planning and decision-making in order to increase public acceptance.

**Karlstrøm, H. and Ryghaug, M., 2014. Public attitudes towards renewable energy technologies in Norway. The role of party preferences. *Energy Policy*, 67, pp. 656–663.**

How do citizens in Norway view renewable energy technologies? This paper addresses this question with particular focus on differences between energy technologies and between different groups of the public. Public attitudes to hydro dams, onshore and offshore wind, bioenergy combustion plants, and gas plants with and without carbon capture and storage were analysed through a survey study. While most socio-demographic variables did not seem to explain different public attitudes, the authors find that political preferences influenced people's views of renewable energy. Energy issues seemed to crosscut traditional left-right party coalitions. People's views of renewable energy linked to their preferences for parties emphasizing environmental values, both to the left and to the right of the political spectrum.

**Perlaviciute, G. and Steg, L., 2014. Contextual and psychological factors shaping evaluations and acceptability of energy alternatives: Integrated review and research agenda. *Renewable and Sustainable Energy Reviews*, 35, pp. 361–381.**

Research on the acceptability of renewable energy technologies has often either addressed contextual factors (objective costs and benefits) or psychological factors (people's perceptions and evaluations of costs and benefits and how they influence the acceptance of energy technologies). This paper combines contextual and psychological factors in a new framework in order to better understand the factors that influence the acceptability of energy technologies. Based on a literature review, the authors argue that both changing contextual factors and addressing psychological factors can increase public support for renewable energy. Policymakers should therefore make sure to consider contextual and psychological factors in their strategies to enhance the acceptability for low carbon energy transitions.

**L'Orange Seigo, S., Dohle, S. and Siegrist, M., 2014. Public perception of carbon capture and storage (CCS): A review. *Renewable and Sustainable Energy Reviews*, 38, pp. 848–863.**

Based on a review of literature on public perception of carbon capture and storage (CCS), this paper summarises existing research about factors influencing of public acceptance of CCS, such as fairness, attitudes, knowledge, trust and perceived benefits and risks. The reviewed literature identifies knowledge deficits about CCS among the public; and the authors argue that the public needs more information about



the technology. However, they also warn against overestimating the effect that more knowledge has on public acceptance. Other factors such as people's prior experience with the fossil fuel industry, the perceived benefits of the CCS project, fairness and trust in project developers seem to have more effect on public acceptance. The authors also argue that more research about the local context of particular CCS projects is needed in order to get a better understanding about which factors influence public acceptance of CCS at the project level.

**Walker, B.J.A., Wiersma, B. and Bailey, E., 2014. Community benefits, framing and the social acceptance of offshore wind farms: An experimental study in England. *Energy Research and Social Science*, 3(C), pp. 46-54.**

Community benefits are payments made to communities who are affected by the development of renewable energy. This paper studies whether community benefits affect the local acceptance of offshore wind power. The study finds that providing community benefits indeed can increase people's support for a particular wind farm. Interestingly, collective community-wide benefits seemed to be more significant for local support than individual benefits. However, when the researchers introduced a critical perspective on community benefits as 'bribery', the support for the wind farm decreased. Thus, the authors argue that it is important to consider how community benefits are perceived locally and that it may be a good option to focus on collective rather than individual benefits.

**Ladenburg, J., Termansen, M. and Hasler, B., 2013. Assessing acceptability of two onshore wind power development schemes: A test of viewshed effects and the cumulative effects of wind turbines. *Energy*, 54, pp. 45-54.**

This study represents one of many studies that focus on particular factors influencing the acceptability of renewable energy. Here, the authors analyse the effect of the number of wind turbines people see daily on their attitudes towards developing new wind farms in Denmark. They find that the more wind turbines people have in their neighbourhood, the more negative they are towards further development of onshore wind power. However, this is only true if people can see at least one of the wind turbines from their homes. Further, it seems that acceptability increases if the further development of onshore wind power happens through replacing smaller with larger turbines instead of installing a greater number of turbines. Hence, policymakers should consider both the number of turbines and their visibility from people's homes when developing strategies for future onshore wind implementation.

**Delicado, A., Junqueira, L., Fonseca, S., Truninger, M., Silva, L., Horta, A. and Figueiredo, E., 2014. Not in Anyone's Backyard? Civil Society Attitudes towards Wind Power at the National and Local Levels in Portugal. *Science & Technology Studies*, 27(2), pp. 49-71.**

In a rapidly growing literature on public acceptance of wind power, research on Southern Europe has been significantly underrepresented. This paper wants to explain the rapid growth of wind energy in Portugal by looking at citizens' and environmental NGOs' attitudes towards wind power on the national and local level, among other things. The authors find that a very attractive feed-in-tariff and strong centralised top-down planning have been success factors for wind power development in Portugal. Citizens and the environmental movement, however, were less positive towards wind power than publics in other European countries. Interestingly, the wind power success happened despite the not so favourable public attitude.

**Devine-Wright, P., 2009. Rethinking NIMBYism: The Role of Place Attachment and Place Identity in Explaining Place-protective Action. *Journal of Community & Applied Social Psychology*, 19, pp. 426-441.**

P. Devine-Wright is one of the most prominent representatives for a growing numbers of scholars who engage in critical discussions of the NIMBY (not in my backyard) concept. Public opposition to renewable energy projects is very often explained with NIMBY attitudes of people; that means, that they support renewable energy on a general basis, but oppose particular projects when developed in their neighbourhood. In this paper, the author uses insights from social and environmental psychology about place attachment and place identity to explain opposition to renewable energy projects. He argues that we should rethink NIMBYism as place-protective action. Instead of labelling public opposition as NIMBY, which often implies viewing the public as selfish, ignorant and irrational, policymakers should engage with people's emotional reactions to



changes in their environments as issues of place attachment and identity. The challenge for developers and policymakers is to design projects that are perceived as improving rather than disrupting places.

**Burningham, K., Barnett, J., and Walker, G., 2015. An Array of Deficits: Unpacking NIMBY Discourses in Wind Energy Developers' Conceptualizations of Their Local Opponents. *Society and Natural Resources*, 28 (3), pp. 246–260.**

A large number of studies has focused on local opposition to renewable energy, particularly wind power. However, a growing strand of research has argued that it is equally important to study other renewable energy actors, such as developers and policy-makers, and how they relate to and engage with the public. This paper analyses how wind power developers view local opposition. The authors find that developers thought about opponents as NIMBYs (NIMBY = Not In My Backyard), that is, that people in general are supportive of wind power development, but obstruct it in their neighbourhoods. Developers described these opposing publics as problematic, lacking knowledge, being selfish and irrational, and therefore opposing the wind project. The authors argue that this view of public in terms of deficits informs how developers engage with publics and hence, may also influence public responses. Viewing public opponents as NIMBYs may therefore act as self-fulfilling prophecy and lead to even more opposition.

**Heidenreich, S., 2015. Sublime technology and object of fear: offshore wind scientists assessing publics. *Environment and Planning A*, 47(5), pp. 1047–1062.**

This paper follows a similar approach as the previous one, and examines how offshore wind scientists construct the public(s). The development of offshore wind energy is often connected to expectations that the public will be positive about or at least indifferent to the technology. Because turbines are placed at sea—out of sight, out of mind—they are expected to avoid the public resistance experienced with respect to onshore installations. Although this narrative of a positive public was dominant among offshore wind scientists, the author finds a continued presence of narratives of irrational public resistance and construction of publics as NIMBY ('not in my backyard'). This deficit view of publics has possible implication for scientists' technology development and engagement with the public.

## 2.2. Energy citizenship

Energy citizenship related to low-carbon energy refers to people's active participation and engagement with energy technologies, projects, policymaking, decision-making etc. The first contribution in this subsection (Walker et al., 2011) presents a framework with four main characteristics, which researchers, policymakers and practitioners may consider in order to gain a better understanding of public engagement with renewable energy. A growing strand of energy-related Social Sciences and Humanities (SSH) research argues that transitions to low-carbon energy societies not only require passive public acceptance and support, but active participation of citizens, who are democratically engaged in transition processes. Devine-Wright (2007) introduces the term energy citizenship for this kind of public engagement. Rasch and Köhne (2016) support the claim empirically by showing that people's resistance against hydraulic fracturing was as much about negotiating citizenship and people's relation to the state, as it was about fracturing. However, as Sarrica et al. (2014) demonstrate, people are often addressed as passive energy consumers by politicians, developers and media, rather than as active energy citizens.

Many studies address the question of how to increase citizen engagement and motivate action towards low-carbon societies. Whitmarsh et al. (2011) argue, for example, that people's carbon capability needs to be increased. The contribution by Barrios-O'Neill and Schuitema (2016) discusses how online and interactive media can be used to engage citizens. Energy justice, which is discussed later in the bibliography (see subsection 2.5. 'Energy justice'), is also key for public engagement. Related to this is the issue of local knowledge. Christen and Hamman (2014), for example, show that participation processes that only were based on expert knowledge lead to social inequities.

The last three contributions in this subsection deal particularly with community energy projects and people's motivations to participate in these. Bauwens (2016) stresses that motivations to join in these projects are manifold. Hence, diverse policies are needed. The next contribution mentions financial benefits and



regional development as motivations for participation and emphasises that project implementation is more successful when involving bottom-up participation (Li et al., 2013). The last contribution deals with citizen participation in low carbon experiments and underlines that these experiments need to be successful in order to encourage public participation (Heiskanen et al., 2015).

**Walker, G., Devine-Wright, P., Barnett, J., Burningham, K., Cass, N., Devine-Wright, H., Speller, G., Barton, J., Evans, B., Heath, Y., Infield, D., Parks, J. and Theobald, K., 2011. Symmetries, expectations, dynamics, and contexts: A framework for understanding public engagement with renewable energy projects. In: Devine-Wright, P. ed. 2011. *Renewable Energy and the Public: From NIMBY to Participation*. London: Earthscan, pp. 1-14.**

The 13 authors of this book chapter introduce a novel framework for a better understanding of the development of renewable energy technologies (RET), which focuses on four dimensions. (1) 'Symmetry' refers to that we should look at both publics and RET actors (i.e. actors developing and promoting RETs) and the interactions between them. (2) 'Expectations' addresses the importance of understanding both the publics' and the RET actors' expectations of each other, of the technology, the project and the decision-making processes. These expectations shape public acceptance and engagement. (3) 'Dynamics' means that we should acknowledge that expectations and engagement change over time. (4) 'Contexts' emphasises the importance of the wider context of renewable energy projects such as policy and economy as well as the particularities of local communities, cultures and places. In addition, the other chapters in this book, a collection of international research on public engagement with RETs, provide a very useful overview of critical issues to consider when engaging publics in RET development with case studies about solar, wind hydrogen, marine, bio- and nuclear energy.

**Devine-Wright, P., 2007. Energy Citizenship: Psychological Aspects of Evolution in Sustainable Energy Technologies. In: J Murphy, ed. *Framing the Present, Shaping the Future: Contemporary Governance of Sustainable Technologies*. Earthscan, pp. 63-86.**

Drawing on the disciplines of Human Geography and Environmental Psychology, the author presents the concept of 'energy citizenship'. Contrary to the traditional understandings of users, energy citizenship stresses the hybrid relationships that people can have with energy (as users, consumers, protesters, supporters, prosumers etc.). Energy citizenship builds on a view of people as active participants to be democratically engaged in sustainable energy transitions. Energy citizenship is both about being aware of your responsibility related to climate change and energy transitions and about acting upon this awareness, e.g., through changing consumption patterns or supporting community renewable energy projects. The author argues that we need people to be active energy citizens in increasingly decentralised energy systems.

**Rasch, E.D. and Köhne, M., 2016. Hydraulic fracturing, energy transition and political engagement in the Netherlands: The energetics of citizenship. *Energy Research and Social Science*, 13, pp. 106-115.**

This paper deals with citizen engagement in the case of hydraulic fracturing in the Noordoostpolder in the Netherlands. The authors argue that new actors and new forms of citizenship are produced through processes of social mobilization and resistance towards fracking. They propose to view each site of energy transition as 'field of force' where citizens negotiate their role in decision-making. Citizens define their relation to the state through their resistance toward hydraulic fracturing. The resistance is as much about citizenship and negotiating who gets to decide on land use and energy as it is about the hydraulic fracturing itself.

