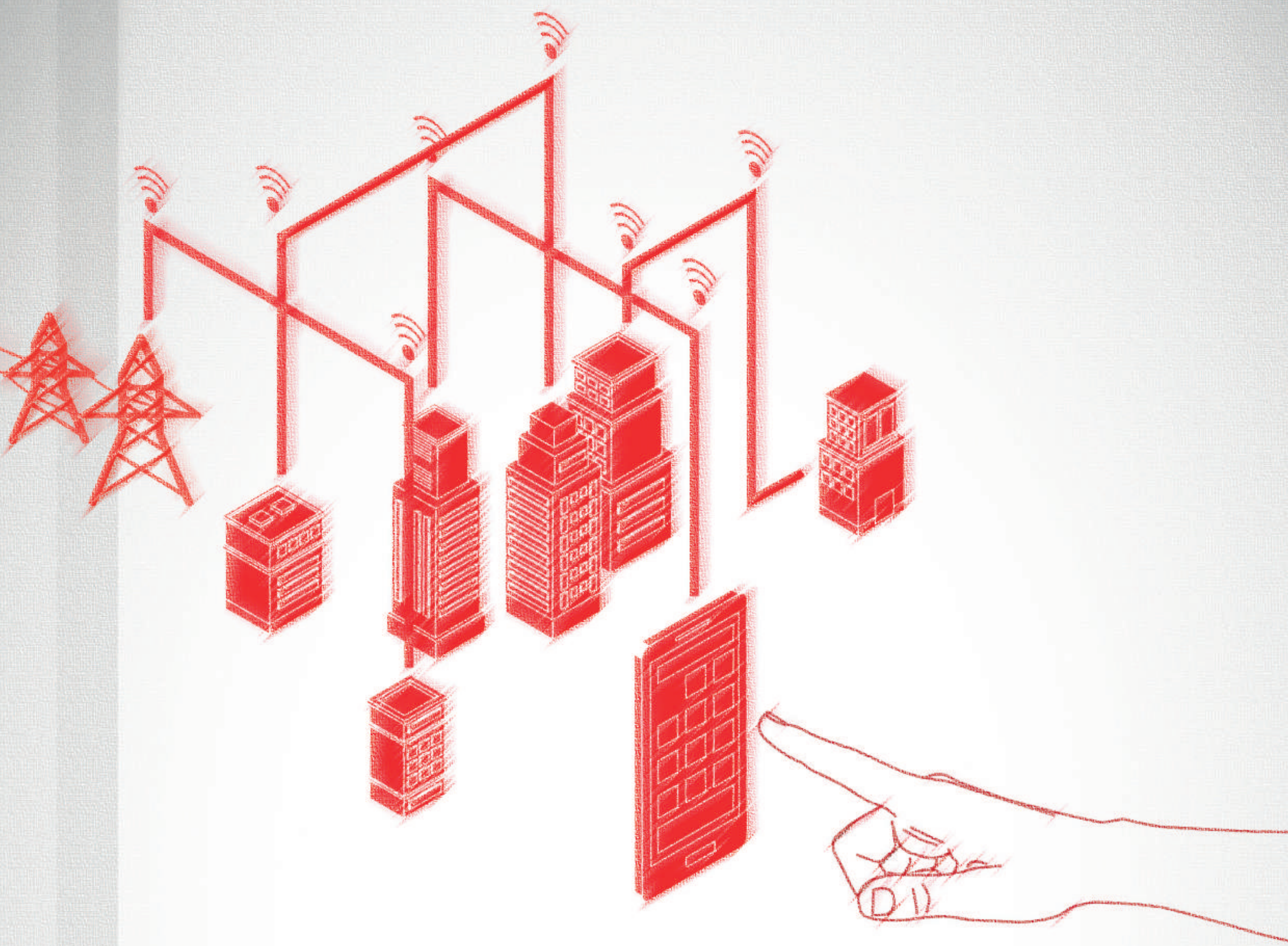

ENERGY SYSTEM OPTIMISATION AND SMART TECHNOLOGIES

a **social sciences and humanities** annotated bibliography

SHAPE ENERGY

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Executive summary

The challenge

- Systems perspectives on energy involve a holistic view on balancing demand and supply; system optimisation can support security of supply, affordability, sustainability and profitability.
- A central, and relatively recent, element of system optimisation is the move towards smart grids, and smart technologies, which concern interconnection of system elements usually through the internet. As well as increasing the resilience of the network, it is hoped this will help *"citizens take ownership of the energy transition [and] benefit from new technologies"*[1].
- 'Smartification' of the energy system introduces a range of new societal conditions and consequences.

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. The aim of this bibliography is to give policymakers a selected yet broad impression of the SSH research community focusing on 'energy system optimisation and smart technologies'. Wherever possible, policy deductions or research and innovation recommendations are mentioned.

Coverage

- Disciplines covered in this bibliography are broadly representative of the current SSH research community in the area, with a slight bias towards Economics, Sociology and Science & Technology Studies. Nevertheless, robust accounts from Psychology, Politics, Ethnography, Development, Environmental Social Science, Geography, Planning, Law, History and other fields are also included.
- Geographically, research presented is primarily from Western and Northern Europe, but with diversity across these regions, and inclusion of some Eastern European and non-European contributions.
- Techno-economic accounts are very highly represented in the field of energy system optimisation and smart technologies, a fact highlighted by researchers themselves. Much of this research concentrates on financial cost/benefit of smart grid and technical design, while approaches focusing on social practices or user-centric design are increasing but still underrepresented. The latter were deliberately given higher visibility in this bibliography.

Key findings

- Numerous papers presented here focus on how questions of smart technology diffusion, innovation, and adoption might be shifted away from monetary incentives or cost/benefit analyses of technologies.
- A unifying message across many topics and disciplines - from energy justice or socio-technical scenarios, to Economics or Ethnography - is that co-operation between techno-economic and SSH approaches needs more attention and is crucial for successful smart grid realisation.
- Another important debate for SSH researchers is the deconstruction of overly optimistic visions of smart societies. Many authors urge caution in considering the (financial and social) costs and benefits of smart technologies for all of society, including issues of privacy intrusion. There are calls for more research on both policy initiatives, preferably targeting the community level, and clear communication strategies which fully consider these aspects.

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1 European Commission, 2015. Delivering a New Deal for Energy Consumers, [online] Available at: https://ec.europa.eu/energy/en/publications/new-deal-energy-consumers [Accessed 30 May 2017].

Contents

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)[2]. SHAPE ENERGY aims to develop Europe's expertise in using and applying energy-related Social Sciences and Humanities (energy-SSH)[3]. 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[4] 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.

2 shapeenergy.eu

3 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.

4 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 [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: energy system optimisation and smart technologies

Energy system optimisation and smart technologies concerns, among other things, the integration of renewable energy sources (RES) into the energy system through the application of novel, internet-enabled ('smart') technologies, which can help compensate for the volatility of renewable energy supply. Such technical innovations in the system are leading to a variety of (intended and unintended) changes in social patterns, and the re-design of fundamental aspects of the energy system. In line with many descriptions of future energy systems and 'smart grids', consumption is a key component of change in smart energy transitions, a field where SSH researchers are at the forefront of research and development. As one example, the installation of smart electricity meters (digital meters with two-way communication potential) induce far-reaching possibilities for influencing consumption patterns, and thus impacting on system optimisation. Other key topics include: demand response (possibly enabling new, dynamic, energy pricing), prosumption (e.g. production and consumption of electricity by users), or self-healing networks and markets, among many others. The information and communication technologies (ICT) enabling these innovations can trigger new social arrangements and new ways SSH researchers can look at ensuing societal changes. In this bibliography, great emphasis is placed on the 'smart' component in energy system optimisation, including issues relating to smart grids, smart markets, and smart cities. Furthermore, literature which takes a holistic systems view, and which ties consumption back into system constraints, was targeted.

Methodology

In researching this bibliography, a deliberately tight focus on smart grids and associated smart technologies was taken. This is a focused and emerging field, and readers may be interested to know that many issues concerning particular aspects of energy supply and energy demand are more centrally covered in the other SHAPE ENERGY bibliographies ('Competitive, secure, low-carbon energy supply' and 'Energy efficiency and using less' respectively). As the topic pertains to a developing field in both STEM and SSH research, it is not surprising that this bibliography includes a variety of techno-economic accounts focusing on smart grids.

A literature search was conducted through the most common international academic search engines (e.g., *Scopus*, *Science Direct*, *Google Scholar*, *Social Sciences Citation Index*) and a deliberate search of leading journals (according to impact metrics and qualitative assessments such as relevance for the topic and expert recommendations). Another source for inclusion of references, as well as section and subsection divisions, was the consultation of several STEM and SSH experts in the field. Selection of papers from search engines was made on the basis of thematic relevance to the focus of this bibliography rather than high citation numbers. Disciplinary and geographical diversity were the second most important criteria. Finally, an emphasis was given to recent papers (rather than necessarily seminal, even though the latter has been accounted for in many sections). Most selected papers have been published after 2010, preferably as recently as possible. This is in part due to the rapidly changing nature of the smart grid sector that requires up-to-date research.

