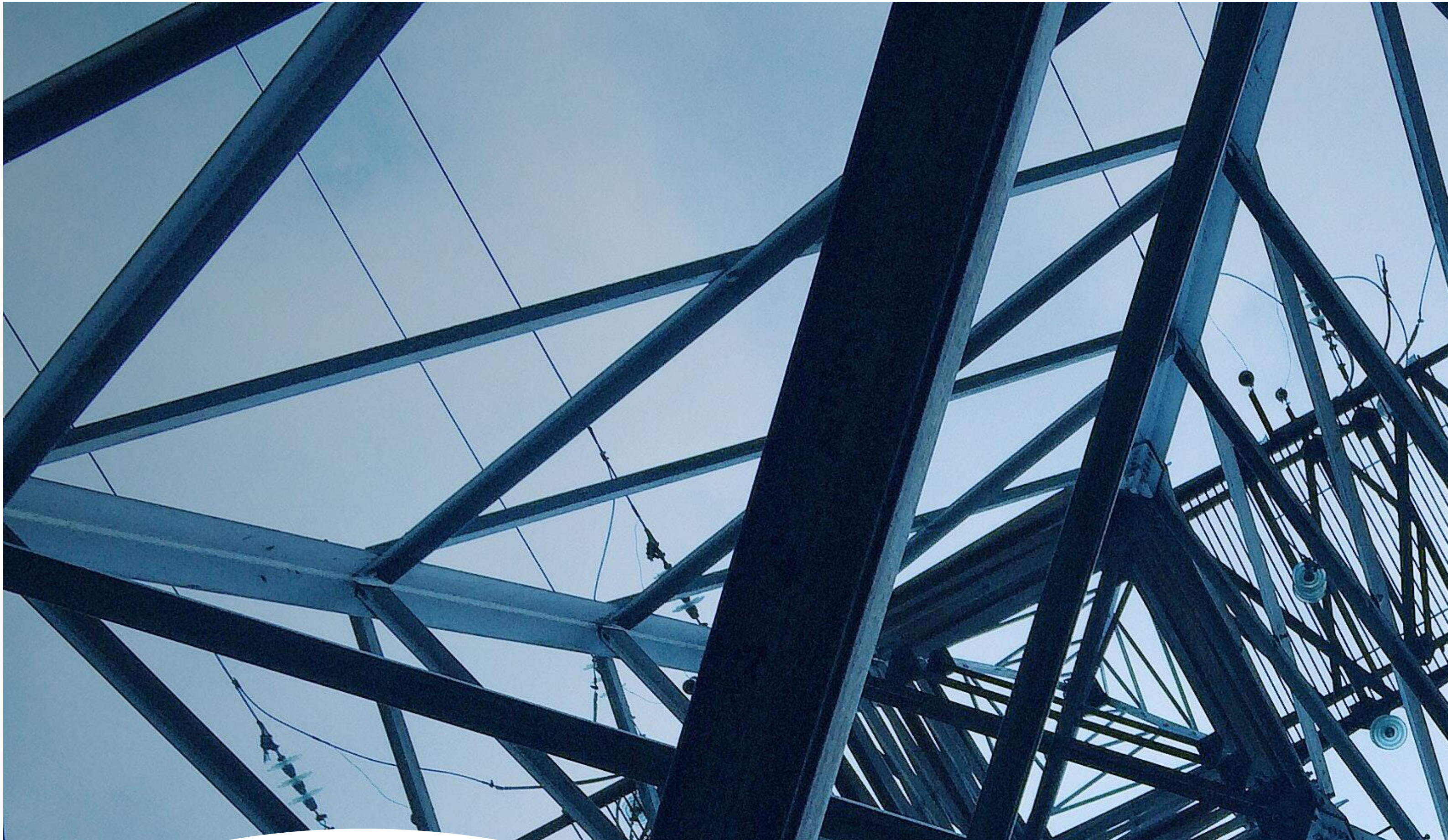

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RTPI RESEARCH PAPER APPENDIX

2019

PLANNING FOR A SMART ENERGY FUTURE

Appendix A: Academic literature review

THE Landmark PRACTICE

regen transforming energy

UWE Bristol University of the West of England

Pell Frischmann
Excellence through innovation

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This research was funded by RTPI South West.

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Introduction

This literature review was conducted in support of a research project that focused on how the UK's planning systems can better facilitate the delivery of smart energy, and therefore ensure an affordable, clean energy system for the future. The project, funded by the Royal Town Planning Institute South West, was led by Regen, in collaboration with Pell Frischmann, The Landmark Practice and the University of the West of England. The main report and other appendices can be found at www.rtpi.org.uk/smartenergy.

This research considers the characteristics of a smart energy system, and identifies potential interfaces with planning regulation, policy and practice. The research provides an overview of the technological changes that are expected to be necessary to deliver a smart energy future, and considers the interface that these changes are likely to have with the goals, tools and practices of spatial planning in England.[i]

While the research project acquired this intelligence through an online questionnaire aimed at different stakeholder groups, together with a series of workshops and personal interviews, the research team was keen to gain an appreciation of the wider discourse surrounding the planning of smart energy. Reviewing relevant literature was therefore an important part of the project, and underpinned the way the project's other research tools framed spatial planning issues relating to smart energy systems.

This review focuses on academic sources only, and particularly articles that have appeared in refereed journals. These papers were identified and accessed following a keyword search of UWE Bristol's online databases. This process generated a significant number of results, and this review focusses on the most relevant entries.

Overall, this review identifies that there is limited literature on the interface between planning systems and smart energy systems. Furthermore, where planning is mentioned, its contribution to the design and implementation of smart energy is only discussed in broad terms, which makes it difficult for robust conclusions to be made. Given this gap, the research therefore makes a very valuable contribution to both practical and theoretical debates surrounding smart energy planning and sets a useful foundation for further research in this area.

Context

Energy systems are currently transitioning from being fossil fuel-based to being zero-carbon in response to a range of factors. The most significant of these include a need to reduce greenhouse gas emissions (GHG), to reduce imported fossil fuels, and to reduce the costs of energy to 2050.[1] Although there is recognition that this change will need to continue into the future, there is uncertainty over the exact change considered to be necessary.[2]

To achieve the necessary transitions in energy generation and supply, a number of challenges

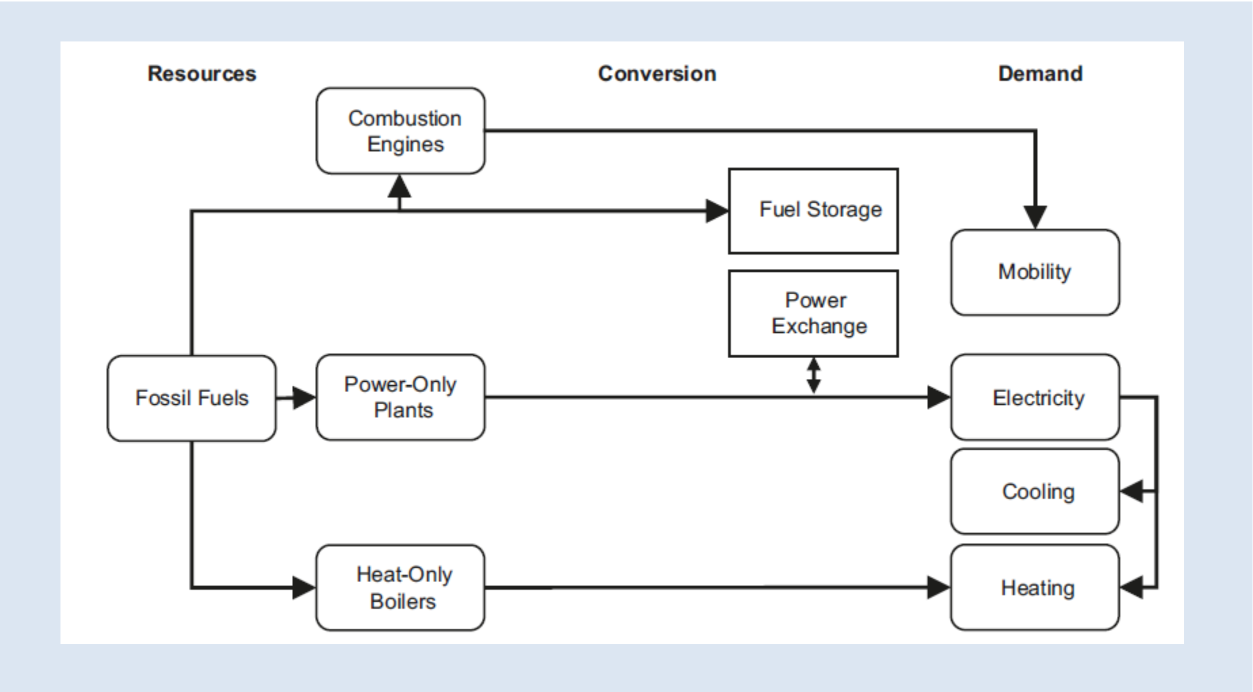
[i] 'National planning policy' refers to the UK Government's policy on spatial planning in England, unless otherwise noted.

need to be responded to.[3] For example, new technologies and infrastructures will need to be developed in order to utilise, and expand the use of, renewable energy resources. To ensure that new technologies are successfully implemented, work will be required to design and develop new markets, products, services and industries. Similarly, new policy and institutions will be necessary to ensure that the technologies developed and promoted are those best fitted to meet national and local need, opportunity and circumstances.