**Sarrica, M., Brondi, S. and Cottone, P., 2014. Italian views on sustainable energy: Trends in the representations of energy, energy system, and user, 2009-2011. *Nature and Culture*, 9 (2), pp. 122-145.**

From the perspective of social psychology, the authors analyse Italian political debates and newspaper articles about sustainable energy from the years of 2009-2011. They were interested in how energy, energy systems, and users were represented. They find that citizens were represented as passive consumers of energy. In parliament, citizens were viewed as obstacles to top-down decisions. The idea of active energy citizenship and public participation was absent. Rather, politicians and other stakeholders considered it appropriate for citizens to stay passive.



**Whitmarsh, L., Seyfang, G. and O'Neill, S. 2011. Public engagement with carbon and climate change: To what extent is the public 'carbon capable'? *Global Environmental Change*, 21(1), pp. 56-65.**

Public engagement in climate change mitigation is undoubtedly necessary to meet targets for greenhouse gas emissions. In this paper, the authors aim to get a better understanding of people's motivation and ability to reduce carbon emissions. For that purpose, the authors combine psychological and sociological perspectives by using the concept of 'carbon capability'. Carbon capability relates to people's ability to make informed judgments and take decisions about the use and management of carbon. Based on their findings from a UK survey, the authors argue that people's carbon capability is too low and does not lead to active citizen engagement and actions towards low-carbon lifestyles. Policy should therefore focus on increasing public carbon capability in terms of (1) knowledge, skills, motivations, and judgments for decision-making, (2) individual behaviour and practices, and (3) broader engagement with carbon governance.

**Barrios-O'Neill, D. and Schuitema, G., 2016. Online engagement for sustainable energy projects: A systematic review and framework for Integration. *Renewable and Sustainable Energy Reviews*, 54, pp. 1611-1621.**

Extending the literature on public engagement with energy, this paper studies how the energy sector can engage people in sustainable energy projects through online and interactive media. The authors focus particularly on the challenges of online engagement and on solutions to these challenges. They propose a Socially Dynamic Communications Framework (SDCF), which addresses the identified challenges and proposes solutions. In general, the authors conclude that although challenges (such as lack of control, legal and ethical issues) exist, the potential of online engagement in combination with traditional public engagement is promising. It seems rather more risky for the energy sector, not to engage with people online.

**Christen, G., and Hamman, P., 2014. Des inégalités d'appropriation des enjeux énergétiques territoriaux? Analyse sociologique d'un instrument coopératif autour de l'éolien "citoyen". [Vertigo] *La revue électronique en sciences de l'environnement*, 14(3), [online] Available at: <http://www.erudit.org/en/journals/vertigo/2014-v14-n3-vertigo02337/1034925ar/abstract/> [Accessed on 24 May 2017]**

This article explores the means citizens have at their disposal to play a part in the production of sustainable energy. To do so, the authors performed a survey in a French rural area in Alsace, where a shareholding instrument for a 'citizen wind project' was implemented. Although the instrument aimed at reconciling the citizens with the wind technology, it could not prevent social inequities in the participatory process. These social inequities related to unequal exposure to environmental risks, unequal abilities to participate and different levels of knowledge. The authors insist on the fact that participatory processes based solely on expert knowledge rather than on local expertise are failing to consider and prevent the appearance of social inequities in the participatory process.

**Bauwens, T., 2016. Explaining the diversity of motivations behind community renewable energy. *Energy Policy*, 93, pp. 278-290.**

Community-based renewable energy (CRE) initiatives can be an important contribution to low carbon energy transitions. These are initiatives led by citizens with the aim of developing local collaborative solutions for renewable energy technologies. Based on two case studies from Flanders in Northern Belgium, this paper studies why citizens participate in CRE initiatives. The author finds that members of CRE projects have many different motivations to join and that they therefore should not be considered as one homogeneous group. Motivations to participate can be driven by norms or material incentives. The diversity of motivations can be explained (1) by differences between the CRE projects itself and whether they focus more on market or community aspects, (2) by spatial localization of the members of CRE, and (3) by different attitudes to institutional innovation, e.g., whether they belonged to the segment of early adopters. In general, norm-driven members of CRE projects are investing more and are more engaged in the governance of the initiatives. The author argues, therefore, that we need a policy mix that takes into account this diversity of motivations for participating in CRE initiatives. This would make policy making more complex, but also more effective. Particularly, a stronger focus on norm-driven motivations seems promising.



**Li, L.W., Birmele, J., Schaich, H. and Konold, W., 2013. Transitioning to Community-owned Renewable Energy: Lessons from Germany. *Procedia Environmental Sciences*, 17, pp. 719–728.**

This paper investigates success factors for implementing community-owned renewable energy projects. Based on a case study of Freiamt in Germany, the authors analysed the motivations of the different stakeholders to participate and invest in community renewable energy projects. They find that residents were mainly motivated by financial benefits and an expected improvement on regional development while climate change mitigation played a smaller role. Further, they emphasise the importance of bottom-up approaches and community participation in planning processes for a successful implementation.

**Heiskanen, E., Jalas, M., Rinkinen, J. and Tainio, P., 2015. The local community as a “low-carbon lab”: Promises and perils. *Environmental Innovation and Societal Transitions*, 14, pp. 149–164.**

On the way towards a low-carbon society, local experiments provide an arena where we can learn about the use and deployment of emerging sustainable technologies. Based on a Finnish case study of a ‘low carbon lab’ municipality, this paper studies how local citizens involved in such experiments experience these. The authors find that local citizens evaluate sustainability experiments differently from technologists. Technologists view experiments mainly as learning arena where both success and failure provides important insight. By contrast, it seemed critical for participating citizens that low carbon experiments were successful and achieved concrete results, in order to maintain investments and participation in climate action. In order not to discourage citizen engagement with low carbon technologies, the authors argue that local experiments should not be too risky. Rather, they could provide an arena for learning about the deployment and adaptation of market-ready low carbon technologies.

### 2.3. Consumers and prosumers

Energy use within the home and setting of everyday life is a coveted place of inquiry for Social Science and Humanities (SSH) researchers. The inner workings of the way energy gets used by people, embroiled as they are in everyday activities, tend to be elusive and poorly understood. At the same time, there is a distinct sense of change potential in this part of the energy system. Proponents of this system change argue that behaviour must change or that technology that can make energy consumption less irrational should be implemented.

This subsection constitutes in many respects a critique of such approaches, and its contributors seek to expand our understanding of everyday energy use as something more than consumption itself. For instance, when scholars open up the ‘black box’ of household energy consumption by studying users’ attitudes towards energy use, they often find that it is just a small part of what constitutes ‘doing’ a home. In fact, several of the contributors in this subsection urge us to think about energy use more as part of a greater ‘doing’, as they advocate for a practice theory approach (Palm and Darby, 2014; Shove, 2003; Wilhite et al., 2000). These contributions make clear that energy use itself is not often something users consciously engage in. Rather, the activities that take place have such necessary aims as cleanliness or comfort, and the consequent energy use is but a side effect of these.

Another approach to the problem of individual user behaviour is provided by Schot et al. (2016), who emphasise the energy users’ relationship with the larger energy system. Both these aspects must be kept in mind by decision makers, such as architects (Janda, 2011) or policy makers seeking both to make changes at places of future consumption as well as measuring their impact after the fact. Realising that energy use is a convoluted aspect of everyday life creates the need for new ways of engaging users about this issue. One such approach involves including the whole neighbourhood or community, as users are better approached as citizens rather than consumers in order to create engagement (Heiskanen et al., 2010).

The rest of this subsection is dedicated to what we call the ‘prosumer’, an agent we get when combining consumption of energy with production. A good introduction to the concept is found in the literature review conducted by Ellsworth-Krebs and Reid (2016). Similarly, Olkkonen et al. (2016) review the concept and examine particularly how the roles of different stakeholders may change with the coming of the prosumer. Parag and Sovacool (2016) explore the possibilities of changing markets due to the rise of the prosumer.



Finally, Ritzer (2015) provides a critical look at automated prosumption, and the risks of backgrounding the users with the use of automation.

**Palm, J. and Darby, S. J., 2014. The Meanings of Practices for Energy Consumption – a Comparison of Homes and Workplaces. *Science & Technology Studies*, 27(2), pp. 72–92.**

This paper takes a look at the practices of being in a building, and compares the settings of home and work through passive housing and a modern research lab. The goal was finding out more about what sustainable practices entail through interviewing and observing people at home and in the work setting. The analysis uses practice theory to uncover how practices are influenced by the buildings we are in and the technologies within them. Passive houses contribute to sustainable practices, but the workspace offered challenges to this.

**Shove, E., 2003. Users, technologies and expectations of comfort, cleanliness and convenience. *Innovation: The European Journal of Social Science Research*, 16(2), pp. 193–206.**

Inclusive design is often argued to be of decisive importance to reach sustainability goals. A leading practice theorist, Shove argues against this common preconception in favour a more holistic view of how people and their practices, related as they are to everyday ambitions of achieving for instance comfort or cleanliness, should take centre stage. She argues that it is more important to re-specify practices, rather than designing technology to meet conventions of practice, which are taken for granted.

**Wilhite, H., Shove, E., Lutzenhiser, L. and Kempton, W., 2000. The Legacy of Twenty Years of Energy Demand Management: we know more about Individual Behaviour but next to Nothing about Demand. *Society, Behaviour, and Climate Change Mitigation. Volume 8 of the series Advances in Global Change Research*, pp. 109–126.**

Since the 1980s, we have been widely concerned with energy conservation, but consumption in the western world has only increased. The authors of this paper argue that this is due to a focus in Social Sciences on the behaviour of end users. The authors suggest a reframing of energy consumption towards an understanding of energy use as a social demand, i.e. one that is connected with social norms and institutions. This brings about a realisation that energy use is not an end in itself, but a means.

**Schot, J., Kanger, L. and Verbong, G., 2016. The roles of users in shaping transitions to new energy systems. *Nature Energy*, 1 [online], Article number: 16054. Available at: <https://www.nature.com/articles/nenergy201654> [Accessed on 24 May 2017]**

A staple theory of the understanding of people in markets posit them as rational, and thus responsive to information and economic incentives. However, as one will quickly realise, this idea of consumers as making nothing but rational and conscious decisions is flawed. From a different school than practice theorists, these scholars nevertheless aim to understand users more as they are, embedded in, what is called, socio-technical systems and governed by routines shared by their peers.

**Janda, K. B., 2011. Buildings don't use energy: people do. *Architectural Science Review*, 54(1), pp. 15–22.**

While architectural design is necessary to achieve energy reduction in the built environment, this paper argues that it is not enough. As the title aptly emphasises, the energy use ascribed to buildings do not arise from the buildings themselves. The author argues it is necessary to include users in when designing buildings, but also that someone must take responsibility for public education of building literacy. Architects are noted as being in a suitable position for this task.

**Heiskanen, E., Johnson, M., Robinson, S., Vadovics, E. and Saastamoinen, M., 2010. Low-carbon communities as a context for individual behavioural change. *Energy Policy*, 38(12), pp. 7586–7595.**

This article discusses the influence of communities on individual behaviour. It is recommended that energy users be approached in their role of citizens rather than just consumers. The researchers analyse different types of communities and the way they offer solutions to problems involving behaviour change. They offer recommendations regarding the design and support of communities.



**Ellsworth-Krebs, K. and Reid, L., 2016. Conceptualising energy prosumption: Exploring energy production, consumption and microgeneration in Scotland, UK. *Environment and Planning A*, 48, pp. 1988–2005.**

In the last decade or so, the concept of the prosumer has become more prominent within the discourse of energy consumption. It means quite simply that someone who is basically a consumer takes care of some of their consumption demand themselves by producing. This can entail having solar photovoltaic (PV) on their roof, but also for instance chopping wood. Arguing a wanting conceptual foundation for the term, this paper takes a comprehensive look at the prosumer literature as well as presenting data from interview with 28 UK households involved with microgeneration.

**Olkkonen, L., Korjonen-Kuusipuro, K. and Grönberg, I., (in press). Redefining a stakeholder relation: Finnish energy “prosumers” as co-producers. *Environmental Innovation and Societal Transitions*.**

This paper also takes a closer look at prosumers, but in the context of energy companies, their business models and their operating environment. The authors have interviewed energy company representatives as well as having interviewed and observed solar panel users. The findings indicate that relationships between users and energy companies are changing, but that issues take precedence over organisation. Furthermore, prosumers are more vocal of their demands and seem to structure relationships to companies toward more reciprocity.