Structure

SSH scholars are interested in how and if the goals of energy transitions involving smart technologies can be realised, e.g. through acceptance of smart meters, new tariff structures and incentives, or energy entrepreneurship by average citizens. Others focus on visions and imaginaries, critique smart utopias or conduct life-cycle and policy assessments. Therefore, a large part of this bibliography deals with research about consumer perspectives on smart technologies and their current and future roles in the energy system. Consequently, the bibliography begins with 'System integration of consumers through smart technologies' (section 1), followed by 'Defining, envisioning and critiquing smart technologies' (section 2), in order to understand their implicit presumptions and challenge them accordingly. Further, the third section will target 'Societal conditions and consequences of consumer integration into smart energy systems', before 'Policy, markets and system dynamics in smart grids' are introduced (section 4). Along the way, common research problems and crosscutting topics will be addressed as subsections. Each subsection contains five papers (ordered alphabetically), to create a balance between the topics - although this does not imply they are equally strongly represented in the research community and/or policy debates.

1. System integration of consumers through smart technologies

A key issue for smart grids is the inclusion of consumers into the system as an active element that can make a difference to system performance. Crucial concepts of achieving this include demand-side management, prosumers (i.e. producing *and* consuming electricity) or energy citizenship (i.e. embracing energy as fundamental part of life). Many Social Science and Humanities (SSH) researchers are interested in the conditions of acceptance of smart technologies, or critically discuss the rationales behind such technologies, and alternatives to them.

1.1. Smart metering and demand-side management

Smart meters - digital electricity meters with two-way communication potential - are a central technological application in consumer-oriented system optimisation. They can help align demand and supply in energy systems, especially for systems with high shares of renewable energy systems (RES). This results in demand-side management, i.e. the attempt of adapting demand of energy to the supply that RES are able to deliver, given the volatility of wind and solar power. Smart meters are also used for cost and energy efficiency. SSH research in this field tackles real-life and experimental settings of consumer interaction with smart meters, cognitive and social schemes of smart meter usage as well as system effects such as profitability for households or privacy concerns.

Darby, S., 2010. Smart metering: What potential for householder engagement? *Building Research and Information*, 38 (5), pp. 442–457.

In this paper, Darby asks a pointed question: *"To what extent might smart meters improve the prospects for customer engagement"* (p. 442)? In her answers, she differentiates between driving customers toward general demand reduction and financial relief versus mere peak electricity (remote) control that serves grid stability purposes. Relying on qualitative methods and the theory of affordances, she presents a sceptical view that stresses questions of benefit distribution, design hurdles for users and social embedment of technology, issues which have not yet been sufficiently addressed.

Goulden, M., Bedwell, B., Rennick-Egglestone, S., Rodden, T. and Spence, A., 2014. Smart grids, smart users? The role of the user in demand side management. *Energy Research & Social Science*, 2, pp. 21–29.

Based on focus groups with 72 participants involving scenario techniques, two conflicting visions of demand side management are isolated: one that concerns consumers being managed by largely automated technology, and another that relies on more active demand response management. The latter is identified as one pertaining to the notion of 'energy citizens' (see subsection 1.2. 'Prosumers and energy citizens'), holding the most promising accounts for realisation of smart grids. On the policy-level, the authors acknowledge that smart energy systems will likely include a mix of both managing and managed consumer roles, yet urge decision-makers to focus particularly on local community needs in micro-grids and account for synchronisation of possibly contradicting consumer interests against the overall system rationale.

Higginson, S., Thomson, M. and Bhamra, T., 2014. "For the times they are a-changin": the impact of shifting energy-use practices in time and space. *Local Environment*, 19(5), pp. 520-538.

This is a paper that explores the possibilities of behavioural consumer change within daily household routines, with regard to demand response activities. This challenge is identified as a need of future consumer roles in order to make a smart energy system work. In this way, the authors relate to time-shifting energy use and practices of study participants through 24-hour household observation, interviews and data evaluation. *"The results challenge current approaches to demand response and suggest that disruption is a normal part of everyday life around which practices are able to rearrange themselves and that it is, therefore, possible to consider changing energy use practices"* (p. 520).

Lassalle, J., Amelot, A., Chauvin, C. and Boutet-Diéye, A., 2016. De l'artefact à la naissance de l'instrument pour la maîtrise de la consommation d'électricité : approche ergo-sociologique de la genèse instrumentale des smartgrids. *Activites* [online] 13(2). Available at: http://activites.revues.org/2875 **[Accessed on 18 May 2017].**

In the current context of sustainable development issues, smart grids are expected to develop new options enabling users to control their electricity consumption and reach more energy efficiency. To answer this necessity, smart grids are gradually becoming a resource for demand-side management (DSM). However, the issue of the appropriation of such new technologies by end-users is central in understanding the brakes and levers to the construction of their use and their contribution to DSM activity. This article proposes an interdisciplinary approach articulating sociology and ergonomics to study the smart grids' appropriation process considered as an instrumental genesis, i.e. the transition from an artefact to an instrument dedicated to an activity. Such an approach can be divided in three main focus points: *micro*, studying the activity mediated by smart-grid technology as well as the development of resources for and within the activity; *meso*, based on the study of social practices as the birthplace of the mediated activity; *macro*, searching for the interactions between actors of the socio-technical network in which the mediated activity occurs.

Nachreiner, M., Mack, B., Matthies, E. and Tampe-Mai, K., 2015. An analysis of smart metering information systems: A psychological model of self-regulated behavioural change. *Energy Research & Social Science*, Special Issue on Smart Grids and the Social Sciences 9, pp. 85–97.

From a psychological point of view, self-regulated behavioural change is a four stage model comprised of *predecision*, *preaction*, *action* and *postaction*: *"predecision: forming a goal intention, preaction: forming a behavioural intention, action: forming an implementation intention and starting to implement a behaviour and postaction: keeping up carrying out a new behaviour"* (p. 87). The authors discuss implications of different smart meter information systems and strategies for accelerated stage progression. In particular, they found that consumer support for transitioning from preaction to action stage and from action to postaction have been neglected most by the metering information systems under analysis, even though potentials through formed predecisions and preactions (I want to save energy, but how?!) are high.

1.2. Prosumers and energy citizens

The real-life and envisioned application of smart meters on a broad scale lead to concepts such as 'prosumers' (i.e. producing *and* consuming electricity) or 'energy citizenship' (i.e. embracing energy as fundamental part of life). This can signify a paradigm shift in consumer roles from passive service abiders to active service providers involved in self-generated electricity or electric vehicle management. This change is discussed vividly in the SSH community, involving questions such as consumer empowerment and entrepreneurship. In particular, new lifestyles and business models are discussed that are hoped to promote attitude changes into reflexive, sustainably thinking individuals to stimulate the success of low-carbon transitions.

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

This book chapter is concerned with psychological framings that shape individual decision-making related to energy. It is argued that for energy citizens as active, sustainable co-producers to evolve in future systems, socio-cultural frames such as consumer deficit models (i.e. consumers as passive service abiders) and of energy as a 'commodity' (i.e. market-based only view) need to be overcome. Given the history of centralised system patterns of technology and governance, several obstacles are still in place, presented here with special reference to the UK.

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.

Scholars in this paper scrutinise the concept of 'prosumption' and its transfer to the field of energy. Through in-depth interviews and ethnographic studies in microgeneration environments in Scotland, their findings show that there is sufficient value in deepening SSH research on prosumption in both electricity and heat domains. They demonstrate that in many cases, yet not always, adoption of prosumption technologies leads to changes in consumption behaviour.

Gangale, F., Mengolini, A. and Onyeji, I. 2013. Consumer engagement: An insight from smart grid projects in Europe. *Energy Policy*, 60, pp. 621–628.
The paper explores consumer engagement in smart grid projects in Europe, based on the report *Smart Grid projects in Europe: lessons learned and current developments*. The study reveals an increasing focus on consumer engagement issues in European smart grids projects. While most projects primarily apply observation method techniques to gather data on consumer actions to further understand their behavioural patterns, less attention is paid to possibilities of successfully market smart grid related information to consumers. According to the authors, the latter is mandatory for effective inclusion of customers into smart energy systems.

Geelen, D., Reinders, A. and Keyson, D., 2013. Empowering the end-user in smart grids: Recommendations for the design of products and services. *Energy Policy*, 61, pp. 151–161.
In this paper, the authors ask *"To what extent do the current products and services empower residential end-users to become co-providers in the energy system"* (p. 152)? Their finding is that current approaches in smart grid pilot projects are driven by technical and financial considerations primarily. As a supplement, they urge product design to be more open for community level installation (instead of merely home-centred), more interactive regarding communication between consumers and be more guiding when it comes to instigating behavioural change.