For the last 150 years, fossil fuels have made a significant contribution to energy use. Fuels such as oil, natural gas and coal are 'energy dense' fuels that can be effectively stored in liquid, gas and solid fuels respectively.[4] These forms of energy are available 'on-demand', with power plants using fuel to generate electricity in response to energy needs as they arise. Fossil fuel systems are characterised by highly segregated energy branches, and the supply chains for mobility, electricity, cooling and heating have limited interaction with one another (see Figure 1).[5] The systems are relatively simple in their design, with fossil fuels (coal, gas and oil) being converted (via a power plant, boiler or vehicle) to create an end use of electricity, heat or transport. Smart energy systems are inherently more flexible than such fossil fuel-reliant systems because they enable connection of the electricity, heating, cooling, and transport sectors together.[6]

The simplicity of fossil fuel powered systems means that many of the interactions that could occur across energy systems, at a range of spatial scales, have not been properly realised. For example, heat from power plants is often lost to a sea or river, rather than being used for local housing needs.[7]

***Figure 1**: Interaction between sectors and technologies in today's typical energy system. Source: Connolly, Lund and Mathiesen (2016, p1635).*



Since there is no direct replacement for fossil fuels, it is clear that existing energy structures that depend on their use cannot be maintained through the transition to renewable energy. Bioenergy (renewable energy created from natural, biological sources) is the only direct alternative to fossil fuels, and the physical and chemical properties of bioenergy would enable the continued use of existing energy infrastructure and institutions. These benefits are curtailed, however, by the limited availability of sustainable bioenergy.[8] Future energy systems therefore need to ensure that significant amounts of wind and solar power can be used in a way that avoids the unsustainable consumption of bioenergy.

Smart Energy Systems

A variety of terms have been used to encourage discussion on the form that a future energy system might take. Examples include the notion of a 'smart energy system', 'smart energy network' or some kind of 'smart energy grid'. The discussions in the literature about developing smart grids are framed around the need to better manage the fluctuations in supply that characterise the use of renewable energy. Such a grid involves a bi-directional power flow with consumers also producing to the grid. Such a system therefore differs from the traditional power grid, in which there is a clear separation between producers, on one side, and consumers on the other side (in other words a 'uni-directional power flow').[9] A number of papers focus on how consumers can become active in the operation of this power balance, by introducing technical operation systems and/or economic incentives to help make their energy demands more flexible. Examples include the development and design of information and communication systems, heat pumps, and electric vehicles. [10] Discussions surrounding smart grids in the literature tend to have a sole or predominant focus on the electricity sector, with relatively few emphasising the need for the intelligent management of a complete set of energy forms, of which electricity is just one.

The term 'smart energy system' seems to offer this desired level of completeness.[11] The term was first introduced in 2012 and was included in the title of a notable book published in 2014 that advocated for adopting a smart 'whole systems approach' to the choice and modelling of renewable energy systems.[12] A particularly helpful definition is provided by Connolly et al (2013), who explain how a smart energy system

> **"...consists of new technologies and infrastructures which create new forms of flexibility, primarily in the 'conversion' stage of the energy system. This is achieved by transforming from a simple linear approach in today's energy systems (i.e. fuel to conversion to end-use), to a more interconnected approach. In simple terms, this means combining the electricity, thermal, and transport sectors so that the flexibility across these different areas can compensate for the lack of flexibility from renewable resources such as wind and solar".[13]**

A smart energy system is therefore one that seeks to create new forms of flexibility within the energy system, primarily by creating flexibility in the conversion process through integrating the electricity, heating/cooling, and transport sectors. It is important to note that the concept of a 'smart energy system' therefore differs from that of a 'smart grid', which is usually focused on the operation of an electricity system that is designed to facilitate the better integration of fluctuating renewable energy.[14]

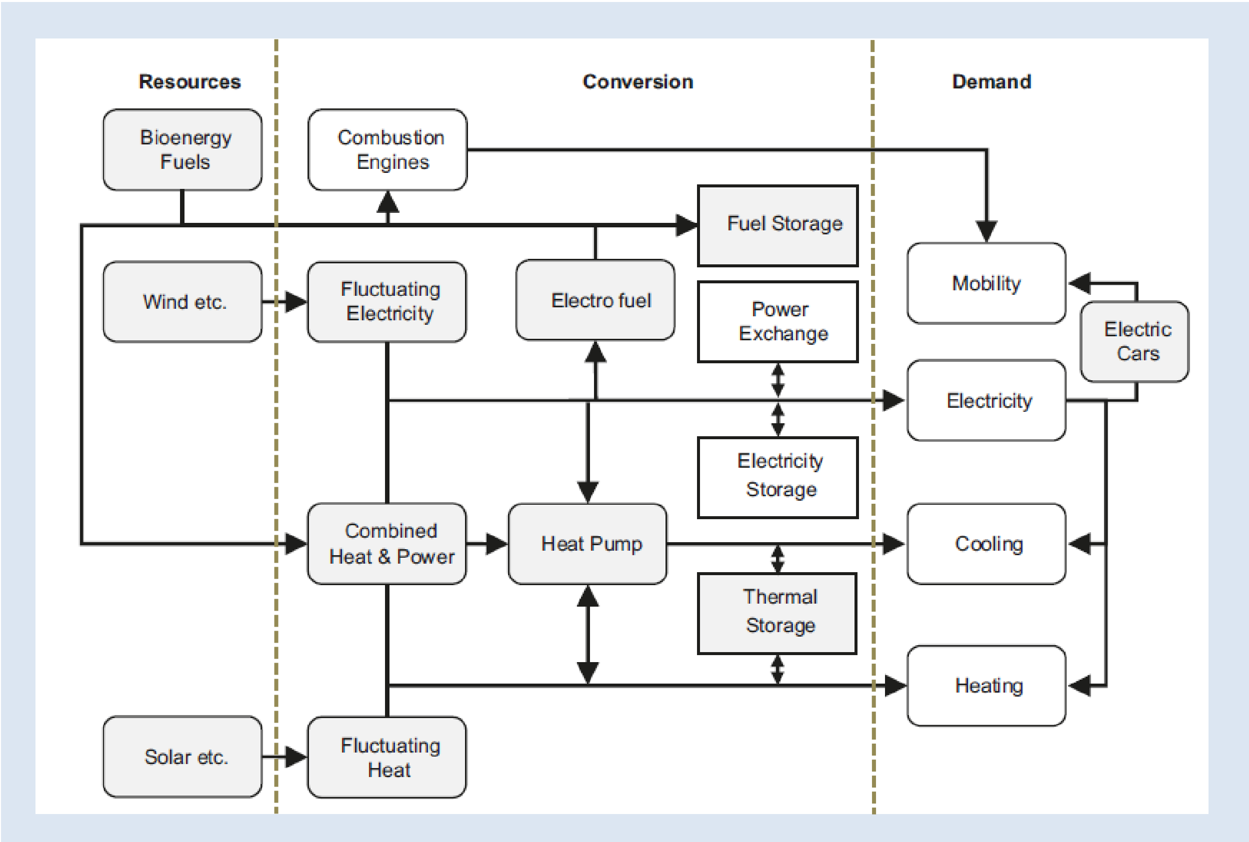
As an approach, a smart energy system envisages combined electricity, thermal, and gas grids, linked with appropriate storage technologies.[15] The smart energy concept consequently provides the basis for a paradigm shift away from single-sector thinking, to a coherent smart energy system. Reflecting this, the smart energy research community is committed to understanding how to design, analyse and discuss the benefits of including all sectors, infrastructures and grids. Three types of grid can be identified:

- **Smart electricity grids** to connect flexible electricity demands, such as heat pumps and electric vehicles, to the intermittent renewable resources such as wind and solar power;
- **Smart thermal grids** (district heating and cooling) to connect the electricity and heating sectors. This enables thermal storage to be utilised for creating additional flexibility and heat losses in the energy system to be recycled; and
- **Smart gas grids** to connect the electricity, heating, and transport sectors. This enables gas storage to be utilised for creating additional flexibility. If the gas is refined to a liquid fuel, then liquid fuel storages can also be utilised.[16]

A smart energy system requires renewable energy resources such as wind and solar power.[17] In contrast to fossil fuels, these resources do not contain large amounts of stored energy so, unless dedicated storage capacity is available, they must be captured and used immediately. An energy system built around renewable energy resources will also have an element of volatility attached to it. These variations, on an hour to hour basis, will depend on whether heat demand is high or low, whether a heat storage is full or not, or whether the electricity demand is high or low.[18] Capturing energy, and stabilising its use, represent key challenges that will demand major shifts to be made to the technologies, regulations, policies, and institutions of many of the world's current energy systems.[19]

Although the large-scale integration of renewable energy is seen as an important thread to the development of a smart energy system, energy storage and energy conservation measures are also needed, as are technologies such as CHP (combined heat and power), heat pumps and the roll-out of electrified transport (through the use of batteries and electrolysers).[20] **Figure 2,** below, attempts to visualise the key components of a smart energy system.[21]

__Figure 2__: Interaction between sectors and technologies in a future Smart Energy System. The flow diagram is incomplete since it does not represent all of the components in the energy sector, but the shaded boxes demonstrate the key technological changes required. Source: Connolly, Lund and Mathiesen (2016, p1636).



Once operational, a smart energy system can enable a wide-range of synergies to occur. For example:

- **Excess heat from industry and electricity** production can be used to heat buildings via district heating;
- **Electricity for heating** purposes makes it possible to use heat storage instead of electricity storage, which is both cheaper and more efficient;
- **Heat pumps for heating** can be used to provide cooling for district cooling networks and vice versa;
- **Electricity for gas** such as hydrogenation makes it possible to use gas storage instead of electricity storage which is cheaper and more efficient;
- **Energy savings in the space heating of buildings** make it possible to use low-temperature district heating which, in addition, makes it possible to utilize better low-temperature sources from industrial surplus heat and CHP;
- **Electricity for vehicles** can be used to replace fuel and provide for electricity balancing.[22]

The smart energy systems concept and approach has been discussed in relation to number of different spatial scales, from the European,[23] to individual countries (e.g. Denmark[24]) and individual cities (e.g. Zagreb[25]).

Despite its benefits, the term ‘smart energy system’ has been described as being nebulous,[26] while the term ‘smart’ has also been described as being somewhat misleading,[27] particularly where it is used to simply explain the application of technology or some kind of ICT solution.

The ‘smart energy city’

The term ‘smart energy city’ has been introduced to help give the smart energy concept a more urban perspective and to help simplify some of the technical explanations of the term.[28] Indeed, the goal for achieving a Smart Energy City (SEC) has also been presented as an urban development ‘strategy’ that seeks to exploit recent opportunities in technology and economy in order

> **“…to provide citizens with a better quality of life, while addressing urban energy challenges such as climate change, shortage of energy resources, and inadequate and deteriorating energy infrastructure”.[29]**

In addition to reaffirming what a smart energy city involves, this definition also outlines the type of interventions that are necessary for a SEC to happen:

> **“The Smart Energy City is highly energy and resource efficient, and is increasingly powered by renewable energy sources; it relies on integrated and resilient resource systems, as well as insight-driven and innovative approaches to strategic planning. The application of information, communication and technology are commonly a means to meet these objectives. The Smart Energy City, as core to the concept of the Smart City, provides its users with a liveable, affordable, climate-friendly and engaging environment that supports the needs and interests of its users and is based on a sustainable economy”[30]**

The term ‘smart energy city development’ is used elsewhere, a programme of works that aims at:

> **“a site-specific continuous transition towards sustainability, self-sufficiency, and resilience of energy systems, while ensuring accessibility, affordability, and adequacy of energy services, through optimized integration of energy conservation, energy efficiency, and local renewable energy sources. It is characterized by a combination of technologies with information and communication technologies that enables integration of multiple domains and enforces collaboration of multiple stakeholders, while ensuring sustainability of its measures.[31]**

Figure 3 overleaf presents a visual interpretation of ‘smart energy city development’.[32] The model characterises SEC development in a system driven by three energy-specific principles, namely those relating to:

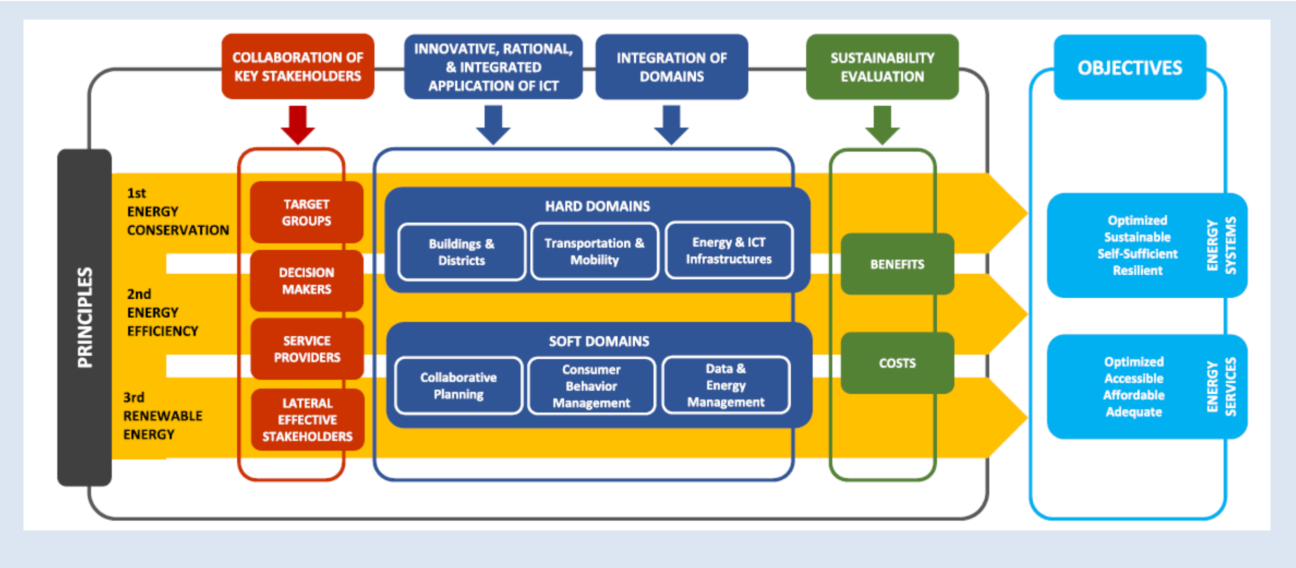
- **Energy conservation**, either by lessening energy use in necessary activities or services or removing energy use from services felt to be unnecessary;

- **Energy efficiency**, or securing less energy consumption for the same level of service, or delivering the same level of energy consumption for higher levels of service; and
- **Renewable energy**, referring to a general push to increase the share of local renewable energy sources.[33]

The three energy principles are amplified by a further four 'general principles', namely:

- Innovative, rational and integrated application of ICT;
- Integration of domains;
- Collaboration of key stakeholders; and
- Sustainability evaluation.

***Figure 3**: Smart Energy City (SEC) Development: the black outer box passes through SEC general principles; three yellow arrows reflect SEC energy specific principles pointing to the light blue box showing SEC objectives. The small red boxes indicate SEC stakeholder groups, small dark-blue boxes indicate SEC domains of intervention, and small green boxes reflect SEC sustainability evaluation aspects (Mosannenzadeh et al, 2017, page 58).*



The model presented at Figure 3 recognises the significant potential of the rational, innovative, and integrated application of new technologies and ICT.[34] In addition to the technological advances associated with the generation, conversion, storage and transfer of energy, the authors of Figure 3 also refer to the role that ICT can play in understanding people's behaviour and enhancing decision making processes, and the fact that improving the interaction between different energy components is also identified as a further area where ICT can make a difference. Despite presenting a positive view on the role that technology can play, the authors do acknowledge the limitations that technology, or certain applications of it, can have in addressing the complexity and multi-dimensionality of urban problems. In this way, the authors recognise that ICT can only be an enabler, rather than as an end to itself.