**Parag, Y. and Sovacool, B.K., 2016. Electricity market design for the prosumer era. *Nature Energy*, 1 [online], Article number: 16032. Available at: <https://www.nature.com/articles/nenergy201632> [Accessed on 24 May 2017]**

The changing relationships between customers and energy business is the topic in this paper as well, as the authors explore how prosumers may be integrated into the energy system in the future. Three possible market models are presented: a peer-to-peer model, where individuals trade amongst themselves; a prosumer-to-grid model, where the integration of numerous individuals are optimised into the system, and; organised prosumer groups, a model that integrates already organised groups of prosumers instead of individuals.

**Ritzer, G., 2015. Automating prosumption: The decline of the prosumer and the rise of the prosuming machines. *Journal of Consumer Culture*, 15, pp. 407–424.**

This paper also takes a look at prosumption, although not with energy per se. He takes issue with the fact that automated machines to a greater degree are displacing the importance of human prosumers. The paper presents some examples of what these machines do, and finds that often humans are no longer aware that prosumption is going on. This trend, the author argues, is only increasing, especially with the rise of the Internet of Things. The author questions the wisdom of making ourselves dependent on ever more autonomous technological systems.

## 2.4. Ethics and religion

Ethical and religious considerations play an often neglected role for public acceptance and public engagement with low-carbon energy transitions. In this subsection, we present a currently underrepresented area of research, which deals with ethics and religion related to energy. Several disciplinary perspectives contribute to this area of research, for example, Philosophy, Ethics, Religious studies, Theology, Anthropology and Science and Technology Studies.

The first group of contributions in the list below discusses energy transitions and the specific roles ethics and religion can play in these transitions. A common argument is that policymakers should engage with the ethics of energy transitions because of the social, political and economic consequences of these change processes (Miller, 2014). They should also look for the potential contribution from religion to energy transitions, such as material and human resources, values and traditions supporting sustainability, influence in the public sphere and moral leadership (Rasmussen, 2011; Köhrsen, 2015; Lothes Biviano et al., 2016).

Another area of research addresses the ethical and religious issues related to particular energy technologies and sources. Nuclear power is most prominent in these discussions (Taebi et al., 2012; Bergen, 2016;



Hillerbrand and Peterson, 2014). But also the research on bioenergy and the ethical challenges related to its governance (Gamborg et al., 2014) and the role of religious belief for public attitudes towards carbon capture and storage (Hope and Jones, 2014) fall into this category of research. In general, this area of research calls for more nuanced debates about energy technologies with more attention to values, emotions and concerns.

The last contribution in this subsection presents a criticism of Energy Economics, market liberalism and the idea of energy as commodity and proposes based on ancient religious wisdom to view energy as gift; a view, which would lead to more sustainability. This relates also to section 3. '[Markets of competitive, secure, low-carbon energy supply](#)'.

**Miller, C., 2014. The ethics of energy transitions. In 2014 IEEE International Symposium on Ethics in Science, Technology and Engineering, ETHICS 2014., 6893445, Institute of Electrical and Electronics Engineers Inc., Chicago, United States, 23–24 May.**

The main argument of this paper is that ethics should be an important element of energy transition management. Energy transitions influence not only energy production but have wider social, economic and political consequences. They entail a redistribution of power, wealth, risk, vulnerability etc. Therefore, policymakers, energy engineers and business should engage with the ethics of energy transitions. The author proposes that this can be done by: (1) Developing ethics criteria for transition outcomes, (2) Ensuring that human and social dimensions are considered in energy system design, (3) Including social outcomes in life cycle assessments, and (4) Creating strategic, open-ended, participatory energy planning.

**Rasmussen, L. L., 2011. Energy: The Challenges to and from Religion, *Zygon*, 46(4), pp. 985–1002.**

In this essay, the author discusses the contributions, which religions and interfaith religious values may have for energy transitions. First, religions have considerable material resources and a huge presence in that 85 percent of the world's population possesses a faith. Second, religions have extensive experience dealing with death and renewal. Third, religions have an important role for public sense making. They give meaning to people's lives and experiences of nature and the world through symbols and rituals. Fourth, there are traditions and values shared by almost all religions, which may support energy transitions. Asceticism, e.g., promotes a simple life contrary to nowadays energy-intensive consumerism. Sacramentalism contrasts modernity's commoditization of all things by extending their value beyond merely economic value. Mysticism works against a human/nature dualism. Prophetic-liberative traditions focus on justice and engage against poverty, inequality and environmental degradation. Finally, the wisdom traditions emphasise moderation and the common good, including energy. Hence, policymakers should also look towards religions and their potential contributions to low carbon energy transitions.

**Köhrsen, J., 2015. Does Religion Promote Environmental Sustainability? – Exploring the Role of Religion in Local Energy Transitions. *Social Compass*, 62(3), pp. 296–310.**

Combining the academic perspectives from the fields of 'Sustainability Transitions' and 'Religion and Ecology', the paper explores how religion can contribute to local energy transitions. Religion may have different functions: showing presence and influencing the public sphere, participating in sustainability projects, and disseminating worldviews and values that support sustainable practices. Contrary to earlier studies, which often highlight the role of religion for sustainability transitions, this paper finds that religion played a minor role compared to other societal actors.

**Lothes Biviano, E., Cloutier, D., Padilla, E., Peppard, C. Z. and Schaefer, J., 2016. Catholic Moral Traditions and Energy Ethics for the Twenty-First Century. *Journal of Moral Theology*, 5(1), pp. 1–36.**

This essay is a contribution from scholars of Catholic Theology, Catholic Social Teaching and Environmental Ethics. Arguing that energy is not only an economic or technological, but also an ethical issue, the authors discuss the potential contribution of Catholic teaching and moral traditions to energy transitions. An energy ethic focusing on justice and global solidarity with people and the environment could inform energy policy. Further, it could enable the Catholic Church to take a moral leadership role, for example, in support of a rapid transition from fossil fuels to renewable energy technologies.



**Taebi, B., Roeser S., and van de Poel, I., 2012. The ethics of nuclear power: Social experiments, intergenerational justice, and emotions. *Energy Policy*, 51, pp. 202–206.**

Either you are for or against! The authors of this paper argue that we need to move beyond the 'usual stalemate' in the debate about nuclear power of either absolutely rejecting or accepting it. This could be done by expanding risk assessment with discussions of the moral acceptability and intergenerational justice of nuclear energy. Further, emotions should be taken more seriously in debates instead of dismissing them as irrational. Through viewing the introduction of nuclear energy as social experiment, the debate would focus more on the conditions under which nuclear energy would be acceptable for society and on the important ethical questions related to that. Such an open debate is important as basis for policy-making on nuclear energy.

**Bergen, J. P., 2016. Reversible Experiments: Putting Geological Disposal to the Test. *Science and Engineering Ethics*, 22, pp. 707–733.**

The idea of viewing nuclear energy as social experiment presented in the previous paper is received with criticism by the author of this paper. He argues that if we want to consider a technology an experiment it should be reversible. That means that it must be possible to stop the technology's development and implementation and reverse its negative consequences. Taking geological disposal of high-level radioactive waste (GD) as example, he concludes that GD is not a reversible technology for radioactive waste management. Hence, responsible experimentation with nuclear power should involve considering its reversibility in the design of the technology by developing strategies to undo negative consequences and in terms of keeping alternative solutions to GD alive.

**Hillerbrand, R. and Peterson, M., 2014. Nuclear Power is Neither Right nor Wrong: The Case for a *Tertium Datur* in the Ethics of Technology. *Science & Engineering Ethics*, 20, pp. 583–595.**

Coming from the fields of Ethics and Philosophy, the authors argue that we should not view nuclear power as either entirely right or entirely wrong. They also claim that we should not evaluate single energy technologies, but whole energy scenarios, in order to reach an informed moral judgement. The authors claim that this will contribute to a more nuanced and less polarised public debate over nuclear power.

**Gamborg C., Anker, H.T. and Sandøe, P., 2014. Ethical and legal challenges in bioenergy governance: Coping with value disagreement and regulatory complexity. *Energy Policy*, 69, pp. 326–333.**

This paper presents an analysis of - what the authors call - the current stalemate on bioenergy governance in the EU. The authors argue from an ethical and legal perspective that bioenergy governance should be more open and transparent regarding two issues: (1) the disagreements about underlying values and concerns, and (2) the regulatory complexity of bioenergy governance. This will lead to a better governance.

**Hope, A.L.B. and Jones, C.R., 2014. The impact of religious faith on attitudes to environmental issues and Carbon Capture and Storage (CCS) technologies: A mixed methods study. *Technology in Society*, 38, pp. 48–59.**

This study investigates how religious beliefs impact environmental values and attitudes to Carbon Capture and Storage. Muslim, Christian and Secular informants participated in the study. All three groups expressed pro-environmental concerns, but for different reasons. Muslims and Christians referred to divine creation, emphasizing intergenerational justice and the God given responsibility of environmental stewardship. However, the belief on an afterlife influenced the sense of urgency related to climate and environmental problems. Muslims were more negative towards CCS than the other groups because it disrupts natural balance and is problematic according to teachings on stewardship and intergenerational justice. The secular participants were more concerned about environmental problems and had a greater sense of urgency since they did not believe in divine intervention or an afterlife. They focused on the responsibility of humans to act fast to reduce CO<sub>2</sub> emissions.

**Bergmann, S., 2015. Energy as Gift or Commodity? About the Ambivalence of Growth, Market and Technology in the Times of Climatic Change. In: *Religion, Space, and the Environment*, New Brunswick and London: Transaction, pp. 315–322**

Combining perspectives from the Anthropology of Religion and Ecological Phenomenology, the author presents a criticism of Energy Economics for missing out on many aspects, such as risks, limits of energy



or the natural processes (such as the development of oil and gas deposits) that makes nowadays energy production possible in the first place. He argues that we in alignment with ancient wisdom of many religions should think of energy as 'gift' and as 'common good' rather than as 'commodity'. This thinking would lead to more sustainability since it takes into account ecological and social values. A liberalised market, however, where energy is considered a 'commodity', leads to energy becoming a tool for power and dominance, and does not contribute to sustainability.

## 2.5. Energy justice

The concept of 'energy justice' introduces the idea of a fair sharing of benefits and burdens related to energy services and decision-making processes. It identifies when, where and how injustices occur and how they can be eliminated. The literature listed below provides a general idea of energy justice, the definition and tenets of the concept, and recommendations for achieving energy justice in transitions to low-carbon societies.

Energy justice has three tenets: distributional justice, recognition justice and procedural justice. Distributional justice concerns the physically uneven distribution of energy services and responsibilities and it specifies how benefits and burdens are shared. Recognition justice deals with failure to recognise or with misrecognition, which means that ignored or misrepresented parts of the society should be identified and that differences such as social, cultural, gender etc. should be eliminated. The last tenet is procedural justice, which focuses on fairness of decision-making processes. It asserts that all stakeholders should be treated justly; they should be informed well and take part in the processes through open decision-making (Jenkins et al., 2016; Heffron et al., 2015).

Energy justice is a rather new research topic, and not much literature has been published so far. Heffron and McCauley (2014), for example, examine the impact of the three tenets of energy justice on energy supply and energy security. Fuller and McCauley (2016) focus on filtering energy issues from climate justice and environmental justice contexts and its importance on social mobilisation for energy transitions. Energy justice, then, contributes to frame and increase activism and advocacy in the transitions. Chatterton and colleagues (2016) consider the disparities in household energy consumption and highlight the related energy justice issues. Yenetti and Day (2016) focus on the potential damage of large-scale renewable investments on communities if energy injustice issue is ignored. Reames (2016) approaches the energy justice issue by considering spatial, racial/ethnic, and socioeconomic characteristics. From a geographical perspective, McCauley and colleagues (2016) examine the problems related to Arctic resource explorations and suggest the replacement of current energy policy with an energy justice centred approach. Energy justice related to wind power is also investigated, with particular focus on distributional justice (Liljenfeldt and Pettersson, 2017) and on procedural justice (Simcock, 2016).