Wallenborn, G. and Klopfert, F., 2011. *Empowering consumers through smart metering*. Report for the BEUC, the European Consumer Organisation, [online] Available at: https://doi.org/10.13140/2.1.2711.4561 **[Accessed May 25 2017].**
The authors present a comprehensive report that focuses on the view point of consumers and analyse what a truly 'smart' meter could be, leading to several questions: Are smart meters useful to consumers? How should we deploy smart grids and meters to reach the 2020 EU objectives? How can we guarantee that current policies will look beyond 2020 and avert technological lock-in? Their answer: to deploy modular smart meters gradually to accompany the evolution of demand; to involve consumers in the creation and definition of the devices' functionalities before standardisation; consumers should be able to choose the type of smart meter that best meets their needs. As a result of this latter point, the authors recommend that smart data and its use be developed similarly to 'open source' movements: affected parties should have access to their consumption data and its potential transfer to third parties should be based on prior consumer consent.

1.3. Acceptance and refusal of smart technologies

The introduction of new technologies into established social environments always bears the risk of rejection, i.e. non-usage by consumers who stick to their familiar routines. This applies to smart technologies as such, but also to broader technological changes resulting from energy system optimisation like grid extensions due to RES increases. Therefore, SSH scholars target a range of issues around smart technology acceptance and embedment in local communities and cultural framings. Increasingly, these debates include approaches critically examining the theoretical foundations and purpose of acceptance, as well as discussions of neighbouring concepts such as 'acceptability' or 'trust'. For more discussion on the issue of acceptance, please refer to the annotated bibliography on 'Competitive, secure, low-carbon energy supply'.

Batel, S., Devine-Wright, P. and Tangeland, T., 2013. Social acceptance of low carbon energy and associated infrastructures: A critical discussion. *Energy Policy*, 58, pp. 1–5.
This paper critically discusses different facets of the term 'acceptance'. The authors argue and present empirical indications that it must not be conflated with the notion of 'support', which is crucial for technology adoption and behavioural change. Further expressions of public responses to energy infrastructures include resistance, apathy or uncertainty and deserve increased attention by the research community. The aim is to

better understand the complexities surrounding 'acceptance' and avoid biased searches for its successful application only.

Buchanan, K., Banks, N., Preston, I. and Russo, R., 2016. The British public's perception of the UK smart metering initiative: Threats and opportunities. *Energy Policy*, 91, pp. 87–97.

In this paper, focus groups of British consumers are evaluated regarding smart meter perception and pertaining services like automation, community rewards and gamification. Only automation of energy management received overall positive responses, as long as consumers keep control over if and when it would be applied. The most important conclusions the authors draw for policy-making are supplying the public with the 'bigger picture' of smart grid benefits and ensuring that smart grid services fit effortlessly in people's everyday lives.

Ellabban, O. and Abu-Rub, H., 2016. Smart grid customers' acceptance and engagement: An overview. *Renewable and Sustainable Energy Reviews*, 65, pp. 1285–1298.

This paper is an interdisciplinary endeavour by more technically oriented scholars who refer to social science discussions around 'acceptance' and relate the concept to smart grids. In their view, acceptance of smart grid products and services remains an enormous challenge. For energy systems researchers and decision-makers, their advice is to pursue strategies of integrated technology and automation where electricity suppliers interact more extensively with consumers to stipulate active behavioural patterns and enable mutual learning in novel energy education environments.

Marres, N., 2012. *Material Participation: Technology, the Environment and Everyday Publics*. Basingstoke: Palgrave Macmillan.

This book introduces a new way to relate everyday engagement with technology like smart meters to forms of participation that can be connected to 'acceptance' discussions in smart grids. Material participation, i.e. the idea that some kind of political activity is possibly embedded in continuous technology application, makes everyday use of it a political action. This is especially salient when use of technology coincides with a green political agenda, for example.

Wolsink, M., 2012. The research agenda on social acceptance of distributed generation in smart grids: Renewable as common pool resources. *Renewable and Sustainable Energy Reviews*, 16, pp. 822–835.

Wolsink discusses applications of his widely known acceptance concept to microgrids that he strongly interlinks with renewable energy deployment. In his evaluation, microgrids will only evolve in novel institutional structures that react to the decentralised logic of smart grids. In particular, he urges governance to be more 'polycentric', i.e. involving community levels much stronger in order to allow for diversity in microgrid incentives that are essential to their actual realisation.

1.4. System security, privacy and control

The application of smart technologies instantly raises questions about privacy and access to data. Particular issues which SSH researchers have explored in this context include concrete design propositions for smart grid privacy frameworks as well as notions of (perceived) control by consumers and issues of data distribution among utilities, users and third parties.

Döbelt, S., Jung, M., Busch, M. and Tscheligi, M., 2015. Consumers' privacy concerns and implications for a privacy preserving Smart Grid architecture—Results of an Austrian study. *Energy Research & Social Science*, Special Issue on Smart Grids and the Social Sciences 9, pp. 137–145.

The authors rely on an online survey and deepening focus groups to describe consumers' perspectives on trustworthy authorities for energy data storage and privacy threats. Results are that consumers perceive Austrian energy utilities as trustworthy to store data, yet as decentralised as possible and including transparency about who uses what data set for what purpose. To realise this, the authors suggest a self-management platform for consumers to regulate access possibilities to their data by third parties.

Fell, M.J., Shipworth, D., Huebner, G.M. and Elwell, C.A., 2014. Exploring perceived control in domestic electricity demand-side response. *Technology Analysis & Strategic Management*, 26 (10), pp. 1118–1130.

Another account that looks at control issues of consumers in relation to demand-response systems, based on focus groups in the UK. Among the available tariff structures three options were offered to participants of the study: fixed and dynamic time of use (TOU) pricing and direct load control. Important results include that *"almost everyone saw direct load control as reducing their control, although some framed this only in terms of control over appliances, while others were concerned about their overall autonomy"* (p. 1118).

Hansen, M. and Hauge, B., 2017. Scripting, control, and privacy in domestic smart grid technologies: Insights from a Danish pilot study. *Energy Research & Social Science*, 25, pp. 112–123.

Based on a Danish smart grid trial, the crucial notion of 'control' is addressed, primarily from a household perspective using smart technologies. In the originally scripted experimental setting, participants were subject to remote control of smart devices. It showed that people tried to take control over the technology and de-script its initial automation. Privacy concerns through violations of the 'private home' are crucially intertwined with these perceptions of (loss of) control and, according to the authors, determine greatly developments of active or passive smart grid users.

King, N.J. and Jessen, P.W., 2014. For privacy's sake: Consumer "opt outs" for smart meters. *Computer Law & Security Review*, 30, pp. 530–539.

Smart meters collect, store and make available for third party actors vast amounts of data about residential energy consumption. This can be a source of concern for consumers, even though it may be considered adequately dealt with from a technical point of view. A question then arises if consumers should be able to opt out of having smart meters installed. This paper explores this issue as it relates to the US and EU context.

Winter, J.S., 2015. Citizen Perspectives on the Customization/Privacy Paradox Related to Smart Meter Implementation. *International Journal of Technoethics*, 6, pp. 45–59.

Paper that critically assesses possible privacy concerns from a consumer perspective, applying the 'framework of contextual integrity'. Through interviews, instruction talks and periods of participant reflexivity, residential smart metering is mainly targeted. In the end, *"issues identified in this study included concern about unauthorized use and sharing of personal data, data leaks or spoofing via hacking, the blurring distinction between the home and public space, and inferences made from new data types aggregated with other personal data that could be used to unjustly discriminate against individuals or groups"* (p.45).

2. Defining, envisioning and critiquing smart technologies

A holistic view on energy system optimisation and smart technologies must include definitions, typologies and critiques of smart energy systems and/or its technologies. Therefore, this section initially deals with historical accounts of energy system optimisation, before typologies, critiques, visions and scenarios are introduced. A multifold picture of smart energy systems emerges that partly results in more realism regarding 'smart utopias', but also provides more detail in actually unfolding its narratives.

2.1. Historical accounts of energy system optimisation

As smart technologies are a very recent development in the early 21st century, historical accounts of energy system optimisation generally do not include them specifically. Still, smart grid innovations must be regarded in a larger historical-evolutionary context that they are inevitably embedded in.

Hughes, T.P., 1992. *The Dynamics of Technological Change: Salients, Critical Problems, and Industrial Revolutions.* In: G. Dosi, R. Giannetti, and P. A. Toninelli, ed. *Technology and Enterprise in a Historical Perspective*. Oxford: Clarendon Press. pp. 97–118.
A very influential account on how large technical systems developed through the continuous cycle of solutions for both technical and social problems, which in turn create novel challenges for energy system actors and policy-makers to take care of. Special emphasis is put on the idea of 'reverse salients' which embodies a type of threshold challenge for a system to overcome in order to further evolve.