The model assumes the integration of both hard/tangible and soft/intangible domains. The former includes buildings and districts, as well as infrastructure related to transport and mobility and energy and ICT. Transport and mobility infrastructure includes technological innovations that encourage or facilitate a shift from oil-based fuels to alternative vehicle technologies that can use electric and draw from renewable energy sources, together with interventions designed to increase the use of public transport.

Hard energy infrastructure, meanwhile, is defined to comprise electricity infrastructure (smart grid), thermal infrastructure, and data infrastructure. Solutions in this domain are considered necessary in order for the infrastructure to become more resilient and to enable the integration of renewable resources into the energy infrastructure. In addition, energy infrastructure is also defined to comprise interventions that allow for the interconnection, monitoring and control of flows within energy networks.

Table 1 provides a summary, by category, of the infrastructures found across hard domains. The authors usefully identify the spatial scale towards which specific interventions are directed, ranging from the building, block, district and city.[35] Soft domains (see **Table 2**) relate to the application of human, intellectual and organisational capital, together with relevant software, to facilitate data and energy management, the shaping of consumer behaviour, and the promotion of collaborative planning.[36] Solutions relating to collaborative planning and decision making include tools designed to assist with the communication of data, knowledge, and ideas between stakeholders. They also include tools for facilitating the application of multi-stakeholder decision support systems, simulations, and scenario analysis tools. Solutions relating to consumer behaviour include those that seek to increase awareness amongst stakeholder groups about their energy consumption, presenting options for limiting their energy use, and communicating how shifts in personal behaviour can lessen energy use.

With respect to energy and data management, interventions are designed to optimise the overall energy system, from the sides of both energy supply (generation, distribution) and energy demand[37]. A wide variety of tools and instruments are encompassed within this category, with each having the potential to assist with the management, analysis, forecasting, and monitoring of SEC domains through the collection, storage, processing, and transformation of data.

***Table 1**: Smart energy solutions and technologies in hard domains of intervention with spatial scale (Source: Mosannenzadeh, 2017a, page 61-62)*

Domain	Sub-domain	Solution	Examples of applied technologies	Spatial scale			
				Building	Block	District	City
Buildings & districts	Existing (difficult)/new	- Improve conditioning system	- Insulation of pipes, radiant panels	x			
		- Improve conditioning control (heating/cooling)	- Sensors, self-learning algorithms, versatile	x	x		
		- Improve heat recovery	design	x	x	x	x
		- Connection with high-efficiency grids	- Recuperators (air, waste water)	x			
		- Thermal storage	- District heating, district cooling	x			
		- Mechanical ventilation	- Tanks, thermal inertia, phase-change material	x			
		- Hybrid ventilation systems	(PCM)	x			
			- Centralized or distributed ventilation machine				
			- Active overflow ventilation				
	Existing/new	- Adaptive facade systems	- Biomimetic facade	x	x	x	x
		- Solar active solutions	- Solar thermal, photovoltaic, active shading	x	x	x	x
		- High-efficiency generators	- Heat pumps, biomass & condensing boilers,	x			
		- Improve lighting system	chillers	x	x	x	x
		- Improve lighting control	- LED lamps	x			
		- Electric storage	- Photocells, presence and lux control	x	x	x	x
			- Batteries				
Mobility & transportation	Vehicles & fuel shifting	- Shift vehicle technology: electric vehicles, hydrogen vehicles	- Plugin, battery, hydrogen/electricity produced by renewable energy sources, second generation of biofuels	x	x	x	
	Multimodality & inter-modality	- Multi-modal and shared transportation: instrumenting vehicles for car-sharing	- Mobile applications, integrated payment options, real-time multi-modal information		x	x	x
		- Shift to other modes of transportation & personalizing travel	system, vehicle location technologies		x	x	x
			- Similar to previous solution				
		- Improve public transportation: exploiting ticketing, social media, routing, and mobile data			x	x	x
			- Similar to previous solution				
	Infrastructures	- Design transportation infrastructure: charging points, filling stations, hydrogen stations for H_2 vehicles, intelligent parking systems	- Plugins, induction charger, wall-boxes, H_2 technologies, sensors		x	x	x
Energy & ICT infrastructure	Electricity infrastructure (smart grid)	- Smart metering (monitoring)	- Smart meters, smart sensors	x	x	x	x
		- Automated distributed control to manage fluctuating production	- Smart switches, smart breaker, Transformer On-Load Tap Changer (OLTC)			x	x
		- Active loads	- Electrical vehicles, storage	x	x	x	x
		- Renewable and distributed energy generators	- Photovoltaic, heat pump, wind	x	x	x	x
		- Electrical energy storage	- Batteries, hydrogen fuel-cells, electric	x	x	x	x
		- Cyber security	vehicles, flywheels	x	x	x	x
			- Encryption algorithm				
	Thermal infrastructure	- Smart District Heating & Cooling (DHC)	- Meters, control, hydraulic equipment			x	x
		- Thermal energy storage	- Excavation, hydraulic equipment, large water			x	x
		- Enhance Geothermal Systems (EGS)	pits			x	x
		- Improve waste management/incineration	- Drilling, hydraulic equipment				x
		- Industrial heat recovery	- Biodigesters			x	x
			- Databases, market information				
	Data infrastructure	- Big data center for gathering data	- Green servers			x	x
		- Digital and communication infrastructure	- Power-line communication, fiber optic	x	x	x	x
Cross-cutting	–	- Energy dashboard	- Wi-Fi, web, electronic devices	x	x	x	x
		- Interacting energy networks	- Meters, control, hydraulic and electric equip-			x	x
		- Internet of things	ment	x	x	x	x
			- Wi-Fi, auto management, smart meters & switches				

The model advocates the full and engaged use of key stakeholder groups, with this being linked to a necessity for ensuring social inclusion and an investment in social capital. The authors identify four broad categories of stakeholder which they describe as: decision makers, service providers, target groups, and so-called 'lateral effective stakeholders'. **Figure 4** below identifies the specific nature of these groups.[38]

The importance of evaluating the sustainability of SEC development is also recognised by the model. Developers are directed to think about relative costs and benefits, although the complexity of undertaking such an appraisal is acknowledged given the varying temporal and spatial dimensions of each project.[39] For example, a rapid advancement in technology may generate new smart energy solutions to make practices, which were previously regarded as unsustainable, become sustainable.

***Figure 4**: Smart Energy City Stakeholders; each box encloses one stakeholder group and the arrows imply the interaction between stakeholders (Mosannenzadeh et al, 2017a, page 60).*

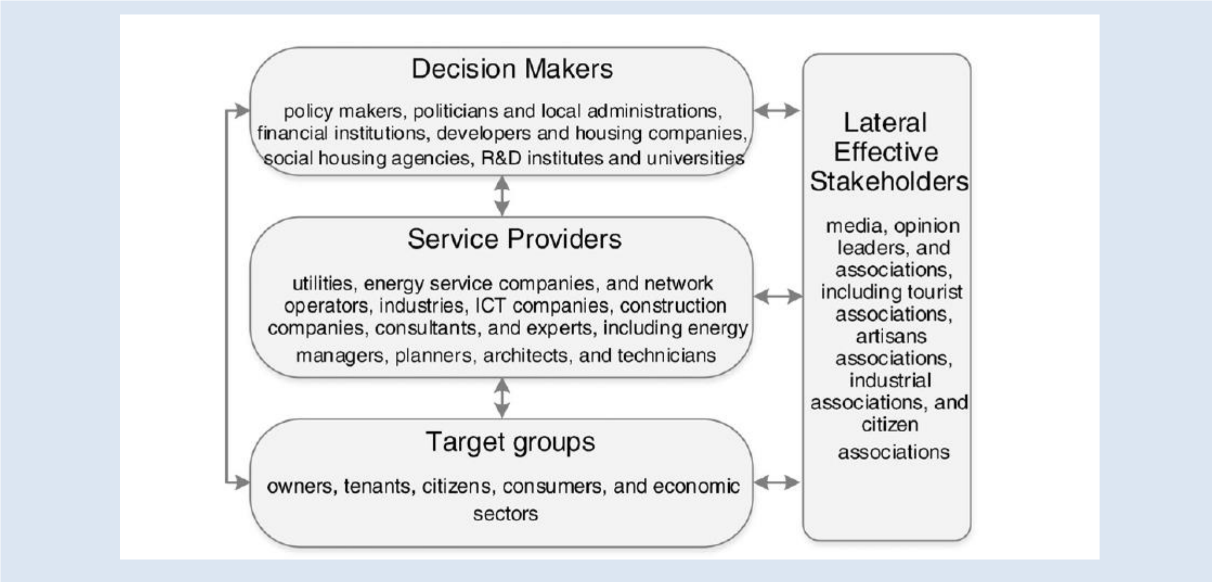


***Table 2**: Smart energy solutions and technologies in soft domains (Source: Mosannenzadeh, Bisello, Vaccaro, D'Alonzo, Hunter, G. and Vettorato, 2017, page 62)*