SHAPE ENERGY will also issue a cross-cutting theme report with a more detailed discussion of the concept of energy justice and recommendations for how to address energy justice in energy projects.

**Jenkins, K., McCauley, D., Heffron, R., Stephan, H., and Rehner, R., 2016. Energy justice: A conceptual review. *Energy Research & Social Science*, 11, pp. 174–182.**

In this review, the authors focus on the three tenets of energy justice, which are distributional justice, recognition justice and procedural justice. In addition, they offer a whole system approach in which energy policy needs to address the unequal distribution of ill, subsidies, pricing and consumption indicators (e.g. smart meters) within the context of local and global pressure. Therefore, the energy justice concept can contribute to providing a global account of energy's social, economic and environmental impacts.

**Heffron, R.J., and McCauley, D., 2014. Achieving sustainable supply chains through energy justice. *Applied Energy*, 123, pp. 435–437.**

This paper examines the relationship between energy justice, supply and security. The three tenets of energy justice are considered to have an impact on the growth of industry supply chain. The wind energy sector in Denmark is used for demonstration.



**Heffron, R. J., McCauley, D. and Sovacool, B. K., 2015. Resolving society's energy trilemma through the Energy Justice Metric. *Energy Policy*, 87 pp. 168–176.**

The authors focus on three tenets of energy justice and this is the first study that adds quantitative analysis to the energy justice literature. They introduce an energy justice metric (EJM) for China, the US and the EU and also a EJM for UK energy sources. The energy justice metric can be a solution to the energy trilemma, a concept demonstrating the difficulty of balancing the competing concerns of the economic, political and environmental challenges related to energy systems; it should be secure, affordable and sustainable.

**Fuller, S., and McCauley, D., 2016. Framing energy justice: perspectives from activism and advocacy. *Energy Research & Social Science*, 11, pp. 1–8.**

This study considers how activists and advocacy organisations frame and interpret energy justice. The authors use two related analytical perspectives. One of them is boundary framing, which considers what is effectively inside and outside a given frame. The other one, normative claims, focuses on how problems should be approached and solutions developed. Their research examines environmentally oriented organisations in three cities: Berlin, Paris and Philadelphia. Based on their findings, the authors emphasise the need for more research on the issue of energy justice.

**McCauley, D., Heffron, R., Pavlenko, M., Rehner, R. and Holmes, R., 2016. Energy justice in the Arctic: Implications for energy infrastructural development in the Arctic. *Energy Research and Social Science*, 16, pp. 141–146.**

The paper attempts to identify injustices in the energy infrastructural development in the Arctic region. The authors examine the justice claims made by business, government and civil societies. They suggest a replacement of the current stakeholder-centred approach of energy policy with a more energy justice centred approach.

**Yenneti, K., and Day, R., 2016. Distributional justice in solar energy implementation in India: The case of Charanka solar park. *Journal of Rural Studies*, 46, pp. 35–46.**

Distributional justice is an important issue, particularly related to large-scale renewable energy development. This paper examines a large solar park in India and the related distributional concerns. The authors look at the distribution of benefits and burdens for different groups such as village communities, business developers, and state government. They observe that most benefits stay at the regional and national level. Further, the upper caste of the community benefited. By contrast, the lowest strata of the community's basic needs have been endangered and their capability sets have been decreased.

**Reames, T. G., 2016. Targeting energy justice: Exploring spatial, racial/ethnic and socioeconomic disparities in urban residential heating energy efficiency. *Energy Policy*, 97, pp. 549–558.**

This paper studies energy justice in relation to fuel poverty. Heating energy use intensity (EUI) is used as a proxy for energy efficiency and higher EUI indicates relatively less energy efficiency. The findings demonstrate that block groups with lower median incomes, a greater percentage of households of racial/ethnic minority headed households and a larger percentage of the population with less than high school education experienced higher mean heating EUIs and hence less energy efficiency. Using the EUI indicator can therefore direct energy efficiency interventions.

**Liljenfeldt, J. and Pettersson, Ö., 2017. Distributional justice in Swedish wind power development – An odds ratio analysis of windmill localization and local residents' socio-economic characteristics. *Energy Policy*, 105, pp. 648–657.**

Energy justice, and in particular distributional justice, has increasingly become an important issue in wind power development in Sweden. This paper examines the energy justice issues related to the siting of wind power plants. One motivation for the research is to investigate whether it is easier to build windmills in economically marginalised communities, as some earlier research indicated. Hence, the authors carried out an analysis about the relation of people's rejection or approval of wind turbines to socio-economic characteristics. They find that the rejection rate is higher in areas with more highly educated people than in areas with more unemployed people. The authors conclude that the observed inequities require further attention by policymakers and wind power developers.



**Simcock, N., 2016. Procedural justice and the implementation of community wind energy projects: A case study from South Yorkshire, UK. *Land Use Policy*, 59, pp. 467–477.**

With a case study on a community wind project in South Yorkshire, this paper studies how stakeholders interpreted procedural justice. There were many different opinions on the projects in terms of procedural justice. According to the author, these differences can be explained by two factors: (1) People had different expectations of procedural justice and what it actually means, and (2) These expectations were reinforced by contrasting experiences of the implementation process. Hence, also community wind projects can be experienced as unjust by parts of the local community.



### 3. Markets for competitive, secure, low-carbon energy supply

This section on markets for competitive, secure, low-carbon energy focuses particularly on the 'competitiveness' dimension of low-carbon energy transitions. Social Sciences and Humanities (SSH) research on markets is dominated by Economics, which also is the discipline within energy-SSH that has had the most significant influence on energy policy formation. Economics has also had most impact, in terms of citations, in the academic world. The first two subsections of this section compile non-economic energy-SSH related to markets. Subsection 3.1. 'Innovation and R&D' looks at how market actors can drive innovation for a low-carbon transition and how to create favourable conditions for innovative technological solutions. The importance of learning gets particular attention in this subsection. Subsection 3.2. 'Commercialization, industry and business' deals with how already established actors can reshape themselves to contribute to solutions for low-carbon transitions. The last two subsections demonstrate the above-mentioned dominance of Economics. Subsection 3.3. 'Energy markets' looks, among other issues, at the regulation of markets in order to facilitate competitiveness and sustainability. Further, the subsection addresses particular economic policies. As an important aspect of the research on energy markets, Subsection 3.4. 'Energy prices' pays particular attention to the literature on pricing and prices.

#### 3.1. Innovation and R&D

The energy system and its transition towards one that is more sustainable will have to rely on the concerted efforts of many different actors. These actors need favourable conditions in order to have the ability to innovate solutions, which may aid the transition toward a low-carbon energy system. Often, this will have to mean greater scales of cooperation. This is made clear in a proposition by Brook et al. (2016), who argue that in order to promote innovation in this area and avoid political impasse, stakeholders from industry and research should be included in a framework within the United Nations Framework Convention of Climate Change (UNFCCC). The argument goes that putting these forces together will allow them to learn together and co-produce robust solutions.

A large amount of the Social Sciences and Humanities (SSH) research on the role of industry and markets in low-carbon transitions deal with different concepts of learning. Garud and Karnøe (2003) introduce the concepts of 'bricolage' and 'breakthrough' to address how emerging technology paths are shaped by the distributed agency of many actors. Similarly, Karnøe and Garud (2013) examine how competency regarding wind-turbine development was reliant on multiple, simultaneous learning processes; implying innovation policy should not envisage linear paths towards low-carbon energy supply. Additionally, Neij et al. (2017), through an example on solar photovoltaics (PV) deployment, emphasise the importance of learning being locally anchored. Along similar lines, Sørensen (2013) criticises the conceptual straight line between innovation and deployment by looking at the social aspect of technology development. Heiskanen et al. (2015) look closer at local levels of learning as well, aided by the help of the strategic niche management perspective, a view that argues for the need for protective spaces when developing new technology. In addition, local and cultural peculiarities may have an impact on how innovation cycles are able to share information, as evidenced by the contribution of Sovacool (2010). However, how can innovation come about in the first place?

Fuchs (2014) explores how external shocks, like large nuclear disasters, affect power balances in energy sector governance, leading to new thinking and commitment to new strategies. In a less dramatic vein, Levidow et al. (2013) showcase the role of government support measures in the UK for developing biogas alternatives, and Kostakis et al. (2013) return to the local context, as collaboration with Commons-oriented communities using peer-produced products and tools give rise to complex projects.

**Brook, B., Edney, K., Hillerbrand, R. and Karlsson, R., 2016. Energy research within the UNFCCC: a proposal to guard against ongoing climate-deadlock. *Climate Policy*, 16(6), pp. 803-813.**

The United Nations Framework Convention on Climate Change (UNFCCC) negotiation process is a global effort to decarbonise our economy, but still struggles with the risk of political impasse. Admitting that the alternatives for innovative decarbonisation is resource consuming, this paper proposes that an international



'Low-Emissions Technology Commitment' should be incorporated into the existing UN framework to coordinate work and effectively distribute the load of abatement cost.

**Garud, R. and Karnøe, P., 2003. Bricolage versus breakthrough: distributed and embedded agency in technology entrepreneurship. *Research Policy*, 32(2), pp. 277–300.**

The authors have explored wind turbine development in Denmark and in the United States, and discovered two disparate ways of doing such projects in terms of how agency is distributed within processes. The findings implicate that one kind of project, which is quite common, namely the resource heavy and carefully planned approach geared toward achieving "breakthrough", might in fact be inferior to a more 'organic' method, which the authors call the 'bricolage' approach. This is initially a bottom-up approach driven by actors with local knowledge.

**Karnøe, P. and Garud, R., 2013. Path Creation: Co-creation of Heterogeneous Resources in the Emergence of the Danish Wind Turbine Cluster. *European Planning Studies*, 20(5), pp. 733–752.**

The authors explore the concept of path creation through the study of a Danish wind turbine cluster. They describe the inner workings of this rather successful cluster as developed through the co-creation of multiple learning processes in which many different actors come together such as competencies, regulations, users and markets. This implies public policy aimed at catalysing similar projects should not presuppose they unfold in a linear fashion.

**Neij, L., Heiskanen, E. and Strupeit, L., 2017. The deployment of new energy technologies and the need for local learning. *Energy Policy*, 101, pp. 274–283.**

A common concern within the innovation literature when it deals with the deployment of technology is the issue of learning. This paper looks at the deployment of solar photovoltaics (PV) among end users, and based on literature reviews and empirical evidence from the field, implicate the importance of local, tacit knowledge – the kind of learning often derived simply from doing. This implies the importance of local learning for the policy makers.

**Sørensen, K.H., 2013. Beyond Innovation. Towards an extended framework for analysing technology policy. *Nordic Journal of Science and Technology Studies*, 1(1), pp. 12–23.**

One of the main criticisms brought to bear on innovation research and policy by SSH scholars is that it conceptualised in a linear way, which belies its often-complex nature. This paper introduces the concepts of socialisation and domestication as a way to describe how actors incorporate knowledge and technology into the already ongoing activities in society. It does this by applying it to four examples of policy and technology development.

**Heiskanen, E., Nissilä, H. and Lovio, R., 2015. Demonstration buildings as protected spaces for emerging sustainable solutions – the case of solar building integration in Finland. *Journal of Cleaner Production*, 109, pp. 347–356.**

Within strategic niche management theory, which this paper draws on, the idea is that for innovative technologies there can exist a window of opportunity for it to gain solid foothold in markets. This means that facilitators can act in order to open or stabilise such windows. This paper reports from the use of demonstration buildings as leverage for windows of opportunity for solar panels, and offer implications for the use of demo projects to provide continuity for niche technology.

**Sovacool, B. K., 2010. The importance of open and closed styles of energy research. *Social Studies of Science*, 40(6), pp. 903–930.**

Drawing on evidence from six different countries, this paper deals with differences in 'research style' across six different national contexts. It finds that research styles can be distinguished on the basis of whether they are open or closed. The former, which is exemplified by Denmark, Brazil and China, has a high level of inclusion, shared ownership of results, and cooperation. The closed variant, which are found in Norway, USA and France exhibit limited access, competition and rigid centralization.