Jefferson, M., 2015. There's Nothing Much New under the Sun: The Challenges of Exploiting and Using Energy and Other Resources through History. *Energy Policy*, 86, pp. 804–11.
An account of the early history of mankind struggling to exploit natural resources to provide useful energy (*exergy*). Again, this paper shows how socio-technical challenges have to be solved on a continuous basis, otherwise societies might fail not only in their aspirations for appropriate energy use but also as a whole.

Mayntz, R., 2009. *The Changing Governance of Large Technical Infrastructure Systems.* In: R. Mayntz, Über Governance. Institutionen und Prozesse Politischer Regelung. Schriften Aus Dem Max-Planck-Institut Für Gesellschaftsforschung, Band 62. Frankfurt am Main, New York: Campus. pp. 121-50.
A quasi-historical account but with a strong systems background, investigating structural changes (technical and organisational) in the production of services which in turn have consequences for the need for regulation – and vice versa novel governance efforts change the way of producing services.

Trentmann, F., 2009. Disruption is normal: blackouts, breakdowns and the elasticity of everyday life. In: E. Shove, F. Trentmann and R. Wilk, eds. *Time, consumption and everyday life: Practice, materiality and culture*. Oxford: Berg. pp. 67-84.
In this book chapter, historian Trentmann explores the phenomenon of 'disruption' through historical case studies and analysis of how new energy (and other societal infrastructure) systems may be disrupted. Trentmann observes that consumer culture, in contrast to its promises to make life smoother and easier, in fact may leave us more vulnerable to disruption. *"Disruption reveals the material world as tenuous and fragile, one that involves a lot of energy, maintenance and adjustments from consumers"* (p. 81).

Solomon, B.D. and Krishna, K., 2011. The coming sustainable energy transition: History, strategies, and outlook. *Energy Policy*, 39(11), pp. 7422-7431.
Solomon and Krishna highlight and explore a number of historical energy transitions, from wood to fossil fuels, and three countries' responses to the OPEC oil embargo (Brazil, France, US). They include a section specifically on the Smart Grid, in particular focusing on the current policy dimensions of Smart Grid implementation. The authors have a particular concern with speed of transition, and conclude that a global energy transition *"is extremely unlikely (if not technically impossible) ... in three decades or less"* (p. 7430).

2.2. Typologies and critiques of smart technologies

The 'smartification' of society seems omnipresent and the term, in some authors' view, has achieved an inflationary status. As a result, some SSH scholars have expressly dealt with definitions and typologies of smart technologies to make sense of the promises and self-descriptions developers, designers and industry are supplying. Critiques of smart technologies entail discussions around the 'smart utopia' or research on empty or floating signifiers of 'smartness'.

Bigerna, S., Bollino, C.A. and Micheli, S., 2016. Socio-economic acceptability for smart grid development – a comprehensive review. *Journal of Cleaner Production*, 131, pp. 399–409.

In this comprehensive smart grid systems approach, 148 papers are reviewed and divided by inclusion of *direct* (financial cost/benefit) and *indirect* (privacy, cyber security, regulation, consumer perceptions) costs of smart grids. The review shows that a majority of mostly technical and economic papers address financial cost issues, yet underestimate indirect cost matters which the authors consider crucial for smart grid acceptability. Among indirect costs, the order of importance in reviewed papers is cyber security, regulation, privacy and consumer perceptions.

Levinson, M., 2010. Is the Smart Grid Really a Smart Idea? *Issues in Science and Technology*, 27(1), [online] Available at: http://issues.org/27-1/levinson/ **[Accessed 23 May 2017].**

Online Journal contribution that discusses costs and benefits of smart grids from a financial and privacy point of view. Levinson argues that for the smart grid to be cost-effective, it requires vast amounts of customers to adapt their consumption behaviour in order to allow for demand response and reap the envisioned benefits for all parties – an uncertainty at the time. Given customer sensitivity to behavioural change in households and possible violations of privacy, he asks if it might be smarter to concentrate real-time dynamic pricing on commercial and industrial users instead.

Luque-Ayala, A. and Marvin, S., 2015. Developing a critical understanding of smart urbanism? *Urban Studies*, 52, pp. 2105–2116.

The idea of 'smart urbanism' is on the rise, evoking hopes of urban renewal through digital technologies and ensuing practices. These are expected to mitigate problems such as poverty, exclusion, and even climate change. Given these far-reaching objectives, the authors suggest to critically engage with why, how, for whom and with what consequences smart urbanism is emerging. In particular, they propose to theorise and conceptualise smart urbanism more diversely, e.g. to discover normative alternatives such as bottom-up approaches to its realisation.

Townsend, A.M., 2013. *Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia*. 1st ed., New York: W. W. Norton & Company.

This book explores the smart city from multiple angles, both corporate and civic, where electricity grid innovations are but one example of how digitalization changes modern cities The focus is on both historical-evolutionary and utopian views of cities and the socio-technical revolutions it brings along. One of them are smart grids, as the author exemplifies also in connection to social media potential for triggering energy savings through monitoring on web platforms and sharing with friends. (See also subsection 3.3. 'Smart cities, communities and city living labs').

Wilson, C., Hargreaves, T. and Hauxwell-Baldwin, R., 2015. Smart homes and their users: a systematic analysis and key challenges. *Personal and Ubiquitous Computing*, 19, pp. 463–476.

While a technology-focused approach to smart home still prevails, more user-oriented literature is detected by the authors in this comprehensive literature review throughout numerous disciplines. Still, in their view, the way users are approached lacks sophistication and should be guided by an organising framework the authors develop to more fruitfully connect research in the field and direct attention to some underestimated phenomena: privacy and control. (See also subsection 1.4. 'System security, privacy and control').

2.3. Socio-technical imaginaries and visions of smart energy systems

This subsection details research on smart grids as imaginaries and visions, as many of the far-reaching goals it may entail - such as virtual power plants or prosumers - are still future aims rather than current reality. In particular, Social Sciences and Humanities analyse the effects of future expectations for decisions and actions in the present, but also how technology and social organisation interact in imagined futures and visions on smart grids.

Ballo, I.F., 2015. Imagining energy futures: Sociotechnical imaginaries of the future Smart Grid in Norway. *Energy Research & Social Science*, Special Issue on Smart Grids and the Social Sciences 9, pp. 9–20.

A paper that presents a rather techno-economic imaginary of a smart grid in Norway, which, according to this analysis, lacks extensive public debate. The major aspects of this expert-driven vision for Norway are presented and primarily framed by technological progress and market rationales. Public concerns and social implications such as privacy, security or external control of appliances are less included, and, as a conclusion by Ballo, should be promoted.

Groves, C., Henwood, K., Shirani, F., Butler, C., Parkhill, K. and Pidgeon, N., 2016. The grit in the oyster: using energy biographies to question socio-technical imaginaries of 'smartness'. *Journal of Responsible Innovation*, 3, pp. 4–25.

Relying on interviews and multimodal methods, this paper argues that energy biographies derived from this extensive qualitative data play an equally vital role as technological visions in understanding and possibly re-shaping imaginaries of smartness. Referring in part to Strengers (2013) concept of everyday life smartification, energy biographies help to re-imagine smartness in the context of collective engagement, in families and communities, for instance, instead of solely relying on rationalistic individuals.

Köktürk, G. and Tokuç, A., 2017. Vision for wind energy with a smart grid in Izmir. *Renewable and Sustainable Energy Reviews*, 73, pp. 332–345.

The authors explore the vision of realising a wind energy system in the Turkish city of Izmir with the help of smart grid technologies. They evaluate its potential based on the regional circumstances mainly from a techno-economic perspective and unfold the vision with practical recommendations and outlooks.

Strengers, Y., 2013. *Smart Energy Technologies in Everyday Life: Smart Utopia?* Dordrecht: Springer.

This book examines the premises of what the author names a global utopian project of smart grids. In a first part, it is argued that utopian elements in smart energy visions resemble past energy utopias, and the everyday life practices for average consumers involved in this vision are unravelled. In the following, the four residential smart strategies of energy feedback, dynamic pricing, home automation and micro-generation are discussed.

Tricoire, A., 2015. Uncertainty, vision, and the vitality of the emerging smart grid. *Energy Research & Social Science*, Special Issue on Smart Grids and the Social Sciences 9, pp. 21–34.

The paper argues that the global smart grid sector is divided by competing visions that hamper development and cause uncertainty for involved actors. These actors, described through social network analysis and interviews with French stakeholders, are mainly established ones (energy sector incumbents) and new entrants (e.g. ICT field actors) with differing visions on the added value of smart grids. As a result, a true smart grid sector as a merger of both has not yet developed, leading to low degrees of cooperation between the numerous local and global actors identified in the paper.