Domain	Sub-domain	Solution	Examples of applied technologies
Collaborative planning	Collaborative tools	- Stakeholder cooperation platform - Process-based collaborations - Innovative ways to frame & analyze data - Building & urban simulation & scenario planning tools - Decision-support systems - Shared frameworks - Performance-based public procurement	- Database, digital platforms - Cognitive maps, card sorting - Hackathons, social innovation labs - Infographics, network analysis, simulations - Modeling tools, Geographic Information Systems (GIS) - Decision-support systems - Performance metrics
Consumer behavior management	Information & awareness	- Social media for disseminating information - Open access information dissemination platform - Serious games - Feedback measures: improving availability & accessibility of knowledge on energy use - Education and training	- E-services - Database, digital platforms - Mobile applications, sensors, alarms - Energy dashboards, energy apps, alarms - Information campaigns, e-learning
	Demand management	- Car sharing, car-pooling, teleworking, last mile logistics, mobile ITS (location-based route/travel information and traffic light systems) - Intelligent community-based initiatives - Energy auditing tools and procedure - Demand response strategies	- GPS, mobile applications, internet, Wi-Fi, supply chain technology, shared logistic networks, sensors, devices; databases, centralized distribution systems - Sensors, information platform - Sensors, Wi-Fi, databases - Time varying pricing, interruptible and voluntary load reduction
Energy & data management	Management	- Energy network and infrastructure management system - Building management system	- Wireless technologies, controller-embedded gateways & servers, sensors - Performance monitoring, optimized managing tools, self--learning systems, "dynamic energy profiles" - Database, standards, open data, big data
	Analysis	- Interoperability and data protocols between city domains - Local resource and consumptions assessment systems (roof/-energetic/ground cadaster) - Zoning: quarters/district energy islands - Special building cadaster	- Databases, GIS
Cross-cutting	Monitoring	- Monitoring tools for the continuous improvement of the system	- Databases, algorithms - Sensors, Wi-Fi, databases
	Energy resilience	- Connect key information sources with city monitoring systems (sensors, people), with city 'life-lines' infrastructures (transport, power, water & communication)	- Sensors, Wi-Fi, databases
	Financing	- Innovative financing mechanisms (crowd funding), encourage dynamic models of PPP (e-government), smarter procurement (cloud-based software), dynamic pricing schemes	- Internet, database

Barriers

A number of commentators have focused on the barriers for delivery or implementing certain parts of a smart energy system. For example, commentators have previously focused on the motivations and barriers associated with microgeneration,[40,41] while other studies have been focused towards energy efficiency and renewable energy.[42,43] More recently, authors have focused on consumer engagement with smart home technologies.[44]

Broader perspectives on delivery have been provided to help urban planners create an energy efficient city.[45] Work has also been undertaken to focus on the obstacles for energy planning at the urban scale (as considered below)[46], and the prospects for municipality-led energy projects have also been considered.[47] A number of studies have been undertaken to help identify potential delivery issues with smart-energy systems, with authors[48] outlining the type of resources and actions felt to be necessary to increase roll-out. Mosannenzadeh has been a particularly important contributor to the discussion through her research that has sought to identify, and subsequently categorise, the type of barriers that can impact on the implementation of smart energy city projects across Europe. [49]

Particular insight has been provided via the work of the EU-funded CONCERTO programme which sought to generate intelligence and ideas for the delivery of 'energy solutions for smart cities and communities'.[50] The initiative supported local communities towards the sustainability of energy systems through local innovative energy efficiency interventions and by integrating local renewable energy sources in both new and existing urban districts. Collectively, the programme funded projects in 58 cities across 23 different countries. An initial assessment of the difficulties and barriers faced by these cities was undertaken in 2010.[51] By conducting research with the necessary authorities and stakeholders, the researchers were able to draw together a wide-range of barriers that they ordered under five categories: administrative, technical, social, legal, and economic. These barriers were then classified against three broad perspectives; micro (project/end user), meso (organization), and macro (state, market, civil society).

This initial work has been updated more recently, with the study highlighting a list of 35 barriers (as shown in **Table 3**).[52] Each of these was assigned to nine separate categories: policy, administrative, legal and regulatory, financial, market, environmental, technical, social, and information and awareness. The researchers then considered, via a structured questionnaire delivered by interview, the frequency and impact of these barriers in 43 CONCERTO projects.

It is clear that many of the barriers outlined in Table 2 have an urban planning dimension, most notably B1 (lack of long term and consistent energy plans), B7 (long and complex procedures for the authorisation of project activities), B14 (unfavourable local regulations for innovative technologies), B2 (negative effects of project intervention on the natural environment), B27 (deficient planning) and B35 (perception of interventions as complicated and expensive with negative socio-economic or environmental impacts).

Although the scores denoting impact are helpful in identifying ranked concern (with B2 being most significant), the authors provide some additional context by outlining some of the qualitative comments that respondents offered to accompany their assessment. For instance, in relation to B14 the authors refer to the impact of regulation relating to building aesthetics, with regulations relating to the historical preservation of buildings being identified as being particularly significant.[53]

Indeed, the authors note how:

> **"…in Italy, Spain, and France, where the number of historical buildings is very high, it is difficult to reconcile historical preservation and environmental aspects, in particular in the case of solar panel installations on buildings. This aspect was observed in a number of CONCERTO communities"[54]**

Table 3*: Barriers to the implementation of smart energy city projects: frequency and level of impact (Mosannenzadeh, Di Nucci, and Vettorato, 2017, p. 194). Level of impact changes on a range of 0 (neutral or no impact) to 5 (very high impact). The values indicated in this table were developed by Pezzutto et al. (2015).* [55]

Barrier Category	*Barrier*	Barrier code	Frequency	Level of Impact[a] (from 0 to 5)
Policy	Lack of long-term and consistent energy plans and policies	B_{01}	0.05	2.67
	Lacking or fragmented local political commitment and support on the long term	B_{02}	0.14	3.1
Administrative	Difficulty in the coordination of high number of partners and authorities	B_{03}	0.16	1.3
	Lack of good cooperation and acceptance among partners	B_{04}	0.26	2.9
	Lack of public participation	B_{05}	0.07	2.07
	Lack of institutions/mechanisms to disseminate information	B_{06}	0.02	3.07
	Long and complex procedures for authorization of project activities	B_{07}	0.19	1.93
	Time consuming requirements by EC concerning reporting and accountancy	B_{08}	0.12	4.0
	Complicated and non-comprehensive public procurement	B_{09}	0.12	2.3
	Fragmented ownership	B_{10}	0.19	4.0
Legal and Regulatory	Inadequate regulations for new technologies	B_{11}	0.09	1.13
	Regulatory instability	B_{12}	0.07	1.37
	Non-effective regulations	B_{13}	0.02	1.48
	Unfavorable local regulations for innovative technologies	B_{14}	0.12	1.6
	Insufficient or insecure financial incentives	B_{15}	0.19	1.22
Financial	High costs of design, material, construction, and installation	B_{16}	0.07	2.37
	Hidden costs	B_{17}	0.21	0.8
	Insufficient external financial support and funding for project activities	B_{18}	0.26	2.8
	Limited access to capital and cost disincentives	B_{19}	0.23	0.83
	Economic crisis	B_{20}	0.21	2.4
	Risk and uncertainty	B_{21}	0.07	1.07
Market	Split incentives	B_{22}	0.05	0.8
	Energy price distortion	B_{23}	0.05	1.02
Environmental	Negative effects of project intervention on the natural environment	B_{24}	0.06	4.33
Technical	Shortage of proven and tested solutions and examples	B_{25}	0.16	2.03
	Lack of skilled and trained personnel	B_{26}	0.28	3.07
	Deficient planning	B_{27}	0.16	1.13
	Lack of well-defined process	B_{28}	0.12	1.93
	Retrofitting work in dwellings in occupied state	B_{29}	0.05	1.7
Social	Inertia	B_{30}	0.16	2.03
	Lack of values and interest in energy optimization measurements	B_{31}	0.16	0.67
	Low acceptance of new projects and technologies	B_{32}	0.16	1.77
Information and Awareness	Insufficient information on the part of potential users and consumers	B_{33}	0.16	2.03
	Lack of awareness among authorities	B_{34}	0.02	2.03
	Perception of interventions as complicated and expensive, with negative socio-economic or environmental impacts	B_{35}	0.14	2.03

[a] Level of impact changes on a range of 0 (neutral or no impact) to 5 (very high impact). The values indicated in this table are found by Pezzutto et al. (2015).