**Fuchs, G., 2014. The Governance of Innovations in the Energy Sector: Between Adaptation and Exploration. *Science & Technology Studies*, 27(1), pp. 34-53.**

Large technical systems, like that of the electricity system, is often characterised by slow evolution and resistance to change. In the last decades, this is exemplified by the fact that the changes that have happened have been due to extreme external challenges, like the meltdown of nuclear power plants. The paper argues that rather than having a direct impact, such events are cause for a shift in power balance and skilfully interpreted by new actors in the governance structure of the established regimes.

**Levidow, L., Papaioannou, T. and Borda-Rodriguez, A., 2013. Innovation Priorities for UK Bioenergy: Technological Expectations within Path Dependence. *Science & Technology Studies*, 26(3), pp. 14-36.**

This paper looks at the bioenergy commitment of the UK, which has become stronger this last decade. The authors note that the government, eager to displace more fossil intensive resources, have spurred much development within industry with the help of subsidies. However, the authors note that given the states close involvement, its expectations for benefits shape the innovation process such that it results in mostly input-substitutes rather than wider infrastructural innovation.

**Kostakis, V., Fountouklis, M. and Drechsler, W., 2013. Peer production and desktop manufacturing. The Case of the Helix\_T Wind Turbine Project. *Science, Technology, & Human Values*, 38(6), pp. 773-800.**

The topic of this paper is the use of Commons-based peer production, which the authors argue can contribute towards making novel solutions for a wider distribution of renewable energy sources in small scale. In this case, the authors base their insights on a project, which created a locally self-produced wind turbine for the low-cost residential market. This implies that it is possible for individuals based on interest and community participation and some local production capacity, like a 3D-printer, to engage in complex innovation projects.

### 3.2. Commercialisation, industry and business

This subsection also deals with innovation, but where the last part dealt with how market actors can drive innovation for a low-carbon transition, this subsection deals with how already established actors can reshape themselves and their already ongoing processes in order to contribute to the solution, in particular through the deployment of new kinds of business models. For instance, Apajalahti et al. (2017) look at how organisations shape the fate of emerging technology fields when they bring their incumbency to bear on them. Similar to the contribution by Brook et al. (2016) in the previous subsection, Andrade and de Oliveira (2015) argue for the necessity of including the private sector in a United Nations framework, but warn that industry self-interest must be dealt with.

Several approaches in this subsection argue that firms can actually increase their value when making themselves eco-friendly and allocating resources to participating in a transition to a low-carbon economy (Al-Najjar and Anfiadiou, 2012; Foxon, 2011). Still, Hahn et al. (2010) emphasise the importance for firms to keep an eye on trade-offs related to such activity. Mekhilef et al. (2011) and Karlsson et al. (2016) provide case studies where new business models for creating low-carbon solutions have proven successful, within solar energy use and agricultural biogas production respectively. Another important development within aspects related to how industry can reshape itself to cater to the low-carbon economy is the provision of energy services, of which Boons et al. (2013) provide a review, and Kindstrom et al. (2017) provide two case studies. Finally, Lund (2009) investigates the impacts of energy policies on industry growth in renewable energy, indicating that even small countries can gain success through clever policies for supporting new business models.

**Apajalahti, E-L., Temmes, A. and Lempiälä, T., 2017. Incumbent organisations shaping emerging technological fields: cases of solar photovoltaic and electric vehicle charging. *Technology Analysis & Strategic Management Journal*, February 2017, pp. 1-14.**

This paper draws from innovation studies to examine how so called incumbents, or already established firms, shape the emerging technological fields of solar energy and electric vehicles. Based on longitudinal



case studies, the paper discusses how the firms engage with and impact these fields. This is shown to be happening more than previously thought, and is also shown to benefit the companies who engage in it as they bend the fields to preserve their relevance.

**Andrade, J. C. S. and de Oliveira, J. A. P., 2015. The role of the private sector in Global Climate and Energy Governance. *Journal of Business Ethics*, 130, pp. 375–387.**

The authors scrutinise the discrepancy between the role the private sector plays in making climate change mitigation happen, and the limited direct role they play in international arenas where negotiations of such solutions are taking place. Identifying business as an intrinsic 'rule maker' and the many voluntary regimes which exist, the paper argues for a stronger role of businesses in the global decision-making arena - but that this must take into account the often present selfish nature of private influence.

**Al-Najjar, B. and Anfimiadou, A., 2012. Environmental Policies and Firm Value. *Business Strategy and the Environment*, 21(1), pp. 49–59.**

As businesses are given the onus of reducing their impact on the environment, it is steadily becoming part and parcel of business strategy. This paper looks at the supposed mutual exclusion of the two motivations of making money and reducing environmental impact, and find that it is not so. In fact, in a review of firm value in the UK from 1999–2008 which this paper presents, businesses who engage in eco-friendly behaviour show increased efficiency and excellence.

**Foxon, T.J., 2011. A coevolutionary framework for analysing a transition to a sustainable low carbon economy. *Ecological Economics*, 70(12), pp. 2258–2267.**

In order to facilitate a transition towards a sustainable, low-carbon economy, this paper argues for the application of a coevolutionary framework, which takes into account ecosystems, technologies, institutions, strategies and practices. Such a method, the author argues can overcome lock-ins within the current systems. The framework can be used to undertake empirical analyses at several levels, as well as assess the economic potential of transitions.

**Hahn, T., Figge, F., Pinkse, J. and Preuss, L., 2010. Trade-offs in corporate sustainability: you can't have your cake and eat it. *Business Strategy and the Environment*, 19(4), pp. 217–229.**

Corporate sustainability is often measured by its ability to meet the demands of economic, environmental and social demands. The authors turn our attention to the fact that there is often conflict resulting in trade-offs between these areas. Considering this is necessary if we are to achieve corporate sustainability. The authors thus present a framework for dealing with such trade-offs, but also introduce a special issue on this topic with a literature review.

**Mekhilef, S., Saidur, R. and Safari, A., 2011. A review on solar energy use in industries. *Renewable and Sustainable Energy Reviews*, 15(4), pp.1777–1790.**

Emphasising the versatility of solar power, the authors seek to investigate their use in industries, where they argue their use is even easier to integrate with existing systems than elsewhere. For instance, they can be applied directly into a process, or just as part of the regular electrical supply. Economics of scale applies, as viability increases with the size of the facility. The authors find the systems especially useful in the building and processes industries and for water desalination systems.

**Karlsson, N., Halila, F, Mattsson, M. and Hoveskog, M., 2016. Success factors for agricultural biogas production in Sweden: A case study of business model innovation. *Journal of Cleaner Production*, 142(4), pp. 2925–2934.**

Biogas produced from organic waste is presented as a promising sustainable energy resource, however, as the authors point out, its viability has been challenged by low profitability. The paper presents findings from a qualitative study which identified success factors from the Swedish agriculture sector in producing biogas, and proposes the use of business model innovation (BMI) to reproduce those factors. Long-term profitability was found to be important, and the authors suggest creating public-private networks to invest in farm-based biogas.



**Boons, F., Montalvo, C., Quist, J. and Wagner, M., 2013. Sustainable innovation, business models and economic performance: an overview. *Journal of Cleaner Production*, 45, pp.1–8.**

In order to cater for sustainable development and the innovation which it will require, these authors propose the use of business models in making progress in this area. They argue that business will benefit from the holistic framework which business models constitute, and that it can also be used by researchers as an analytical tool which can be used to assess how businesses create sustainable value, as well as providing a logical link between the firm and the larger system. This paper introduces a special issue on this topic.

**Kindstrom, D. Ottosson, M. and Thollander, P., 2017. Driving forces for and barriers to providing energy services. A study of local and regional energy companies in Sweden. *Energy Efficiency*, 10, pp. 21–39.**

This paper takes as its point of departure the Swedish local and regional energy companies, and seeks to explore barriers and drivers for implementing energy services, from development to sales and deployment. The authors find that even though there is a push behind such services in the industry, there is lack of strategic direction within the firms as well as a prevailing distrust of the demand among end users for such services. Implications for managerial policy is discussed.

**Lund, P. D., 2009. Effects of energy policies on industry expansion in renewable energy. *Renewable Energy*, 34(1), pp. 53–64.**

This paper deals with the commercialization processes and industrial growth within renewable energy. Through empirical analyses and case studies, different technologies and regions, energy policy and support measures are considered. The findings implicate that supporting home markets often leads to growing industrial activity. The author argues that there are huge prospects for investments in renewable energy not just for large firms, and that this opportunity should encourage countries to look for industrial opportunity when formulating energy policies, since it could provide double dividend for public support needed for renewable energy.

### 3.3. Energy markets

Energy markets are commodity markets in which energy is demanded and supplied. Electricity, gas, oil, and carbon markets are typical examples of these markets. Efficient energy markets are very critical for the economic and social development of a country. An energy market usually has three key functions: producing, transmitting and selling energy. Governments very often regulate markets in order to improve competition for the interest of the consumer and to secure energy supply. Commonly, the producing and transmitting elements of markets have been considered as engineering problems. However, the latest developments in the literature indicate the importance aspects of the markets, which the Social Sciences and Humanities (SSH) address.

This subsection provides a collection of SSH research related to energy markets. This field of research is dominated by Economics. Soyfas and Sari (2003) investigate the energy consumption and economic growth nexus for developed and emerging economies. The paper is pioneering work, which distinguishes between the short-term and long-term energy policies and analyses the importance of endowed energy sources for the causal relationship between consumption and growth. Bajanova (2016) looks at the competitiveness of the European energy market.

Energy markets are usually subject to market failures. Edenhofer et al. (2013) examine market failures and their cure in renewable energy markets. Apergis and Payne (2012) investigate the relationship between renewable and non-renewable energy consumption and economic growth. They find a bi-directional causality between them all. Helm (2014) assesses the European internal energy market and climate packages and suggests an urgent reassessment of the policies since the prices are increasing, competition is going down, and yet climate is not changing.

Other research looks at markets for particular energy sources. Movilla, Miguel and Blazquez (2013) focus on the photovoltaic (PV) solar energy market in Spain. They state that the market is not profitable and must be subsidised so that technological advancement can make the market more profitable in the future. Their simulation model shows that a profitable market is possible, depending on the policies and scenarios.



Schleicher-Tappeser (2012) claims that the PV markets may be profitable if the production (load) and consumption of power is balanced. The last contribution (Eurelectric, 2016) represents the industry perspective on how to design the electricity market to facilitate low-carbon transitions.

**Soytas, U. and Sari, R., 2003. Energy consumption and GDP: causality relationship in G-7 countries and emerging markets. *Energy Economics*, 25(1), pp. 33-37.**

This study examines the causal relationship between Gross domestic product (GDP) and energy consumption in the top 10 emerging markets and the G-7 countries. For their analysis, the authors use cointegration and vector error correction (VEC) techniques, with respect to times series properties of annual energy consumption and GDP. Even though there are a variety of studies in this field, the results are different. This paper analyses 16 countries and states different causalities between energy consumption and GDP. The results of variance decompositions support the causal relationships that are discovered by using VEC model. In addition, for some countries including Turkey, energy conservation in the end may harm economic growth as well.

**Бянова, Н., 2016. Конкуренция и конкурентна среда на електроенергийния пазар в ЕС**  
**Virtual library of the Economic Academy of Svishtov, [online] Available at: [http://dlib.eacademy.bg/bitstream/handle/10610/3012/n48\\_349\\_tom1Konf\\_80%20tom%201.pdf?sequence=1&isAllowed=y](http://dlib.eacademy.bg/bitstream/handle/10610/3012/n48_349_tom1Konf_80%20tom%201.pdf?sequence=1&isAllowed=y) [Accessed on 24 May 2017] (English: Bayanova, N., 2016. Competition and competitive environment on the EU power market)**

This paper examines the competitiveness of EU power markets as a result of the reform launched in 1996. The authors find that the policy of liberalization and integration of national power markets of the EU Member States does not lead to stronger competition among a greater number of participants. Rather, it creates 'national energy champions', which grow into European energy giants. The conclusion is that effective legislation should be created and relevant control of its implementation should be established in order to improve the state of market competitiveness.

**Edenhofer, O., Hirth, L., Knopf, B., Pahle, M., Schlömer, S., Schmid, E. and Ueckerdt, F., 2013. On the economics of renewable energy sources, *Energy Economics*, 40, pp. 12-23.**

In this study, the authors review main aspects of economics of renewable energy (RE) technologies, which can lead to an optimal RE policy by looking at it from three interrelated perspectives: (1) Social objectives and model-based estimates, (2) Market failures and (3) Multiple policy instruments in order to solve those failures. Based on this review, the authors argue that the real-world options for policymakers in the field of renewable energy need to be assessed and that more research is needed in order to make optimal RE policies.