2.4. Socio-technical modelling of and scenarios for smart grids

Dealing again with envisioning the future of smart energy systems to optimise its conditions, some SSH researchers engage in creating energy scenarios where they particularly focus on socio-economic indicators. In this interdisciplinary field between Engineering, Social Science and Systems Research, scholars often try to pay tribute to genuinely socio-technical views of energy.

Börjeson, L., Höjer, M., Dreborg, K.-H., Ekvall, T. and Finnveden, G., 2006. Scenario types and techniques: Towards a user's guide. *Futures*, 38, pp. 723–739.

Very helpful account that tries to put some order to the different approaches, which deal with future projections of energy and beyond. Explores the fundamental rationales applied in various scenario techniques such as *predictive, explorative* or *normative* scenario types, including shares of quantitative / qualitative data. Involves focused discussion on SSH contributions to socio-technical scenarios: "*Technical studies focus on objective trends. Hermeneutic studies aim at increasing a common understanding of social reality, whereas emancipatory studies aim at widening the perceived scope of options*" (p. 724).

Connolly, D., Lund, H. and Mathiesen, B.V., 2016. Smart Energy Europe: The technical and economic impact of one potential 100% renewable energy scenario for the European Union. *Renewable and Sustainable Energy Reviews*, 60, pp. 1634–1653.

This publication presents a pathway to a 100% renewables based energy system in Europe by 2050. The corresponding impact is quantified in nine steps relating to energy, the environment (carbon emissions), and economy (total annual socio-economic cost). This 'Smart Energy Europe' scenario is more financially costly than fossil-fuel alternatives, but is estimated by the authors to cause huge local investments in domestic technologies (RES-induced) compared to a decrease in fossil fuel imports.

Fortes, P., Alvarenga, A., Seixas, J. and Rodrigues, S., 2015. Long-term energy scenarios: Bridging the gap between socio-economic storylines and energy modeling. *Technological Forecasting and Social Change*, 91, pp. 161–178.

The authors in this paper apply a mixed methods approach that combines the advantages of both qualitative and quantitative research, rather than being separated which they consider the usual case. Instead, they try to use 'socio-economic storylines' in the case of Portugal and link these with quantitative energy modelling data to achieve a more holistic perspective. They "*conclude that a combined method that links socio-economic storylines and energy modeling increases the robustness of energy scenario development because providing a coherent context for modeling assumptions allows better reasoning, which is most valued for the decision-making process*" (p. 161).

Yanev, S., Stoyanov, I. and Stoyanov, V., 2013. Justification of smart grid modelling criteria. *Information, Communication and Control Systems and Technologies*, Year II, No. 1/2013, pp. 17-20, [online] Available at: http://www.utp.bg/wp-content/uploads/2016/01/1-2.pdf **[Accessed 23 May 2017].**

The article presents an overview of the existing solutions for smart grids and modelling criteria for different types of consumers, focussing on Bulgaria. Its purpose is "*to define the most suitable design criteria for the modelling of Smart Grids using photovoltaic power source and supplying a data server*" (p. 17). Besides techno-economic prerequisites the authors identify in the Bulgarian context, their focus is also directed at "*active customer participation to enable far better energy conservation*" (p. 19) and issues of cyber security.

Zio, E. and Aven, T., 2011. Uncertainties in Smart Grids Behavior and Modeling: What are the Risks and Vulnerabilities? How to Analyze Them? *Energy Policy*, 39, pp. 6308–6320.

Uncertainties pertaining to complex smart grid systems are identified that are of technological, environmental, financial, social and political nature. To deal with these uncertainties and transfer them into manageable yet scientifically sound decision-making models, more approaches of uncertainty analysis should be researched beyond purely probabilistic rationales, the authors argue. In particular, they emphasise the need for interdisciplinary co-operation between technical, economic and social sciences to achieve this ambitious goal and make first concrete recommendations.

3. Societal conditions and consequences of consumer integration into smart energy systems

Energy system optimisation and smart technologies bring along a range of societal conditions and consequences that are relevant to the SSH community. These concern affordability of energy, value design in smart grids, or social aspects of sustainability. They also involve discussions around societal experiments and visions as well as gender-related aspects of system optimisation.

3.1. Affordability and energy justice in smart grids

A crucial condition of energy system transformation is the justice of cost distribution and fair access to the benefits it brings along for everyone involved. SSH researchers are at the cutting edge of research in this field as they seek to determine causes and reasons for energy poverty as well as paths toward easing the problems they discover.

Alexander, B.R., 2010. Dynamic Pricing? Not So Fast! A Residential Consumer Perspective. *The Electricity Journal*, 23, pp. 39–49.

This paper asks if the installation of smart metering will move residential customers to 'dynamic' pricing and discusses some real social implications associated with this development. Alexander expresses special concern for young children, seniors, and disabled or sick people. She points out that remedying undue burdens on the poor depends on identifying them, and that seniors are often afraid of higher bills. She doubts the significance of relatively short pilot programs on dynamic pricing, *"based on a relatively small group of volunteers who receive extensive education and 'hand holding'"* (p. 42).

Darby, S.J., 2012. Metering: EU policy and implications for fuel poor households. *Energy Policy*, 49, pp. 98–106.

Darby once more provides a lucid overview of relevant definitions and functions of smart metering, as well as explaining the European political-legal situation with regard to smart metering, on one hand, and fuel poverty, on the other hand. The author warns against charging prepaying customers higher unit prices; recommends combining clear smart metering data with advice, and suggests preferential treatment for poor households during times of abundant supply.

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.

This paper looks closer at how energy justice has emerged as a new social science research agenda which seeks to apply justice principles to energy policy, and provides a conceptual review exploring its central tenets. Based on this comprehensive review, a global research agenda is suggested with both evaluative and normative potential. Energy justice research offers a way to identify first and foremost when injustice occurs, but also contributes to future development.

Oldfield, E., 2011. Addressing Energy Poverty Through Smarter Technology. *Bulletin of Science, Technology & Society*, 31, pp. 113–122.

Oldfield notes that energy poverty prevents economic and social growth. As a relief, he proposes developing ICT, web-based standards and energy mapping; in particular, he points out the need for interoperable data at different regional to national scales, paired with 'multigranular' spatial databases for data exchange, to support adaptive decision-making that can identify emerging value chains.

Wolsink, M.P., 2013. Fair distribution of power-generating capacity: justice, microgrids and utilizing the common pool of renewable energy. In: K. Bickerstaff, G. Walker and H. Bulkeley, eds. *Energy Justice in a Changing Climate: Social Equity and Low-Carbon Energy*. London, New York: Zed Books. pp. 116–138.

Wolsink sees two possible development paths for policies aimed at increasing fair distribution in microgrids: enhancing *"the autonomy of cooperating end-users to further their options to install renewable DG [distributed generation]"*, or furthering *"the construction of smart-metering [...] for increased surveillance [...] by energy* *companies [...] in line with centralized goals"* (p. 136). He concentrates on control: who regulates energy, information and financial flows? Who regulates access to microgrids, particularly for participants who cannot contribute? Who controls variability of tariffs?

3.2. Value-oriented design and user interaction in smart grids

Research on value-oriented design (design which takes account of the underlying ethical, or other, values of its potential users) and user interaction embodies an important branch of SSH relevant to energy system optimisation and smart technologies. SSH researchers may examine human-machine interactions in smart grids and ask more broadly about social costs, or concretely about micro-scale translations of smartification. Ethics researchers look at the value design of smart grids and strive for recognising individual and collective capabilities in the debate.

Katzeff, C. and Wangel, J., 2015. Social Practices, Households, and Design in the Smart Grid. In: L.M. Hilty and B. Aebischer, eds. *ICT Innovations for Sustainability*, *Advances in Intelligent Systems and Computing*. Dordrecht: Springer International Publishing. pp. 351–365.

Katzeff and Wangel argue for a new interactive smart grid design focused on social practices (rather than individual consumers) and 'communities of practice': *"[W]hat people do, and why and when they do it, is not to be seen as the result of individual decision-making, but as both an outcome and a part of an intricate multi-dimensional ecology of everyday life practices, each sustained by a specific mix of materials, images, and skills"* (p. 354).

Ribeiro, P.F., Polinder, H. and Verkerk, M.J., 2012. Planning and Designing Smart Grids: Philosophical Considerations. *IEEE Technology and Society Magazine*, 31, pp. 34–43.

The authors assess three tools that can be used by engineers to incorporate socio-philosophical aspects into design. Evaluation is based on each tool's ability to cover technological, dimensional and stakeholder complexity. Since each of these complexities is *"characterized by intrinsic norms"* (p. 37), the researchers identify these moments for every tool and make application recommendations.