For some of the barriers, further analysis of the views received would have been helpful. For instance, while for B27 (deficient planning) the authors refer to the implementation difficulties when systems do not 'accurately consider the conditions of both [the] natural and built environment', the example offered refers to a case where wind turbines were installed in a location where wind speed was ultimately inadequate.[56] Consequently, given that, for example, it is difficult to appreciate whether respondents were responding to inadequate regulations for the management of development, or as the example suggests, poor planning by project teams or energy developers.

Although this additional analysis would have been helpful for the majority of the identified barriers, the research also helped to identify the uniqueness of smart energy technologies and how they are often characterized by relatively high costs of design, material, installation, and construction and higher risk and uncertainty.[57] Hidden costs (B17), such as the general overhead costs of project implementation, are also described as being higher for new technologies, leading to the view that 'individuals with low-income, and companies with a limited access to capital, are not able to invest in such technologies'.[58] Similarly, the unique and innovative nature of some technologies was leading to low acceptance (B32), due to unfamiliar procedures and a lack of knowledge about the costs and benefits of new technologies among both consumers and authorities[59]. Associated with this, the authors also refer to a lack of institutions/mechanisms for disseminating project information (B06), a barrier that was mentioned in few CONCERTO projects. Similarly, the complexity of relevant actor networks, and the challenge of engaging with a diverse selection of stakeholders, was also identified as a challenge pertinent to smart energy developments.

The CONCERTO programme helped to offer guidance to both project coordinators and policy makers. For the former, the authors note:

> **"Considering the pivotal role of new technologies in SEC projects and numerous barriers associated with it, the selection of a technology should be preceded by careful consideration of related regulations and financial incentives, social acceptability and previous experience and expertise. Accordingly, employment of skilled and trained staff, especially operators and managers, for deployment and operation of new technologies is paramount for project success. Consequently, education and training within the project can improve project implementation".[60]**

For policy makers, the following advice is given:

> **There is a need for upgrading national, regional, and local regulations for the adoption of new technologies. Regulatory and support scheme stability at the national level is a fundamental feature for reducing investment risks and encouraging the private sector to take on new technologies. Accordingly, provision of new and appropriate business models, e.g. for public-private partnerships is essential for an appealing and successful collaboration between the public and private sector. Provision of wide-scale platforms and networks is fundamental for learning from other experiences and building knowledge around new technologies. This should be part of policies for general increase of information and awareness among all stakeholders, specifically general public and authorities on real costs and benefits of smart energy solutions in short to long term. Finally, the prioritization analysis of barriers shows that a consistent political support during the long term is paramount for successful implementation of SEC projects.[61]**

Energy planning at the urban scale

Cajot *et al*. (2017) outline the need for broader energy planning at the urban scale.[62] While the authors outline the significant role that buildings have in determining energy consumption and the emission of greenhouse gases, they acknowledge the importance of planning in helping to deliver a more holistic, cross-city framework for energy. Such a view develops previous work that identified how the transition towards renewable energy sources requires the strong intervention of municipalities in energy planning who need to develop appropriate institutional frameworks and help facilitate a 'two-way communication policy'.[63] Equally, Madlener and Sunak (2011) identify the 'inextricable link between urban planning and energy planning', with their paper outlining the influence that planning can have on the supply and consumption of energy at a range of spatial scales.[64] These interventions can extend from direction over the design and orientation of buildings, to the design of heating and cooling systems at the district scale.

Despite these associations, Cajot et al. (2017) refer to the work of Peter et al[65] and Strasser[66] by acknowledging how 'the consideration of energy as a central aspect of urban planning still lacks a proper framework and clearly designed methodologies'.[67] Cajot et al. (2017) therefore contend that the 'research and planning communities need to develop a new understanding of the role and form that urban planning should take in order that can take on the 'pressing issues' related to energy'.[68] Indeed, by acknowledging how urban planning must go beyond the traditional tasks of designing the city's spatial aspects and defining strategic targets, Cajot et al. (2017) explain how planning systems:

> **"…must be carefully and profoundly rethought to take ownership of, and appropriately address, energy and resource issues. This means that planners are expected to handle simultaneously both qualitative aspects such as aesthetics of urban form or quality of life, along with more the quantitative concerns for energy system design and engineering."[69]**

While identifying this need for urban planners to acknowledge and proactively plan for energy, Cajot et al. (2017) refer to some of the key obstacles to effective energy planning at the urban scale. Presenting energy planning as a kind of 'wicked' problem[70], the authors initially refer to the challenges that arise from the fact that energy planning, as an activity, is poorly defined. They cite the work of Thery and Zate (2009)[71] who define energy planning as a process responsible for determining the optimal energy mix for an area given projected demand. While this suggests a simple task of equating supply and demand considerations together, Cajot *et al.* also acknowledge the role, importance, and complexity of inherent technologies surrounding the supply, conversion, storage, and transportation of energy. In addition to considering these factors, energy planners must also take a more active role "in organising their energy systems from within their geographical boundaries".[72] Despite these expectations, they acknowledge the challenges that surround energy planning, given the complexities that arise from overlapping scientific, political and administrative systems and processes. Reflecting on these challenges, they go on to outline a 'paradigm change' for the stakeholders that need to be involved in energy planning. Specifically, by referring to the work of Coelho, Antunes and Martins (2010)[73], they consider the broadening nature of those who need to be involved:

> **"…from a limited group of specialists, including local and national authorities,**

energy companies and operators, to a wider one including as well as local producers, energy consumers, transportation companies, technical officers, international institutions, manufacturers of end-use appliances, financial institutions and environmentalist groups".[74]

Cajot et al. (2017) identify other important obstacles, including the disassociation of energy planning from the standard activities of a planning department. Citing the work of Caputo and Pasetti[75], they also suggest that municipal offices often lack knowledge and authority regarding energy planning. This latter point is attributed to the fact that urban planners often struggle to access important data, and that the dynamic nature of energy based-technology makes it difficult for 'planners to anticipate change and to understand which technologies they should invest in'.[76] Furthermore, they go on to acknowledge that:

"Energy planning in cities is dependent on different highly time-bound and volatile parameters, such as fuel prices and operational costs, energy conversion technology investment costs, improving and emerging technologies, population growth and high urbanisation rates, changing political actors and agendas, unstable international and national policy frameworks etc".[77]

The long-term nature of some urban planning projects can be problematic if they cut across different political, economic and policy cycles.[78] The design, phasing and construction of development is also felt to be critical if energy goals are to be achieved.[79]

Conclusions

A key finding of the literature review is the paucity of academic research into the interface between planning systems and smart energy systems. Whilst there is a growing body of research into what smart energy comprises and the principles that a smart energy system should seek to deliver, the ways in which planning can be effective in that delivery is addressed peripherally and in vague terms only.

The main driver to this research project is the imperative for the UK to make the transition to a smart energy future. The UK's planning systems have a fundamental role in facilitating the delivery of smart energy, and this research review provides real and much needed insight to complexities surrounding the delivery and implementation of smart energy. A range of factors were identified through the review with these spanning social, economic and environmental domains. Planning was mentioned at times as having a role to play but the depth of analysis associated with the exploration of this relationship was generally limited. The literature surrounding energy planning makes clear why planning professionals and elected politicians should engage with, and seek to understand, energy stakeholders and their associated technologies. The review identifies and describes issues linked to uncertainty over definition, the fast-paced nature of the energy industry, and the multitude of stakeholders that are inevitably involved. It does not, however, aid understanding of how planning systems, theory and practice might respond in a robust and effective manner to such issues, challenges and to opportunities as they arise in the future.

Focussed academic research into the interface between planning systems and smart energy systems is needed. The purpose of the research is to provide the depth of analysis necessary to underpin planning's role in the energy transition, and to contribute to understanding of how planning systems, policy and practice need to be framed to support and drive the UK's the transition to a smart energy future.

References

[1] Connolly, D., Lund, H., Mathiesen, B. V., Østergaard, P. A., Möller, B., Nielsen, S., Sorknæs, P. (2013) 'Smart Energy Systems: Holistic and Integrated Energy Systems for the era of 100% Renewable Energy' [online]. Available from: http://vbn.aau.dk/files/78422810/Smart_Energy_Systems_Aalborg_University.pdf (Last accessed 20.08.18)

[2] Connolly D., Lund, H., Mathiesen, B. (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, Volume 60, July, pp. 1634-1653.