**Apergis, N. and Payne, J.E., 2012. Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. *Energy Economics*, 34(3), pp.733-738.**

In this study, the causality between renewable and non-renewable energy consumption and economic growth is examined for 80 countries. The results show that there is a bidirectional causality between renewable and non-renewable energy consumption and economic growth. In the long run, consumption of both energy sources has positive effects on real Gross domestic product (GDP). The bidirectional short-run causality between renewable and non-renewable energy consumption also indicates that they can be substituted.

**Helm, D., 2014. The European framework for energy and climate policies. *Energy Policy*, 64, pp. 29-35.**

The focus of this paper is the European energy and climate change policy, particularly considering the European market and its relation to the competitiveness. The policy is examined in two dimensions, namely the internal energy market (IEM) and the climate change package (CCP) with their structural details. Based on the analysis, the authors makes suggestions for how both of them can gain effectiveness. He argues for radical reconsideration of the IEM and the CCP. While the IEM needs to refocus on physical infrastructure, common rules for accounting and a common approach to capacity markets and renewable trading, the CCP needs to pay attention to carbon consumption and future renewables.



**Movilla, S., Miguel, L.J. and Blázquez, L. F., 2013. A system dynamics approach for the photovoltaic energy market in Spain. *Energy Policy*, 60, pp. 142–154.**

Photovoltaic (PV) solar energy in Spain has some weaknesses in terms of profitability. By itself, the PV sector is not profitable. Therefore, the Spanish government relied on subsidies, hoping that the support would increase panel production and stimulate the technological advancement, and hence increase investment. This paper attempts to analyse the PV sector in Spain. The results of the analysis with a computer simulation model show that the success or failure of the investments in PV solar energy depends on the adopted policies and scenarios.

**Schleicher-Tappeser R., 2012. How renewables will change electricity markets in the next five years. *Energy Policy*, 48, pp. 64–75.**

This paper examines the possible effects, conflicts and opportunities of using renewable energy technologies. Thanks to the spread of those technologies, different kinds of markets, production and consumption will appear and the exchange of energy is going to change. The disruptive effect of this transformation will affect regulatories and different businesses as well. It will be important to focus on a lean, transparent structure, which can be flexibly adapted, changing only a few key parameters. Complex regulations and market constructions would need to frequently change in turbulent times and may not be sufficiently transparent for competent democratic control.

**Eurelectric, 2016. *Electricity market design: Fit for the low-carbon transition*. Brussels: Eurelectric, [online] Available at: [http://www.eurelectric.org/media/272634/electricity\\_market\\_design\\_fit\\_for\\_low-carbon\\_transition-2016-2200-0004-01-e.pdf](http://www.eurelectric.org/media/272634/electricity_market_design_fit_for_low-carbon_transition-2016-2200-0004-01-e.pdf) [Accessed on 24 May 2017]**

In this report, EURELECTRIC, who represents the interest of the electricity industry, proposes its recommendations for an electricity market design. Recommendations include: (1) Making sure that the consumers benefit, e.g. through policies that counteract high electricity bills. (2) Making sure that renewable energy technologies are fit for the market with the EU Emissions Trading Scheme (ETS) as main driver. (3) Ensure the integration of renewables into the energy market. (4) Develop a regional approach both to system operation and to security of supply.

### 3.4. Energy prices

In the previous subsection, we presented literature about energy markets. Even though energy prices are determined in energy markets, through competition or by regulations, we address the literature on energy prices in this separate subsection. Even more than the previous subsection, the literature on energy prices represents a heavily quantitative branch of energy-related Social Sciences and Humanities (SSH).

Ketterer (2014) investigates the effects of intermittent wind power generation on the electricity prices in Germany. The results indicate a negative relationship between price level and variability in wind power. However, the variability in wind power increases the volatility in prices. Price volatility, again, can be reduced by market regulations. Sadorsky (2012) analyses the relationships between oil prices and the stock prices of clean energy companies and technology companies. Similarly, Sari and Soytaş (2010) examine the relation between oil prices, exchange rate and precious metal spot prices. Koch et al. (2014) investigate the factors that have impacts on EU allowances. The paper particularly focuses on overlapping climate policies and the role of renewables. Hirth's (2013) paper is about the market value of variable renewable energy and provides an innovative framework, based on a literature review, new market data and power system modeling. Würzburg, Labandeira and Linares (2013) determine the merit-order effect size, the short-term negative relationship between renewable electricity production and electricity price, for the economic evaluation of renewable energies. The merit-order effect in the power market is also investigated for Italy (Clò, Cataldi and Zoppoli, 2015).

Dütschke and Paetz' (2013) paper is about consumer preferences about the pricing programs. The authors conducted both questionnaires and field experiments and report the preferences towards a more dynamic pricing in Germany. The paper by Kalkuhl, Edenhofer and Lessmann (2013) is about the effect of renewable energy policies on welfare and energy prices. Using a broad set of policy instruments, including subsidies,



it is found that without some form of carbon pricing, pragmatic renewable energy policies may dramatically increase the mitigation cost of global warming. Lastly, Olsson and Hillring (2014) investigate the Danish wood market and examine price development as well as relations between Danish and Swedish markets. They put forward the importance of market characteristics for the price development.

**Ketterer, J.C., 2014. The impact of wind power generation on the electricity price in Germany. *Energy Economics*, 44, pp. 270–280.**

How does wind power generation affect the electricity prices Germany? This paper analyses the effect of intermittent wind power on the prices of electricity. It does so by introducing daily levels of German wind power generation as explanatory variable in the mean and the variance equation of a Generalized AutoRegressive Conditional Heteroskedasticity (GARCH) model – an econometric model to predict prices – of the German day-ahead electricity price. The results show that variable wind power reduces the price level, but increases its volatility.

**Sadorsky, P., 2012. Correlations and volatility spillovers between oil prices and the stock prices of clean energy and technology companies. *Energy Economics*, 34(1), pp. 248–255.**

The author aims to model conditional correlations and to analyse the volatility spillovers between oil prices and stock prices of clean energy and technology companies. For doing this, he uses a dynamic conditional correlation multivariate GARCH model. The results show that the correlation between stock prices of clean energy companies and technology stock prices is higher than the correlation between stock prices of clean energy companies and oil prices.

**Sari, R., Hammoudeh, S. and Soytas, U., 2010. Dynamics of oil price, precious metal prices, and exchange rate. *Energy Economics*, 32(2), pp.351–362.**

This paper examines the relationship between oil prices, exchange rates and precious metals spot prices. The relationship between these variables are strong in short run rather than long run. Investing in precious metal investors may diversify a portion of the risk.

**Koch, N., Fuss, S., Grosjean, G. and Edenhofer, O., 2014. Causes of the EU ETS price drop: Recession, CDM, renewable policies or a bit of everything?—New evidence. *Energy Policy*, 73, pp. 676–685.**

The focus of this paper is to find the justifying factors of the price drop of EU allowances (EUAs). EUAs are Carbon credits used in the EU Emissions Trading Scheme (EU ETS). The method used – the marginal abatement cost theory – is not able to explain the substantial amount of variations of EUA price changes. The reform options for EU ETS have been evaluated with the help of the findings of this research, which are not in line with the predominant opinion.

**Hirth, L., 2013. The market value of variable renewables. The effect of solar wind power variability of their relative price. *Energy Economics*, 38, pp. 218–236.**

This paper discusses the market value of variable renewable energy by examining solar and wind elements. Variability of wind speed and solar radiation has an effect on the price on the market. This effect can be seen during windy and sunny times. The author concludes that large-scale renewable investments, which are competitive, are very difficult to accomplish.

**Würzburg, K., Labandeira, X. and Linares, P., 2013. Renewable generation and electricity prices: Taking stock and new evidence for Germany and Austria. *Energy Economics*, 40, pp. S159–S171.**

This paper focuses on the relation between electricity prices and renewable electricity production. The so-called ‘merit-order effect’ describes the mechanism that when the renewable energy production increases, the electricity price decreases. The authors analyse the price effect of renewable energy production in Austria and Germany. Their analysis indicates that the merit-order effect varies. It depends on the region and on the assessment method employed.

**Clò, S., Cataldi, A. and Zoppoli, P., 2015. The merit-order effect in the Italian power market: The impact of solar and wind generation on national wholesale electricity prices. *Energy Policy*, 77, pp. 79–88.**

Similar to the previous paper, this paper focuses on the merit-order effect. The authors analyse the Italian wholesale electricity market in order to find empirical evidence of the merit-order effect. They estimate that



that solar electricity production has generated higher monetary savings than wind electricity production and attribute this to the higher prominence of solar electricity production. An analysis on a year-to-year basis shows that the impact of renewable energy resources on prices and the net monetary benefits (savings minus costs of the supporting schemes) decrease over time, in correspondence with the increasing degree of penetration of solar and wind sources.

**Dütschke, E. and Paetz, A.-G., 2013. Dynamic electricity pricing – Which programs do consumers prefer? *Energy Policy*, 59, pp. 226–234.**

This work focuses on consumer preference of pricing program in Germany. A questionnaire and field experiment are applied. According to the results, consumers are open to dynamic pricing but they prefer simple programs to complex and highly dynamic ones. In addition, the authors find that consumers might be more willing to accept more dynamic pricing programs if they get the opportunity to experience in practice how the pricing programmes can be managed in everyday life.

**Kalkuhl, M., Edenhofer, O. and Lessmann, K., 2013. Renewable energy subsidies: Second-best policy or fatal aberration for mitigation? *Resource and Energy Economics*, 35(5), pp. 217–234.**

The paper focuses the impact of the renewable energy policies on welfare and energy prices. The analysis provides valuable information for policy makers. The paper states that without some form of carbon pricing, pragmatic renewable energy policies may turn out to be a fatal aberration for mitigating global warming as costs explode.

**Campiglio, E., 2016. Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy. *Ecological Economics*, 121, pp. 220–230.**

The paper argues that carbon pricing may not be sufficient for low carbon investment because of the market failures due to the lack of allocation of credits. This failure may lead commercial banks not to respond to price signals. This possibility requires the implementation of additional policies like monetary policies and macroprudential financial regulations.

**Olsson, O. and Hillring, B., 2014. The wood fuel market in Denmark: price development, market efficiency and internationalization. *Energy*, 78, pp. 141–148.**

This paper looks at the Danish wood fuel market. By employing time series analyses, the authors analyse the interconnections between the prices of pellets, chips and straw and relations between wood fuel prices in Denmark and Sweden. The result indicates that price dispersion has decreased notably for wood pellets, but not for wood chips. There is cointegration between prices of wood chips and straw. The Swedish and Danish markets only for wood pellets are integrated. This study concludes that markets for wood chips and wood pellets have different characteristics.



## 4. Pasts and futures of competitive, secure, low-carbon energy supply

Policymaking and planning for long-term change processes in societies, such as the transition to low-carbon energy supply, are challenging. Many different aspects, social, environmental and economic, need to be taken into account. Being reminded of the broader picture and employing a holistic perspective is important. Energy-related Social Sciences and Humanities (SSH) can contribute both through research on histories of past transitions and their implications for today, and with research about visions and scenarios for the future.

This section is divided into three subsections: subsection 4.1. '[Histories of energy](#)' represents historical perspectives both on long-term energy transitions and on developments and events in more recent history. Subsection 4.2. '[Sociotechnical imaginaries and expectations](#)' addresses the important role of visions, imaginaries and expectations of different futures of energy technologies, particularly for policymaking. Finally, subsection 4.3. '[Energy scenarios](#)' is about the application of energy scenarios as tool for policymaking and planning.

### 4.1. Histories of energy

Energy sources, energy availability per-capita, energy infrastructures: these, as well as other related aspects, have been contributing to forge modern societies, in Western countries and beyond. This subsection on histories of energy compiles a selection of literature, which gives readers the possibility to understand, what history usually allows readers to understand: that things have not always been as they currently are; that current situations result as not unavoidable outcomes of clashes, frictions and cooperation among forces; that things might have gone very differently; and that some claims about future developments might prove difficult to be met.