Sahakian, M.D., 2011. Understanding household energy consumption patterns: When "West Is Best" in Metro Manila. *Energy Policy*, Special Section on Offshore wind power planning, economics and environment 39, pp. 596–602.

Sahakian notes that the focus of environmental policy has shifted to consumption, which she considers socio-culturally: as relations among people, forms of social belonging, goods as coded for communication or as symbols that bear meaning. It approaches the biophysical aspect of consumption which is *"a using up of resources with a consideration for throughput, growth, scales, and patterns of resource use"* (p. 597), concentrating on life cycle assessment. Mixes quantitative and qualitative data.

Skjølsvold, T.M., Jørgensen, S. and Ryghaug, M., 2017. Users, design and the role of feedback technologies in the Norwegian energy transition: An empirical study and some radical challenges. *Energy Research & Social Science*, 25, pp. 1–8.

The authors mobilise the notion of 'domestication' of technology in households to illustrate changes in human-technology interaction. Feedback technologies are assessed through *"videotaped guided tours of respondents' households"* (p. 3), 'walking and talking' through everyday consumption. They suggest changing some configurations: To include *"socio-technical knowledge in technology and design education"* (p. 7) (knowledge aspect), perhaps even place social scientists on equal footing to engineers (social aspect), offer monetary incentives for creativity (material aspect), and create *"new modes of routinized interaction"* (p. 7).

Strengers, Y., 2014. Smart energy in everyday life: are you designing for resource man? *Interactions*, 21, pp. 24–31, [online] Available at: http://interactions.acm.org/archive/view/july-august-2014/smart-energy-in-everyday-life-are-you-designing-for-resource-man **[Accessed 23 May 2017].**

Strengers criticises the stereotypical idea of what she calls 'resource man', associated with smart grid visions – a rational, data-driven and tech-savvy consumer, interested and competent in deciding, usually male. The author proposes designing with a new user in mind, suggesting that design should focus more on the domestic setting, thereby closely engaging with the practices of heating, cooling, laundry and cooking.

3.3. Smart cities, communities and city living labs

This strand of SSH research is interested in energy transitions, particularly smart grids, as real-life laboratories or societal experiments. Scholars discuss how system optimisation and the application of smart technology is a running experiment under constant review rather than a pre-designed plan which is merely implemented in certain stages of a 'roadmap', for instance. One culminating point for these experiments and labs can be cities, which are envisioned to achieve their own degree of smartness and sustainability in energy transitions.

Bibri, S.E. and Krogstie, J., 2017. Smart sustainable cities of the future: An extensive interdisciplinary literature review. *Sustainable Cities and Society*, 31, pp. 183–212.

Bibri and Krogstie offer an interdisciplinary review about future smart sustainable cities, discovering research opportunities for applied theoretical studies and theoretical development studies, as well as explorative, analytic, discursive and institutional studies. Yet they call for more theoretical development for the purpose of application, notably for measuring the effect of smartness on sustainability, and for ranking cities with respect to their sustainability contribution.

Burchell, K., Rettie, R. and Roberts, T., 2014. Community, the very idea!: perspectives of participants in a demand-side community energy project. *People, Place and Policy*, 8 (3), pp. 168–179.

The authors researched into participant perspectives from a large-scale demand-side community energy project in the UK called *Smart Communities*. They applied a *"local, informal and friendly"* research style, *"oriented around homes, people and children"* (p. 171), discovering that people were more trusting due to the project's non-commercial, local character. Believe scholars often define 'community' ambiguously, noting varying meanings among participants: many wanted to 'be a part of something', even when disinclined to direct interaction. One participant had believed energy saving was *"one more middle class competitive thing"* (p. 172). This differentiated reality of energy clients is important for policy-makers and entrepreneurs to consider in re-designing the system.

Canzler, W., Engels, F., Rogge, J.-C., Simon, D. and Wentland, A., 2017. From "living lab" to strategic action field: Bringing together energy, mobility, and Information Technology in Germany. *Energy Research & Social Science*, 27, pp. 25–35.

The authors observed a 'living lab' for cross-field innovation in a Berlin campus, where various skilled actors from academia and different industries converged. The living lab is said to furnish room for experimentation without the pressure of immediate market sanctioning. *"The emerging intersectoral field marked by the umbrella term of 'mobility-to-grid' is characterized by a tension between cooperation and competition"* (p. 33), as actors waver between strategies.

Hodson, M. and Marvin, S., 2010. Can cities shape socio-technical transitions and how would we know if they were? *Research Policy*, 39(4), pp. 477-485.

Hodson and Marvin suggest that the multi-level perspective (MLP), as their underlying conceptual tool, provides energy transitions in cities with *"a way of thinking about the relationships, resources and practices, including technologies, institutions, skills, etc., which sustain existing configurations and regimes but also addresses processes of adapting"* (p. 480). The paper refers to ignorance of spatial scale; has special focus on whether large world cities can govern local transitions and even influence national level as drivers of 'systemic' transformations. Claims that an indicator of success is the extent to which transition aims are *"embedded in practice"* (p. 483).

Späth, P. and Rohracher, H., 2010. 'Energy regions': The transformative power of regional discourses on socio-technical futures. *Research Policy*, Special Section on Innovation and Sustainability Transitions, 39, pp. 449–458.

The authors discuss the influence of a guiding vision toward renewable energies and economic change in the alpine Austrian district of Murau, which is declared an 'energy region'. They reinforce the insights from Hodson and Marvin (2010), based on transition research, by demonstrating how local stakeholders implement the vision in concrete regional settings and influence transition processes at the regime level: *"These strategies can be understood as systematic attempts to support discursive shifts at regime level by means of local activities, and aim to modify rather durable power structures"* (p. 449).

3.4. Green ICT and life-cycle-assessment

Contributions in this subsection aim at unravelling environmental and social costs of smart technologies, which emerge as a consequence of their current or projected use. This may be seen as a paradox of green ICT, which is supposed to ease environmental concerns but can also create new ones.

Khor, K.-S., Thurasamy, R., Ahmad, N.H., Halim, H.A. and May-Chiun, L., 2015. Bridging the Gap of Green IT/IS and Sustainable Consumption. *Global Business Review*, 16, pp. 571–593.

The authors of this collaborative paper consider the contents of journals and online proceedings on Green IT/ information systems (IS) with respect to ten organisational theories. They derive minimal effort strategies for companies, and suggest that theories on complexity and legitimacy could contribute to realising a corporate environmental agenda.

Jorge, R.S., and Hertwich, E.G., 2014. Grid infrastructure for renewable power in Europe: The environmental cost. *Energy*, 69, pp. 760–768.

One of the main challenges for the making of the modern grid is allowing it to make better use of intermittent renewable energy sources. The expansion in the grid of more renewable like solar and wind will bring with it a requirement for more transmission lines. This paper looks at the necessity for considering the environmental impacts of the new transmission capacity, finding that electricity transmission in Europe in 2020 will be more material intensive.

Moretti, M., Djomo, S.N., Azadi, H., May, K., De Vos, K., Van Passel, S. and Witters, N., 2017. A systematic review of environmental and economic impacts of smart grids. *Renewable and Sustainable Energy Reviews*, 68, Part 2, pp. 888–898.

This paper takes a closer look at the cost benefit and environmental impact analyses which are undertaken with respect to developing and implementing smart grid systems. The findings indicate their relative usefulness could be improved if there was less variation in how they were undertaken. Analysing methodologies used for economic and environmental evaluation of smart grids from seventeen different cases, the authors suggest work to be done on a standardising basis for models.

van Dam, S.S., Bakker, C.A. and Buiter, J.C., 2013. Do home energy management systems make sense? Assessing their overall lifecycle impact. *Energy Policy*, 63, pp. 398–407.

Within smart grid development and deployment activities there is often much focus on how new technologies may garner benefits, not just when it comes to energy efficiency and emissions reduction, but also monetary savings. This paper provides evidence on the life-cycle impacts of so called Home Energy Management Systems (HEMS), and shows that it takes time for these systems to gain back their environmental cost, and that this has implications for their design.

Nyborg, S. and Røpke, I., 2011. Energy impacts of the smart home-conflicting visions. *Proceedings of the 2011 ECEEE Summer Study, European Council for an Energy Efficient Economy, Stockholm*, pp. 1849-1860.

The paper looks at what visions are formulated regarding the role of households in the smart grid, and their articulation for the functionalities of the smart home. These visions are critically investigated to assess if the development of sustainable energy consumption is supported. The continued coevolution of homes and

ICTs may well have negative consequences for the overall energy impact of a green transition, as the smart grid *"could become a dynamic that constructs and normalizes new energy-demanding practices and facilitates escalating expectations to comfort"* (p. 1849).