[3] Connolly, D., Lund, H., Mathiesen, B. V., Østergaard, P. A., Möller, B., Nielsen, S., Sorknæs, P. (2013) 'Smart Energy Systems: Holistic and Integrated Energy Systems for the era of 100% Renewable Energy' [online]. Available from: http://bit.ly/2v9GGGp (Last accessed 20.08.18).

[4] Connolly D., Lund, H., Mathiesen, B. (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*, Volume 60, July, pp. 1634-1653.

[5] Connolly D., Lund, H., Mathiesen, B. (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*, Volume 60, July, pp. 1634-1653.

[6] Connolly D., Lund, H., Mathiesen, B. (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*, Volume 60, July, pp. 1634-1653.

[7] Connolly D., Lund, H., Mathiesen, B. (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*, Volume 60, July, pp. 1634-1653.

[8] Connolly D., Lund, H., Mathiesen, B. (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*, Volume 60, July, pp. 1634-1653.

[9] Lund, H., Andersen, A. et al. (2012) 'From electricity smart grids to smart energy systems – A market operation based approach and understanding'. *Energy*, 42(1), pp. 96-102.

[10] Lund, H., Andersen, A. et al. (2012) 'From electricity smart grids to smart energy systems – A market operation based approach and understanding'. *Energy*, 42(1), pp. 96-102.

[11] Lund, H., Andersen, A. et al. (2012) 'From electricity smart grids to smart energy systems – A market operation based approach and understanding'. *Energy*, 42(1), pp. 96-102.

[12] Lund, H. (2014) *Renewable Energy Systems: A Smart Energy Systems Approach to the ChoiceAnd Modelling of 100% Renewable Solutions*. Academic Press.

[13] Connolly, D., Lund, H., Mathiesen, B. V., Østergaard, P. A., Möller, B., Nielsen, S., Sorknæs, P. (2013) 'Smart Energy Systems: Holistic and Integrated Energy Systems for the era of 100% Renewable Energy' [online], page [3]. Available from: http://bit.ly/2v9GGGp (Last accessed 20.08.18).

[14] Connor, P., Baker, P., Xenias, D., Balta-Ozkan, N., Axon, C., Cipcigan, L. (2014) 'Policy and regulation for smart grids in the United Kingdom'. *Renew Sustain Energy Review*, 40(0), pp. 269–86.

[15] Lund, H., Alberg Østergaard, P., Connolly, D., and Vad Mathiesen, B. (2017) 'Smart energy and smart energy systems'. *Energy*, Volume 137, October, pp. 556-565.

[16] Lund, H., Andersen, A. et al. (2012) 'From electricity smart grids to smart energy systems – A market operation based approach and understanding'. *Energy*, 42(1), pp. 96-102.

[17] Connolly D., Lund, H., Mathiesen, B. (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*, Volume 60, July, pp. 1634-1653.

[18] Lund, H., Andersen, A. et al. (2012) 'From electricity smart grids to smart energy systems – A market operation based approach and understanding'. *Energy*, 42(1), pp. 96-102.

[19] Lund, H., Andersen, A. et al. (2012) 'From electricity smart grids to smart energy systems – A market operation based approach and understanding'. *Energy*, 42(1), pp. 96-102.

[20] Lund, H., Andersen, A. et al. (2012) 'From electricity smart grids to smart energy systems – A market operation based approach and understanding'. *Energy*, 42(1), pp. 96-102.

[21] Connolly, D, Lund, H. and Mathiesen, B. (2016) Smart Energy Europe: The technical and economic impact of one potential 100% renewable energy scheme for the European Union, *Renewable and Sustainable Energy Reviews*, 60, pp. 1634-1653.

[22] Lund, H., Alberg Østergaard, P., Connolly, D., and Vad Mathiesen, B. (2017) 'Smart energy and smart energy systems'. *Energy*, Volume 137, October, pp. 556-565.

[23] Connolly D, Mathiesen BV, Lund H. (2015) *Smart Energy Europe: From a Heat Roadmap to an Energy System Roadmap*, Aalborg University.

[24] Connolly, D., Lund, H., Mathiesen, B. V., Østergaard, P. A., Möller, B., Nielsen, S., Sorknæs, P. (2013) 'Smart Energy Systems: Holistic and Integrated Energy Systems for the era of 100% Renewable Energy' [online]. Available from: http://bit.ly/2v9GGGp (Last accessed 20.08.18).

[25] Bacekovic, I., and Alberg Østergaard, P. (2018). A smart energy system approach vs a non-integrated renewable energy system approach to designing a future energy system in Zagreb. *Energy*. July. pp. 824-837.

[26] Mosannenzadeh, F., Di Nucci, M., and Vettorato, D. (2017b) 'Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: An empirical approach'. *Energy Policy*, Volume 105, pp. 191-201.

[27] Hollands, R. G. (2008).Will the real smart city please stand up?: Intelligent, progressive or entrepreneurial? *City*, 12, 303–320. http://dx.doi.org/10.1080/13604810802479126.

[28] Mosannenzadeh, F., Bisello, A., Vaccaro, R., D'Alonzo, V., Garfield, H. and Vettorato, D. (2017a) 'Smart energy city development: A story told by urban planners'. *Cities*. 64, pp. 54-65.

[29] Mosannenzadeh, F., Bisello, A., Vaccaro, R., D'Alonzo, V., Garfield, H. and Vettorato, D. (2017a) 'Smart energy city development: A story told by urban planners', *Cities*. 64, p54.

[30] Nielsen, P. S., Ben Amer, S., and Halsnæs, K. (2013) *Definition of smart energy city and state of the art of 6 transform cities using key performance indicators: deliverable 12*, page 3.

[31] Mosannenzadeh, F., Bisello, A., Vaccaro, R., D'Alonzo, V., Garfield, H. and Vettorato, D. (2017a) 'Smart energy city development: A story told by urban planners'. *Cities.* 64, page 57.

[32] Mosannenzadeh, F., Bisello, A., Vaccaro, R., D'Alonzo, V., Garfield, H. and Vettorato, D. (2017a) 'Smart energy city development: A story told by urban planners'. *Cities.* 64, page 57.

[33] Mosannenzadeh, F., Bisello, A., Vaccaro, R., D'Alonzo, V., Garfield, H. and Vettorato, D. (2017) 'Smart energy city development: A story told by urban planners'. *Cities.* 64, page 57.

[34] Mosannenzadeh, A., Bisello, A., Diamantini, C., Stellin, G. and Vettorato, D, (2017b) 'A case-based learning methodology to predict barriers to implementation of smart and sustainable urban energy projects'. *Cities*. Vol. 60, February, pp. 28-36.

[35] Mosannenzadeh, F., Bisello, A., Vaccaro, R., D'Alonzo, V., Hunter, G., and Vettorato, D. (2017a) 'Smart energy city development: A story told by urban planners'. *Cities*, pages 54-65.

[36] Mosannenzadeh, F., Bisello, A., Vaccaro, R., D'Alonzo, V., Hunter, G., and Vettorato, D. (2017a) 'Smart energy city development: A story told by urban planners'. *Cities*, pages 54-65.

[37] Mosannenzadeh, A., Bisello, A., Diamantini, C., Stellin, G. and Vettorato, D, (2017b) 'A case-based learning methodology to predict barriers to implementation of smart and sustainable urban energy projects'. *Cities*. Vol. 60, February, pp. 28-36.

[38] Mosannenzadeh, F., Bisello, A., Vaccaro, R., D'Alonzo, V., Hunter, G., and Vettorato, D. (2017a) 'Smart energy city development: A story told by urban planners'. *Cities*, pages 54-65.

[39] Mosannenzadeh, A., Bisello, A., Diamantini, C., Stellin, G. and Vettorato, D, (2017b) 'A case-based learning methodology to predict barriers to implementation of smart and sustainable urban energy projects'. *Cities*. Vol. 60, February, pp. 28-36.

[40] Allen, S., Hammond, G., and McManus, M. (2008) Prospects for and barriers to domestic micro-generation: A United Kingdom Perspective'. Applied Energy. 85 (2008), pp. 528–544.

[41] Balcombe, P., Rigby, D., Azapagic, A. (2014) 'Investigating the importance of motivations and barriers related to microgeneration uptake in the UK'. Applied Energy. Vol. 130, pp. 403-418.