The literature listed below presents histories of energy. We included long-term analyses as well as studies of quite recent events. Smil (2010) takes a broad perspective and examines the transitions from wood to coal, oil and gas over the last hundreds of years. Historical transitions between energy sources is also discussed by Solomon and Krishna (2011). Augustoni (2014) goes even further back in his analysis of the relation between energy transition and social change, starting from the domestication of fire. The relation between energy and equity is the subject of Illich's (1973) discussion of whether humans' energy needs will continuously increase. The human reliance on ever-increasing quantities of energy is also addressed in Mumford's (1934) book about the machine age.

The next two contributions on the list deal with historical people and their scientific work. While Missemer (2012) describes Jevons' (1865) book 'The Coal Question' as early account of the Rebound effect, Banks (2015) tells the story of Haldane, the engineer who developed the first British ground-source heat pump. The last contributions, then, cover more recent histories and events. Beuse et al. (2000) present a chronicle of 25 years of sustainable energy development in Denmark, focusing on the special role of grassroots and community initiatives. The recent global history of wind energy is in the focus of the paper by Kaldellis and Zafirakis (2011), who based on their analysis, give an optimistic outlook on future wind developments. An analysis of a recent historic event, the citizen protest against a hydropower plant and its implications for energy politics, is presented by Jansson and Uba (2015).

#### **Smil, V., 2010. *Energy transitions: history, requirements, prospects*. Santa Barbara (CA): Praeger.**

Smil explains the third great energy transition, which occurred over the last several hundred years and included the shift from wood to coal, and the rise of oil and natural gas. He does so by retracing the shifts in primary energy resources, electricity generation, development and diffusion of prime movers and energy conversion devices. By means of data related to a variegated set of countries, Smil shows how gradual energy transitions were in the past. Finally, he suggests what to expect from the current energy transition.



**Solomon, B.D. and Krishna, K., 2011. The coming sustainable energy transition: History, strategies, and outlook. *Energy Policy*, 39, pp. 7422–7431.**

By providing a comparative overview of three historical transitions between major energy sources, the authors demonstrate that most of these shifts were initiated because of resource scarcity, high labour costs and technological innovations and take generally over a century. Policy instruments that accelerate a transition are identified, as well as institutional hurdles, nationalist sentiments and centralised power. Climate change urges more rapid changes. Therefore, it is important to recognise that these limitations focus on energy efficiency measures and technologies because it does not require a technological breakthrough and they are cost-effective, easier to implement and provides new job opportunities.

**Agustoni, A., 2014. Uomini, convertitori e «megamacchine». *Energia, potere e società oltre il Pleistocene. Studi di sociologia*, 4(4), pp. 419–434. (English: Men, converters and “mega-machines”. *Energy, power and society beyond Pleistocene*)**

By taking advantage of contributions from leading scholars, such as L. Mumford, F. Cottrell, L. White, R. Adams, N. Elias, H. Innis and J. Schumpeter, the author addresses the relations between energy transitions and social change in history. Starting from fire domestication, he lays his analysis on more and more sophisticated forms of energy conversion devices, among which the organization of human labour.

**Illich, I., 1973. *Energy and equity*. London: Calder & Boyars.**

Do humans need ever-increasing quantities of energy? Illich examines this question through reflections based on the marginal disutility of tools. Once reached a certain threshold, more energy (as well as more speed) gives negative returns. These negative returns not only refer to the uneven distribution of resources between the social classes or to the negative environmental impacts deriving from energy production and distribution. Would energy be produced, or would transport infrastructure be built, in ways that do not harm the environment, high energy availability and high speed – Illich suggest – will nonetheless still polluting social relations.

**Mumford, L., 1934. *Technics and Civilization*. San Diego (CA): Harcourt, Brace and Company.**

This book explores the origins of the machine age and its development through a series of different historical phases. It also undertakes a critical analysis of its social consequences, for example, a growing reliance on ever-increasing quantities of resources and energy, increased environmental impacts and social inequalities.

**Missemer, A., 2012. William Stanley Jevons' *The Coal Question* (1865), beyond the rebound effect. *Ecological Economics*, 82, pp. 97–103.**

In this paper, the author undertakes an analysis of W.S. Jevons' book 'The Coal Question'. Looking back, 'The Coal Question' is particularly known for alluding to the first bases of what we today call the rebound effect, also known as the 'Jevons' paradox'. The rebound effect refers to the increase in energy consumption that follows energy efficiency improvements. Jevons worries were not only related to the exhaustion of the British Empire coalmines. According to Missemer, Jevons also pointed out some moral considerations related to intergenerational justice, that is, the question related to the whether current generations can continue to massively use the energy resources they can exploit without taking into account future generations' right to energy. While based in the 19th century British Empire, Jevons' reflections are still valid for current and future situations.

**Banks, D., 2015. Dr T. G. N. 'Graeme' Haldane - Scottish heat pump pioneer. *International Journal for the History of Engineering and Technology*, 85(2), pp. 250–259.**

This paper tells the story of Dr. T. G. N. 'Graeme' Haldane, a British engineer. Haldane was possibly the first engineer to construct a heat pump system for space heating, Britain's earliest 'ground-source heat pump'. The author argues that Haldane should be remembered as “visionary pioneer of rational electricity supply and sustainable energy usage” (p. 257). Interesting is also Haldane's call for less specialisation and theorisation of engineers. The history shows that the ground-source heat pump has been completely overlooked in Britain due to an abundance of oil and gas. Other countries were faster to adopt it.



**Beuse, E., Boldt, J., Maegaard, P., Meyer, N.I., Windeleff, J. and Østergaard, I., 2000. *Vedvarende energi i Danmark. En krønike om 25 opvækstår 1975-2000*. Aarhus: OVE's Forlag. (English: *Sustainable energy in Denmark. A chronicle about 25 years of growing up 1975-2000*)**

This book is about 25 years of development of sustainable energy in Denmark. However, the authors emphasise that what started in the 1970s just was a resumption of a development, which started hundreds of years before and just was interrupted by a century dominated by fossil fuels. The Danish development of energy in those 25 years has been a particular one and not comparable to most other countries. Strong traditions of working with grassroots organisations, for example, gave the development of sustainable energy a particular touch of being very community-based. In addition to giving a chronological overview over these 25 years of sustainable energy development, the book focuses particularly on the role of grassroots and community initiatives, on wind and solar power and on energy from agriculture and forestry.

**Kaldellis, J.K. and Zafirakis, D., 2011. *The wind energy (r)evolution: A short review of a long history*. *Renewable Energy*, 36(7), pp. 1887-1901.**

The exploitation of wind energy dates back five thousand years. Knowing this and being aware of today's efforts towards low-carbon societies could make us wonder why our energy systems are mainly based on fossil fuels. This paper takes us only thirty years back in time and looks at the recent history of wind energy from the so-called California era in the 1980s to huge constructions of offshore wind parks today. In this review of wind energy development, the authors focus on several issues: global market facts, technology, economics, environmental performance, prospects and R&D. Based on this analysis, they discuss the target of reaching 1TW installed wind power by 2030, which they assess as feasible, in light of the current focus in energy policy on energy security and sustainability.

**Jansson, J. and Uba, K., 2015. *Protesternas makt i Sverige: hur mobilisering och alliansbyggande stoppade vattenkraftverket i Sölvbacka strömmar 1978-79*. *Slagmark: tidsskrift för idéhistorie*, 71, p. 147-161. (English: *The protestors' power in Sweden: how mobilisation and building alliances stopped the hydropower plant in the Sölvbacka streams*)**

In 1979, the Swedish parliament overran a governmental decision. This did not happen very often in Sweden and the authors of this paper describe this event as consequence of a citizen protest against a hydropower plant planned in Sölvbacka in the North of Sweden. By laying out what happened in 1979, the paper shows how small groups of citizens can affect national energy politics through continued mobilization and with the help of important political allies.

## 4.2. Sociotechnical imaginaries and expectations

Radical changes in the energy supply are likely to transform social infrastructures, change established patterns of life and work, and allocate benefits and burdens differently from before. Hence, research should pay greater attention to the social dimensions of energy transitions. Science and technology contribute to producing collective visions of good and attainable futures. Such collective visions, also labelled 'sociotechnical imaginaries' have become a popular area of Social Sciences and Humanities (SSH) research in the last years.

Sociotechnical imaginaries, according to Jasanoff and Kim's definition, are "*collectively imagined forms of social life and social order reflected in the design and fulfillment of nation-specific scientific and/or technological projects*"<sup>9</sup>. The definition has since been extended. It is not anymore limited to nation states, but can be articulated and propagated by other groups in society, such as corporations, social movements and professional societies<sup>10</sup>. Sociotechnical imaginaries have proved particularly useful for policymakers. Imagined futures support policymakers when they have to justify investments in new technologies. On the other hand, the state's capacity to act as responsible agent of the public good is confirmed when science and technology progress. In that way, "*sociotechnical imaginaries serve both as the ends of policy*

<sup>9</sup> Jasanoff, S., and Kim, S-H., 2009. Containing the Atom: Sociotechnical Imaginaries and Nuclear Power in the United States and South Korea. *Minerva*, 47(2), p. 120.

<sup>10</sup> Jasanoff, S. and Kim, S-H., 2015. *Dreamscapes of modernity*. Chicago: University of Chicago Press.



and as instruments of legitimization"<sup>11</sup>. Consequently, national governments engage actively in the creation of sociotechnical imaginaries.

For SSH researchers the concept of socio-technical imaginaries proved useful to explain why some visions of scientific and social organization tend to gain support over others. Jasanoff and Kim (2013), for example, explore national energy imaginaries in the USA, Germany and South Korea and show how differences in these imaginaries can explain national developments related to energy. Similarly, Gjefsen (2013) compares support for carbon capture and storage (CCS) in the US and in Europe and demonstrates that the support for technologies is based on visions of the people and societies where the technologies will be used.

Many different actors produce socio-technical imaginaries. Moving the focus from national governments, Smith and Tidwell (2016) study people's imaginaries in everyday life related to coal and nuclear energy. They show that these imaginaries are related to local, rather than national, contexts. The literature on socio-technical imaginaries has also focused on experts and their visions for the technologies they develop (Sovacool and Ramana, 2015; Cherry et al., 2017). Experts use imaginaries, for example, to gain support for their technologies.

A field of inquiry closely related to research on socio-technical imaginaries is based on the 'sociology of expectations'<sup>12</sup>. Technological expectations describe real-time representations of future technological situations and capabilities. Expectations are quite similar to technological promises and visions. Nonetheless, they are different because they are wishful portrayals of a desired future: by performing such futures, they are made real and have effects for present action. Nissilä, Lempiälä and Lovio (2014), for example, show how expectations influence the development of solar technology in Finland. Similarly, Skjølsvold (2014) discusses expectations related to smart grids and how they influenced policymaking.

**Jasanoff, S. and Kim, S-H., 2013. Sociotechnical Imaginaries and National Energy Policies. *Science as Culture*, 22(2), pp. 189-196.**

Focusing on the USA, Germany and South Korea, this paper shows how national energy imaginaries diverge in their treatment of risk and how this in turn helps to explain past developments. The authors sketch out risks and benefits of energy choices that have risen to political salience. They look at the way public policy has resolved the ownership of those risks and benefits. Based on the insights gained, the authors encourage further inquiry into competing definitions of the public good as imagined and articulated in national energy policies.

**Gjefsen, M. D., 2013. Carbon Cultures. Technology Planning for Energy and Climate in the US and EU. *Science & Technology Studies*, 26(3), pp. 63-81.**

This paper demonstrates that support for new technologies not only happens for economic reasons, but also based on expectations and visions of the people and societies in which the technologies will be used in the future. The authors compare the support for carbon dioxide capture and storage (CCS) in the United States and EU over the last decade. The results of this analysis show how differences in laws and market structures between the US and the EU has resulted in differences in groups of stakeholders in the technology. Hence, although climate change mitigation is a global issue, the authors argue that new technologies for sustainable energy generation need to be understood in relation to how policymakers envision the societal consequences of the technology in addition to the purely technical qualities.