4. Policy, markets and system dynamics in smart grids

Energy system optimisation and smart technologies are driven by market processes as much as by governmental and non-governmental actors. In order to enable RES-based energy systems, markets are discussed as a possible tool for providing reserve electricity as compensation for potential RES volatility. Smart markets are also deemed to provide other new business models, including consumer oriented electricity tariff structures and ICT-based start-ups. These new providers rethink the way electricity is marketed to both consumers and commercial clients. Another field SSH researchers are interested in is concerned with regulatory conditions, legal constraints and socio-technical dynamics within the systems targeted for change. Among the aspects analysed in this research area are specific societal conditions around energy transitions as well as multi-level-governance in Europe.

4.1. ICT-based business and market developments

This subsection tackles the dynamic change in the smart grid economy, which embodies much of the current energy transition. SSH authors explore emerging business models of utilities and novel actors on electricity markets. The latter includes ideas about capacity markets as possible compensation for volatility of wind and solar power, for instance. Others discuss value distribution on markets between providers, regulators and clients.

Bhagwat, P.C., de Vries, L.J. and Hobbs, B.F., 2016. Expert survey on capacity markets in the US: Lessons for the EU. *Utilities Policy*, 38, pp. 11–17.

The authors interviewed twelve energy experts in an anonymous questionnaire about US capacity markets which are intended to *"improve resource adequacy [...] by maintaining sufficient reserve margins"* (p. 12). Experts faced regulatory uncertainty and neighbouring markets with different product definitions / auction times. They suggested linking remuneration to performance under scarcity – which may be relevant for demand response and could tackle the problem of consumers not benefiting from reduced prices.

Giordano, V. and Fulli, G., 2012. A business case for Smart Grid technologies: A systemic perspective. *Energy Policy*, 40, pp. 252–259.

Giordano and Fulli aim at shifting business value from delivering electricity as a commodity, to offering a bundle of *"value added services"* (p. 252). Several case studies focus on the interplay between various types of service providers, for the purpose of mitigating investment risks and spreading costs via an interoperable multi-sided platform. The role of policy-makers is seen as *"promoting awareness to protect low income and vulnerable consumers"* (p. 258).

Hall, S. and Foxon, T.J., 2014. Values in the Smart Grid: The co-evolving political economy of smart distribution. *Energy Policy*, 74, pp. 600–609.

The authors argue that there is a mismatch between where benefits accrue and where costs are incurred in UK smart grid investments, leading to a problem of value capture and redeployment. Based on semi-structured interviews with stakeholders they identify ways in which municipalities can be important for business models for the delivery of smart infrastructure when they pursue specific economic opportunities through smart grid investment.

Roos, A., Ottesen, S.Ø. and Bolkesjø, T.F., 2014. Modeling Consumer Flexibility of an Aggregator Participating in the Wholesale Power Market and the Regulation Capacity Market. *Energy Procedia*, 58, pp. 79–86.

One of the novel attributes introduced into the energy markets by smart grids is the aggregator, an energy market actor that bases its portfolio on energy which arises from demand response. This paper presents one way of optimizing such activity when participating in the wholesale power market and regulation capacity market. A case study is performed using actual data from a set of Norwegian electricity consumers to test the model and estimate the value of aggregation in the current market framework.

Shomali, A. and Pinkse, J., 2016. The consequences of smart grids for the business model of electricity firms. *Journal of Cleaner Production*, 112 (5), pp. 3830–3841.
Shomali and Pinske examine some of the literature on conditions that affect innovation of electricity firms' business models in terms of value creation, delivery, and capture. Since previous literature covered many positive conditions, while they focus on negative ones, discovering primarily the constraint of institutional opposition to changing *"the paradigm of centralized generation"* (p. 3838).

4.2. Agent-based modelling of smart grids

Models driven and designed by economic theory and method are tools to comprehend market and policy processes around smart technologies and system optimisation. Increasingly, they are built to involve social aspects as well.

Howell, S., Rezgui, Y., Hippolyte, J.-L., Jayan, B. and Li, H., 2017. Towards the next generation of smart grids: Semantic and holonic multi-agent management of distributed energy resources. *Renewable and Sustainable Energy Reviews*, 77, pp. 193–214.
The authors review the history of electricity systems and conclude the need for a new vision of the energy system, one that is adapted to concepts of urban entities subject to big data, distributed generation and seamless communication. They propose a system of systems vision, with a hierarchy of properties that can be *"dynamically reconfigured to optimize the overall system's performance across energy carriers and scales"* (p. 210), thereby ensuring its adaptability.

Macal, C. and North, M., 2014. Introductory Tutorial: Agent-based Modeling and Simulation, in: *Proceedings of the 2014 Winter Simulation Conference*, WSC '14. Piscataway, NJ, USA: IEEE Press. pp 6-20.
Rather than dealing explicitly with the smart grid, this paper introduces the concept of agent-based simulation (ABS) in a tutorial like fashion. Agent-based modelling offers ways to more easily model individual behaviours and how behaviours affect others, and are thus useful for modelling smart grids. Apart from introducing agent-based modelling and simulation by describing the basic ideas of ABS, discussing some applications, this brief tutorial addresses some methods for developing agent-based models.

Malik, F.H. and Lehtonen, M., 2016. A review: Agents in smart grids. *Electric Power Systems Research*, 131, pp. 71–79.
This paper introduces agents as intelligent entities placed within environments to ensure flexible and autonomous decision making. It explores the main features of the smart grid and looks at how agents and their application in the power system can improve upon its smartness. It does this through a literature survey, and finds that agents are useful for monitoring, control, and market activities, ultimately producing a market place for electric vehicles and demand response.

Ringler, P., Keles, D. and Fichtner, W., 2016. Agent-based modelling and simulation of smart electricity grids and markets – A literature review. *Renewable and Sustainable Energy Reviews*, 57, pp. 205–215.
Amongst the literature on agent-based modelling and simulation (ABMS) in wholesale electricity markets, the authors reviewed contributions specifically on smart grids. Their findings: (i) ABMS should follow standards on model description, calibration, verification, validation and publication. Future SG research should (ii) study local markets (demand response, storage, liquidity lack, market power abuse) and (iii) take into account interactions (esp. learning) and coordination between (new) players, institutions and / or markets, to understand system-wide effects.

Rixen, M. and Weigand, J., 2014. Agent-based simulation of policy induced diffusion of smart meters. *Technological Forecasting and Social Change*, 85, pp. 153–167.
Rixen and Weigand study *"how regulatory interventions accelerate the adoption process (speed) and how they increase the long term penetration rate (level)"* (p. 154) of smart meters. They discover that i) speed *"is best induced via educational policies"* (p. 164), while level *"is best induced by monetary grants"* (ibid.); ii) monetary inducements are scalable in terms of level, information policies in terms of speed; iii) poorly chosen target

groups can strongly reduce effectivity (E1) and efficiency (E2); And finally, early interventions cause better E1 and E2, whilst short durations increase E1 and long durations decrease E2.

4.3. Innovation, diffusion and transition research

Social Sciences and Humanities (SSH) researchers in this field argue that it is crucial - for the successful introduction of smart technologies - to take account of the laws of innovation and market diffusion. Classic concepts in this domain are increasingly challenged by perspectives on collaborative, societal innovations (e.g. 'FabLabs', 'Open Design'), changing the patterns of what we consider successful, desirable and sustainable innovations. Transition researchers deal with the different levels involved in transforming the energy system.

Bruns, E., Ohlhorst, D., Wenzel, B. and Köppel, J., 2010. *Renewable Energies in Germany's Electricity Market: A Biography of the Innovation Process*. Dordrecht: Springer.

The history of the 'Energiewende' from the perspective of different innovation pathways is presented in this book. The study shows that the energy transition was – and is – a long incremental process which was by no means triggered by merely decision-making (i.e. nuclear phase-out decision in Germany), but involves numerous evolutionary processes of path dependencies, political windows of opportunity and technology diffusion.

Muench, S., Thuss, S. and Guenther, E., 2014. What hampers energy system transformations? The case of smart grids. *Energy Policy*, 73, pp. 80–92.

As many countries are focused on reducing greenhouse gas emissions and fossil fuel use, this paper points toward the smart grid as a solution for aiding such ambitions. However, it also notes that implementation of smart grid technologies is not moving forward as quickly as it could. Through fourteen in-depth interviews, this paper explores barriers to energy sector smartness, extrapolating policy recommendations from these.

Naus, J., van Vliet, B.J.M. and Hendriksen, A., 2015. Households as change agents in a Dutch smart energy transition: On power, privacy and participation. *Energy Research & Social Science*, Special Issue on Smart Grids and the Social Sciences, 9, pp. 125–136.

The authors outline an analytical framework which *"differentiates three emerging energy management practices (energy monitoring, renewable energy production and time-shifting) and three social arrangements (private, horizontal and vertical) that involve different ways of distributing control over these practices"* (p. 132). They recommend that future research should increasingly use surveys and focus groups to study 'bundles of practices', as systems are to open spaces for renegotiating relationships in transition processes.