[42] Sorrell, S. (2015) 'Reducing energy demand: A review of issues, challenges and approaches'. Renewable and Sustainable Energy Reviews. Volume 47, July 2015, Pages 74-82.

[43] Reddy, S. and Painuly, J. (2004) Diffusion of renewable energy technologies—barriers and stakeholders' perspectives. *Renewable Energy*. Volume 29, Issue 9, July 2004, Pages 1431-1447

[44] Such as Maalsen, S. (2019) 'Smart housing: the political and market responses of the intersections between housing, new sharing economies and smart cities'. *Cities*, Vol. 84, January 2019, Pages 1-7

[45] Miguel, A., Poggi, F. and Ribeiro Amado, A. (2016) 'Energy efficient city: A model for urban planning'. *Sustainable Cities and Society*. Volume 26, pp. 476-485.

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

[47] Bramah, M. (2016) 'The prospects for municipal energy in the UK'. *Town and Country Planning*, p. 96.

[48] Such as Di Nucci, M.R., Gigler, U., Pol, O., Spitzbart, C. (2010) Concerto-Planning and Implementation Process Assessment Report. Concerto Reports, Austrian Institute of Technology, Vienna.

[49] See Mosannenzadeh, F. (2016) Smart Energy City Development in Europe: Towards Successful Implementation. Published PhD. Universita Degli Studi de Trento; Mosannenzadeh, F., Bisello, A., Vaccaro, R., D'Alonzo, V., Garfield, H. and Vettorato, D. (2017) 'Smart energy city development: A story told by urban planners'. *Cities*. 64, pp. 54-65; Mosannenzadeh, F., Di Nucci, M., and Vettorato, D. (2017a) 'Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: An empirical approach'. *Energy Policy*, Volume 105, pp. 191-201; and Mosannenzadeh, A., Bisello, A., Diamantini, C., Stellin, G. and Vettorato, D, (2017b) 'A case-based learning methodology to predict barriers to implementation of smart and sustainable urban energy projects'. *Cities*. Vol. 60, February, pp. 28-36.

[50] See Di Nucci, M.R., Gigler, U., Pol, O., Spitzbart, C. (2010) *Concerto-Planning and Implementation Process Assessment Report. Concerto Reports*, Austrian Institute of Technology, Vienna; and Di Nucci, R.M., Spitzbart, C. (2010) *Concerto Socio-Economic Impact Assessment Report*. Concerto Reports, Austrian Institute of Technology, Vienna.

[51] See Di Nucci, M.R., Gigler, U., Pol, O., Spitzbart, C. (2010) *Concerto-Planning and Implementation Process Assessment Report. Concerto Reports*, Austrian Institute of Technology, Vienna; and Di Nucci, R.M., Spitzbart, C. (2010) *Concerto Socio-Economic Impact Assessment Report*. Concerto Reports, Austrian Institute of Technology, Vienna.

[52] Mosannenzadeh, F., Di Nucci, M., and Vettorato, D. (2017a) 'Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: An empirical approach'. *Energy Policy*, Volume 105, pp. 191-201.

[53] Mosannenzadeh, F., Di Nucci, M., and Vettorato, D. (2017a) 'Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: An empirical approach'. *Energy Policy*, Volume 105, pp. 191-201.

[54] Mosannenzadeh, F., Di Nucci, M., and Vettorato, D. (2017a) 'Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: An empirical approach'. *Energy Policy*, Volume 105, pp. 191-201.

[55] Pezzutto, S., Vaccaro, R. Zambelli, P., Mosanenzadeh, F., Bisello, A. and Vettorato, D. (2015) *FP7 SINFONIA Project: Deliverable 2.1 SWOT Analysis Report of the Refined Concept / Baseline*. Bolzano: European Academy of Bolzano.

[56] Mosannenzadeh, F., Di Nucci, M., and Vettorato, D. (2017a) 'Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: An empirical approach'. *Energy Policy*, Volume 105, pp. 191-201.

[57] Mosannenzadeh, F., Di Nucci, M., and Vettorato, D. (2017a) 'Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: An empirical approach'. *Energy Policy*, Volume 105, pp. 191-201.

[58] Mosannenzadeh, F., Di Nucci, M., and Vettorato, D. (2017a) 'Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: An empirical approach'. Energy Policy, Volume 105, page 195.

[59] Mosannenzadeh, F., Di Nucci, M., and Vettorato, D. (2017a) 'Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: An empirical approach'. Energy Policy, Volume 105, page 195.

[60] Mosannenzadeh, F., Di Nucci, M., and Vettorato, D. (2017a) 'Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: An empirical approach'. Energy Policy, Volume 105, page 195.

[61] Mosannenzadeh, F., Di Nucci, M., and Vettorato, D. (2017a) 'Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: An empirical approach'. Energy Policy, Volume 105, page 195.

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

[63] Sperling, K., Hvelplund, F., and Mathiesen, B. (2011) 'Centralisation and decentralisation in strategic municipal energy planning in Denmark' *Energy Policy*, 39 pp. 1338–1351.

[64] Madlener, R., and Sunak, Y. (2011). Impacts of urbanization on urban structures and energy demand: What can we learn for urban energy planning and urbanization management? *Sustainable Cities and Society*, 1, pp. 45–53

[65] Peter, M., Avci, N., Girard, S., & Keim, C. (2009). Energy demand in city regions-methods to model dynamics of spatial energy consumption. Presented at the ECEEE 2009 Summer Study.

Act. Innovate. Deliver. Reducing energy demand sustainably, European Council for an Energy-Efficient Economy, Stockholm (Sweden), pp. 705 - 714.

[66] Strasser, H. (2015) ‘Implementation of energy strategies in communities. From pilot project in Salzburg, Austria to urban strategy, ADHRAE Transactions. Presented at the 2015 ASHRAE Conference, Amer. Soc Heating, Ref. Air Conditioning Eng. Inc, pp. 176-184.

[67] Cajot, S., Peter, M. M. Bahu, j., Guignet, F., Koch, A., and Maréchal, F. (2017) Obstacles in energy planning at the urban scale. *Sustainable Cities and Society*. 30, page 224.

[68] Cajot, S., Peter, M. M. Bahu, j., Guignet, F., Koch, A., and Maréchal, F. (2017) Obstacles in energy planning at the urban scale. *Sustainable Cities and Society*. 30, page 223.

[69] Cajot, S., Peter, M. M. Bahu, j., Guignet, F., Koch, A., and Maréchal, F. (2017) Obstacles in energy planning at the urban scale. *Sustainable Cities and Society*. 30, page 223.

[70] See Rittel, H. and Webber, M. (1973) ‘Dilemmas in a general theory of planning’. *Policy Sciences*, 4, 155–169.

[71] Thery, R., & Zarate, P. (2009). Energy planning: A multi-level and multi-criteria decision making structure proposal. *Central European Journal of Operations Research*, 17, pp. 265–274.

[72] Cajot, S., Peter, M. M. Bahu, j., Guignet, F., Koch, A., and Maréchal, F. (2017) Obstacles in energy planning at the urban scale. *Sustainable Cities and Society*. 30, page 226.

[73] Coelho, D., Antunes, C. H., & Martins, A. G. (2010) Using SSM for structuring decision support in urban energy planning (16) *Ukio Technol. Ir Ekon.Vystym*. pp. 641–653.

[74] Cajot, S., Peter, M. M. Bahu, j., Guignet, F., Koch, A., and Maréchal, F. (2017) Obstacles in energy planning at the urban scale. *Sustainable Cities and Society*. 30, page 227.

[75] Caputo, P., and Pasetti, G. (2015). Overcoming the inertia of building energy retrofit at municipal level: The Italian challenge. *Sustainable Cities and Society*, 15,120–134.

[76] Cajot, S., Peter, M. M. Bahu, j., Guignet, F., Koch, A., and Maréchal, F. (2017) Obstacles in energy planning at the urban scale. *Sustainable Cities and Society*. 30, page 228.

[77] Cajot, S., Peter, M. M. Bahu, j., Guignet, F., Koch, A., and Maréchal, F. (2017) Obstacles in energy planning at the urban scale. *Sustainable Cities and Society*. 30, page 228.

[78] Cajot, S., Peter, M. M. Bahu, j., Guignet, F., Koch, A., and Maréchal, F. (2017) Obstacles in energy planning at the urban scale. *Sustainable Cities and Society*. 30, page 228.

[79] For example, see Cajot, S., Peter, M. M. Bahu, j., Guignet, F., Koch, A., and Maréchal, F. (2017) Obstacles in energy planning at the urban scale. *Sustainable Cities and Society*. 30, pp. 223-236.

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