**Smith, J. M. and Tidwell, A., 2016. The everyday lives of energy transitions: Contested sociotechnical imaginaries in the American West. *Social Studies of Science*, 46(3), pp. 327-350.**

In this paper, the authors combine perspectives from Science and Technology Studies (STS) on sociotechnical imaginaries and from Anthropology on resource materialities. They focus on two energy producing (coal and nuclear industry) communities in the US in order to study the role of sociotechnical imaginaries in people's everyday life. The authors described these imaginaries as bounded since they relate

<sup>11</sup> <http://sts.hks.harvard.edu/research/platforms/imaginaries/> [Accessed on 24 May 2017]

<sup>12</sup> Borup, M., Brown, N., Konrad, K. and van Lente, H., 2006. The Sociology of Expectations in Science and Technology. *Technology Analysis & Strategic Management*, 18(3/4), pp. 285-298.



to local context rather than national or international issues. Thereby, the paper contrasts most studies of sociotechnical imaginaries focusing on the role of the state and transnational actors.

**Sovacool, B. K. and Ramana, M.V., 2015. Back to the Future. Small Modular Reactors, Nuclear Fantasies, and Symbolic Convergence. *Science, Technology, & Human Values*, 40(1), pp. 96–125.**

How do scientists use imaginaries and versions to get support for the technologies they develop? This paper addresses this question by looking at how scientists associated with the nuclear industry are building support for small modular reactors. The authors find that the scientists use five rhetorical visions that help to create a symbolic convergence among promoters, to attract political and financial support, and to erase previous nuclear failures from public discourse. The paper is a nice illustration for how energy technologies capture imaginations, confirm an ideology, or fit with a particular blueprint about the future.

**Cherry, C., Hopfe, C., MacGillivray, B. and Pidgeon, N., 2017. Homes as Machines: Exploring Expert and Public Imaginaries of Low Carbon Housing Futures in the United Kingdom. *Energy Research & Social Science*, 23, pp. 36–45.**

Two expert visions of low carbon housings, PassivHaus and Smart Homes, are identified as being currently rivals in shaping the impending housing technological pathways and in designing the role of resident. They have been both designed to realise emissions reductions through changing the built environment rather than seeking to impact lifestyles, in accordance with the public's concerns that have been presumed to revolve around comfort, control and security. In truth, it seems to the authors that no serious study has been conducted which tries to consider the complex personal and cultural issues, which conditions the public's acceptability of future housing. To overcome the tensions and discrepancies between the experts' and the public's imaginaries in order to facilitate any low-carbon transition, experts and public agents need to work for the public with the public, rather than around (and without) it.

**Nissilä, H., Lempiälä, T. and Lovio, R., 2014. Constructing Expectations for Solar Technology over Multiple Field-Configuring Events: A narrative perspective. *Science and Technology Studies*, 27(1), pp. 54–75.**

This paper is a contribution to the literature on the sociology of expectations, which addresses how expectations influence the development and advancement of a technological field. The authors analyse the development of the field of solar technology in Finland. They do this by looking at how expectations of the technology are constructed through several events, which were important for the solar technology field. The analysis shows how stories and expectations develop over time and how they contribute to furthering solar technology. Hence, the authors argue that engaging in event-based expectations work can help to understand visions and expectations for a new technology.

**Skjølsvold, T.M., 2014. Back to the futures: Retrospecting the prospects of smart grid technology. *Futures*, 63, pp. 26–36.**

The literature on the sociology of expectation argues that visions and imaginations of the future are performative. This means that these imagined futures influence present action. Inspired by these ideas, this paper analyses the visions and expectation that were formulated in the debate about smart metering technology in Norway. The author look at how these future visions have been used in the policy debate about smart metering and identifies two modes of future performativity: (1) Translative futures work to spark the debate about smart metering and to establish the need for political decisions. (2) Transformative futures do more gradual work of shifting the meaning of what smart metering technology may become in the future. This paper demonstrates the importance of visions and expectation of technologies for policymaking.

### 4.3. Energy scenarios

Scenario approaches consider how the social shaping power of invoking up possible futures, based on the realities of today, and pointing out how to get to these futures, can be wielded as a tool. In contrast, sociotechnical imaginaries, which are described in the subsection above, are treated more or less as unconsciously created and as a by-product of planning processes. Using a scenario-based approach in planning processes can reveal unknowns and reveal important problem questions ahead of time, thus



speeding up implementation (Meyer et al., 2012). For instance, scenarios may be useful for identifying potential risks of new technologies, such as nano- and biotechnology (Jørgensen and Jørgensen, 2009), or when the solving of some technological issues can bring up new problems elsewhere (van den Bergh et al., 2015).

Naturally, parts of the Social Sciences and Humanities (SSH) research on scenarios will relate not just to how scenarios in some cases are useful, but how scenario building itself should be conducted. This entails methodology on how the future should be structured and categorised within a scenario approach (Hughes et al., 2013) as well as the effect on results of scenario based planning, which can be attributed to what kinds of information gets put into them (Giampietro and Sorman, 2012).

There are also specific approaches within SSH which by merit of their main topic of concern, transitions, are paired with a scenario approach on a regular basis, namely the multi-level perspective (MLP) approach, often in combination with the socio-technical scenario approach. For instance, Hofman and Elzen (2010) show that the multi-level perspective is suited to deal with scenarios regarding infrastructures, as they provide deeper insights through a qualitative yet comprehensive approach. In a similar vein, Verbong and Geels (2010) show the uses of these approaches on painting the future of the Dutch energy system in broad but detailed strokes. McDowall (2014) also shows that the socio-technical scenario approach can be combined with other approaches, in this case energy modelling, and is capable of incorporating that information in order to create a more succinct analysis. This subsection also highlights how scenario building can be used to incorporate views of the public in order to create more robust approaches, which heed their potential acceptability (Mathy et al., 2015). Finally, however, Winskel and Radcliffe (2014) issue a warning about the rising trend of what they call Accelerated Energy Innovation, which is a kind of scenario approach, but which is top-down driven in too large a degree, and thus in too much of a hurry to allow for real innovation.

**Meyer, N. I., Hvelplund, F., Karnøe, P., Lund, H., Mathiesen, B. and Morthorst, P.E., 2012. Transition to 100% renewable energy systems in Denmark. *Solutions*.**

Scenario studies are highly relevant to the governance of transitions to low-carbon societies. This paper looks at solutions for a transition to 100% renewable energy in Denmark before 2050. It deals particularly with policy instruments and should consequently be relevant for policymakers. The authors show that it is possible to replace fossil fuels completely with renewable energy. However, this requires new ways of thinking about energy systems and planning; for example, a closer integration of the electricity, heat and transport sectors. Particular interesting for policymakers is the detailed roadmap for the transition as well as suggestion for efficient policies, which the authors include in this paper.

**Jørgensen, M. S., and Jørgensen, U., 2009. Green technology foresight of high technology: a social shaping of technology approach to the analysis of hopes and hypes. *Technology Analysis & Strategic Management*, 21(3), pp. 363–379.**

Technologies, such as nano-, bio- and information and communication technologies are expected to contribute to solutions towards low-carbon transitions. However, these technologies and their abilities to deliver solutions are often viewed based on a linear understanding of technological change. This paper proposes a social shaping of technology approach (SST) to technological change, which means that technology is not only seen as driver of change, but also as shaped by social and environmental conditions. From this perspective, a green technology foresight was carried out by the Danish Environmental Protection Agency. The aim was to get a better understanding of the environmental risk and potentials of nano-, bio-, and information and communication technologies. Based on this technology foresight exercise, the authors discuss recommendation for the future governance of these technologies.

**van den Bergh, J., Folke, C., Polasky, S., Scheffer, M. and Will, S., 2015. What if solar energy becomes really cheap? A thought experiment on environmental problem shifting. *Current Opinion in Environmental Sustainability*, 14, pp. 170–179.**

Environmental problems shifting (EPS) refers to the issue that when we solve one environmental problem, we create another one. However, studying EPS is not easy and has so far been an understudied area in energy-SSH since it requires that we use insight from different areas of research. This paper looks at



the environmental and socioeconomic impacts of three hypothetical energy futures and how solving one environmental problem may create another one. The authors, then, propose guidelines for how to study EPS and how the environmental problem shifting can be mediated.

**Hughes, N., Strachan, N. and Gross, R., 2013. The structure of uncertainty in future low carbon pathways. *Energy Policy*, 52, pp. 45–54.**

This paper suggests that we should systematically register and categorise the various elements of certainty and doubt, which build our visions for the future, when we work with scenarios. Thereby, we can remove the uncertainties around impending technical and social changes when constructing low-carbon scenarios and transitions pathways. Further, it would also lead to an improvement of the efficiency and effectiveness of such scenarios and pathways. To do so, we must describe the dynamics linking the actors and institutions of the studied system so that we are able to sort out future elements of the system as being pre-determined, actor contingent or non-actor contingent. This would help in making clearer how a scenario's content is operationalised into specific policies and as a result improve the overall effectiveness of scenario-based policies as well as easing their assessment.

**Giampietro, M. and Sorman, A.H., 2012. Are energy statistics useful for making energy scenarios? *Energy*, 37(1), pp. 5–17.**

This paper deals with the epistemological issues met when attempting to account different energy forms, due to their unspecified qualitative differences. A joule of electricity has, for example, more value than a joule of coal. The article gives a critical examination of the suitability of energy statistics as they are currently practiced, and provides a novel scheme to account for the various energy forms across diverse hierarchical levels.

**Hofman, P.S. and Elzen, B., 2010. Exploring system innovation in the electricity system through sociotechnical scenarios. *Technology Analysis & Strategic Management*, 22, pp. 653–670.**

This paper argues that it is necessary to look beyond isolated technology change incidents because they lack explanatory power for the remaining system and rather towards larger socio-technical scenarios in what is called a multi-level perspective. They maintain that it is especially appropriate when working with infrastructures such as electricity systems because of the rare occurrence of simple substitution patterns, which results in the need for 'more qualitative storylines' as opposed to linear diffusion perspectives.

**Verbong, G.P.J., and Geels, F.W., 2010. Exploring sustainability transitions in the electricity sector with socio-technical pathways. *Technological Forecasting and Social Change*, 77, pp. 1214–1221.**

This paper applies a framework for exploring future transitions in electricity systems based on a socio-technical scenario approach using the multi-level perspective. They recognise that the regular dynamic of emergent technology within dominant regimes or niches—including but not limited to smart metering—may face special problems in infrastructure scenarios due to issues of sunk investments and the effect of high entry barriers.

**McDowall, W., 2014. Exploring possible transition pathways for hydrogen energy: A hybrid approach using socio-technical scenarios and energy system modelling. *Futures*, 63, pp. 1–14.**

Exploring hydrogen futures has shown to be a difficult endeavour. Uncertainties are high in long-term perspectives on transitions and different priorities and perspectives on hydrogen as option for decarbonising the energy system exist. This paper tries to overcome some of these challenges by confronting a qualitative approach to scenarios with quantitative modelling of energy systems, through what the authors call a 'dialogue' between model and scenario. They look at three transition pathways for hydrogen in the UK. Apart from discussing potential roles of hydrogen for transport, the authors discuss how hydrogen may play a role in decarbonising gas networks.

**Mathy, S., Fink, M. and Bibas, R., 2015. Rethinking the role of scenarios: Participatory scripting of low-carbon scenarios for France. *Energy Policy*, 77, pp. 176–190.**

Are low-carbon scenarios useful in public decision-making? This is the question that the authors attempt to answer in this paper. They do this by developing a 'process-oriented' low-carbon scenario, applying a codevelopment method, which should lead to more consensus. To do so, the authors involved 40



stakeholders from the private and public sections, and the state in the scripting of the low-carbon scenarios for France. This participatory codevelopment method for creating scenarios could help to get more acceptance for low-carbon trajectories.

**Winkel, M. and Radcliffe, J., 2014. The Rise of Accelerated Energy Innovation and its Implications for Sustainable Innovation Studies. *Science & Technology Studies*, 27(1), pp. 8-33.**

An 'accelerated energy innovation' imperative is prominently influencing modern energy policymaking processes. Understood as a response to ever-increasing urgency in calls for sustainable transition, this new mode of energy innovation policy and practice emphasises short-term targets (years instead of decades), support for large-scale deployment and cost reduction rather than long-term research and development, and continuity-based change rather than disruptive innovation. Much of the impetus for change is managed from the top down and, which is not conducive of niche-led innovation.



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