Skea, J., 2013. The renaissance of energy innovation. *Energy & Environmental Science*, 7(21), pp. 21–24.

Skea provides a brief global and historical overview of research and development for energy, before concentrating on investment difficulties today. Notes a divergence between public and private aims, as existing institutional actors in the private sector attempt to defend their current interests. Describes the governmental dilemma of either supporting a technology in a neutral manner (e.g. carbon tax), or bridging *"the 'valley of death' between research and commercial deployment"* (p. 24).

Vesnic-Alujevic, L., Breitegger, M. and Pereira, Â.G., 2016. What smart grids tell about innovation narratives in the European Union: Hopes, imaginaries and policy. *Energy Research & Social Science*, 12, pp. 16–26.

The authors of this account look at innovation discourses (pedigree analysis) on smart grids, identifying narratives in EU policy documents, and studying online forums of citizens. They find that the official innovation vision is aligned with the industry discourse, but that it neglects debating citizens' arguments, moreover acclaiming a smart grid future as determined.

4.4. Policy-making and regulation for smart grids

Smart grids are not only set in motion by technology and its users, but also by policy programs and incentives. In this research area, SSH scholars analyse the complex interactions between different incentives schemes but also different policy-making levels such as regional, national and European. The enabling and constraining effects of these policy mixes and level relations are crucial factors influencing success or failure of energy system optimisation.

Connor, P.M., Baker, P.E., Xenias, D., Balta-Ozkan, N., Axon, C.J. and Cipcigan, L., 2014. Policy and regulation for smart grids in the United Kingdom. *Renewable and Sustainable Energy Reviews*, 40, pp. 269–286.

Since the liberalisation of electricity markets in most countries, Europe has seen a decline in energy sector innovation, a situation which pairs poorly with the ambition of rolling out a smarter grid. This paper deals with this issue as it reviews the situation in the UK, providing a comprehensive report on policy and regulation for smart grids there. Taking into account the viewpoints of many stakeholders, stronger government involvement to ensure swift implementation is warranted.

Oseni, M.O. and Pollitt, M.G., 2017. The prospects for smart energy prices: Observations from 50 years of residential pricing for fixed line telecoms and electricity. *Renewable and Sustainable Energy Reviews*, 70, pp. 150–160.

Oseni and Pollitt study 50 years of pricing in the electricity and telecommunications‘ sectors as a basis for predicting pricing for smart energy. They predict more time-based tariffing (as opposed to location-based), since the latter could be refused for reasons of fairness, without hiding that the same argument may be applied to time-based tariffing. Possibilities of a flat rate for basic consumption are discussed, as with mobile phones, supplemented by additional payments for over-consumption.

Rawlings, J., Coker, P., Doak, J. and Burfoot, B., 2014. Do smart grids offer a new incentive for SME carbon reduction? *Sustainable Cities and Society*, 10, pp. 245–250.

The authors study the possibilities of load distribution for small and medium sized enterprises (SMEs) in a demand-response system. One restriction is that their data is limited to the 1990s, when less IT equipment existed. Nonetheless, they recommend load-shifting for *“space heating, cooling and hot water in the commercial sector and heating in industry” (p. 250)*, as well as identifying an energy storage potential (hot water) in hotels, catering and retail. Future models should focus on premises and equipment.

Römer, B., Reichhart, P., Kranz, J. and Picot, A., 2012. The role of smart metering and decentralized electricity storage for smart grids: The importance of positive externalities. *Energy Policy*, Special Section: Past and Prospective Energy Transitions - Insights from History, 50, pp. 486–495.

The paper argues that volatility can be mitigated by decreasing demand elasticity (advanced metering infrastructure) and decoupling generation and consumption (decentralised storage). Regarding storage, the authors advise restraining explicit development into *niches*. According to interviews with eight German experts, societal benefits outweigh niche-building costs, but individual stakeholders‘ benefits do not outweigh their costs. The cited experts prefer clear regulation (e.g. for pooled property rights / cooperative business models), rather than public financing in terms of loans for smart meters, for example.

Schaechtele, J. and Uhlenbrock, J., 2011. *How to Regulate a Market-Driven Rollout of Smart Meters? A Multi-Sided Market Perspective* (SSRN Scholarly Paper No. ID 1855599), pp. 1-27, [online] Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1855599 **[Accessed 24 May 2017].**

Schaechtele and Uhlenbrock believe that investment in a market-driven smart meter rollout is obstructed by *“fragmentation of benefits among multiple stakeholders”* (p. 1) and therefore assess market structures. They favour *“a combined smart meter and grid operator, with a regulatory setup that permits the socialization of smart meter investment costs among all electricity consumers”* (ibd.). They understand the proposed Advanced Meter Infrastructure (AMI) as a multi-sided market, since it: (i) *“serves several market sides with different products and the number of involved agents rules out efficient negotiations”*; (ii) *“at least one market side exhibits indirect network effects*; and (iii) *“[...] it performs the core function of a shared resource, thereby reducing transaction costs for all market sides”* (p. 10).

4.5. Legal challenges for smart grids

Legal challenges pertaining to energy system optimisation and smart technologies primarily relate to state aid and market rules, consumer rights and procurement procedures, as explored in this subsection.

Angenendt, N., Boesche, K.V., Franz, O.H., 2011. *Der energierechtliche Rahmen einer Implementierung von Smart Grids*. *RdE* 20, pp. 117–126.

In the context of Germany, the authors provide a not exclusively technical definition of SG for both commercial and energy law, concentrating on integration of prosumers into networks that perform the function of competitive platforms, and pointing out there is no single network in Europe. Notable recommendations: (i) if rapid transition is preferred, eliminate 'unbundling'; (ii) clarify that commercial entities do not have to develop the network's capacity and performance more than needed (efficiency).

Borlick, R., 2011. Paying for Demand-Side Response at the Wholesale Level: The Small Consumers' Perspective. *The Electricity Journal*, 24, pp. 8–19.

This paper deals with how one should go about pricing re-captured energy, aggregated from demand response and demand side management, which are central aspects of smart grids implementation. There are a host of legal issues which need to be considered when this new 'energy resource' becomes available to policy makers, for instance how the income from energy sales would impact infrastructure investment, taxes and fair marketing.

Giacomarra, M. and Bono, F., 2015. European Union commitment towards RES market penetration: From the first legislative acts to the publication of the recent guidelines on State aid 2014/2020. *Renewable and Sustainable Energy Reviews*, 47, pp. 218–232..

One of the basic fundamentals underlying smart grid development is the legal framework governing the EU commitment towards renewable energy. This paper provides a historical overview of the development of this framework, including main financial programs. The paper also looks at the issue of State aid, which is a legal term relating to subsidies and free market management. The paper showcases instances of 'correct functioning' of the EU political framework.

McDonald, A.M. and Cranor, L.F., 2008. The Cost of Reading Privacy Policies. *Journal of Law and Policy for the Information Society*, 4(3), pp. 540–565.

McDonald and Cranor discuss the SG relevant notion of micropayments for consumer online data resulting in voluntary privacy losses. They evaluate pros and cons of this market-based variety vs. possible legislation to regulate consumer privacy with web applications. They reach the surprising conclusion that *"instead of receiving payments to reveal information, website visitors must pay with their time to research policies in order to retain their privacy"* (p. 540). In their calculation, web users in 2008 already had to spend between 30 and 40 minutes a day in order to read the necessary privacy policies of websites they were involved with. These results expose important empirical bases for possible SG consumer involvement and privacy regulation.

Quinn, E.L. and Reed, A., 2010. Envisioning the Smart Grid: Network Architecture, Information Control, and the Public Policy Balancing Act. *University of Colorado Law Review*, 81, pp. 833–892.

Quinn and Reed argue that *"all development tracks related to the flow of information in the smart grid are dependent on network-architecture decisions regarding the path and direction of that information"* (p. 892). Situated in the US context, they provide a detailed assessment of advantages and disadvantages in choosing a particular energy information manager: utility providers, non-utility industries, or a federal information or trade regulator.

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Acronyms

DSM	Demand-Side Management
EU	European Union
ICT	Information and Communication Technologies
RES	Renewable Energy Sources
SG	Smart Grid
SSH	Social Sciences and Humanities
STEM	Science, Technology, Engineering and Mathematics
UK	United Kingdom
US	United States

SHAPE ENERGY

Anglia Ruskin University | Global Sustainability Institute

KIT Karlsruhe Institute of Technology

POLITECNICO DI TORINO

LAET

NTNU Norwegian University of Science and Technology

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

Tomas Bata University in Zlín
Faculty of Management and Economics

BSERC black sea energy research centre

energycities

friends of europe

DuneWorks research & advice for sustainability

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