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UK smart grid development: An expert assessment of the benefits, pitfalls and functions

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ABSTRACT

Making electricity grids smarter is a challenging, long-term, and ambitious process. It consists of many possible transitions and involves many actors relevant to existing and potential functions of the grid. We applied a two round Policy Delphi process with a range of sectoral experts who discussed important drivers, barriers, benefits, risks and expected functions of smarter grids, to inform the development of smarter grids. Our analysis of these expert views indicates broad consensus of the necessity for smarter grids, particularly for economic and environmental reasons; yet stakeholders also associated a range of risks and barriers such as lack of investment, disengaged consumers, complexity and data privacy with measures to make the grid smarter. Different methods for implementing smarter grid functions were considered, all thought to be more likely in urban settings. Implications for policy and future research are considered.

1. Introduction and aims

1.1. Definitions and drivers of smart grids

The need to decarbonise electricity supply, maintain and improve security of supply while reducing fossil fuel imports in a world of rising prices is propelling the rapid adoption of technologies which place additional stress on traditional electricity networks [1]. Expansion of electric vehicles and heat pumps particularly, have the potential to substantially increase load across distribution networks, and the associated changes to networks will render current solutions expensive and unreliable [2,3]. Intermittent renewable energy sources of electricity such as wind and solar, are already major elements of generation in Germany, Denmark and elsewhere and look set to increase internationally [4–6] and is supported by national [e.g. [7,8]] and international policy drivers [e.g. [9,10]]. Innovation is therefore required for smarter solutions to ensure systems reliability in the face of increased supply and demand volatility. The International Energy Agency [11] estimated that Europe will have to invest €1.5 trillion in the period 2007–2030 to renew the electricity system [12] and early investment is likely to reap significant long-term savings. Smarter network management technologies might save up to £10bn in the UK alone, even if the uptake of low-carbon technologies remains low [2] and considerably more if uptake is high. These savings come from opening up cheaper options than traditional expansion of wires and reducing or delaying the need for capital investment. Smarter electricity delivery and usage appears to be an integral part of the transition to a low-carbon energy future [13].

However, there are significant challenges associated with a move towards smarter grids (SGs). Regulatory systems developed largely to serve the needs of centralised generation and transmission, and electricity networks evolved within this context; this can mean barriers for more distributed generation, its regulation and monetisation [14,15]. Moreover, regulatory change will be needed so as to achieve ambitious carbon targets set, and to allow the creation of a sophisticated market space that will allow smarter products and services [15].

This process is hampered by the absence of a commonly accepted definition of what a SG is, with different working

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Acronyms

DECC	Department of Energy and Climate Change
DNO	Distribution Network Operator
DSM	Demand Side Management
DSR	Demand Side Response
ESI	Energy Supply Industry
GB	Great Britain
Ofgem	Office of Gas and Electricity Markets
RIIO	Revenue = Incentives + Innovation + Outputs (a network regulation mechanism)
SG	Smarter Grid
SO	System Operator
TSO	Transmission System Operator

definitions across different territories and organisations. Widely accepted SG components tend to include efficient management of supply (including intermittent supply), two-way communication between the producer and user of electricity, and the use of IT technology to respond to and manage demand, and ensure safe and secure electricity distribution. The International Electrotechnical Commission view SG in terms of modernisation [16]; some US definitions depict SG largely in terms of technical solutions [17]; elsewhere the wider social, environmental, economic and behavioural issues are also considered [18,19]. We favour the definition provided by the Smart Grids European Technology Platform: "*electricity networks that can intelligently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies*" [[19], p. 6]. This reflects both the complexity of the system and potential for unknowns in different areas to interact with surprising and substantial implications.

The very lack of a clear definition points to the fluid and dynamic nature of this field. The use of scenarios in different energy sectors has helped guide the response of relevant players [e.g. [20]]. In this paper, we report on a stakeholder elicitation study, using the Policy Delphi technique, to inform the creation of a set of scenarios on UK SG development.

1.2. Uncertainty in the evolving UK electricity supply industry (ESI)

The drivers for SG are diverse. Substantial intermittent generation may emerge from onshore and offshore wind energy, and other renewables; these may range from large developments directly connecting 500 MW+ to the transmission grid, to 1 kW at remote parts of a distribution network. It is impossible to accurately predict the deployment rates of these technologies, their volumes or locations. This impedes the planning of supporting network infrastructure, and creates a difficult situation where: (a) infrastructure extension is needed for developers to plan and invest in new generating capacity, (b) rapid addition of generation, e.g. large wind farms in remote locations, cannot rely on existing networks and (c) network companies must consider whether new extensions will be used and provide a return since their income depends on usage.

The transmission network companies and the UK energy regulator –Ofgem-have begun to respond to these evolving problems but neither Ofgem nor the Distribution Network Operators (DNOs) are well suited to deal with such planning, which requires more innovation and is riskier than it has been in the past. Ofgem is also responsible for protecting consumers by ensuring additional transmission costs are minimised; furthermore, the energy sector is subject to unpredictability and thus uncertainty regarding investment outcomes. This implies risk to investors, and the greater the uncertainty the more risk may be engendered. This increases the required return on investment and thus overall allowable costs to be passed to the consumer, and Ofgem may need to change their approach to allow investment in different and riskier network operator behaviours. It is also apparent that large volumes of intermittent generation will require the System Operator (SO) to consider different approaches to network balancing.

A similar problem impacts demand. There is uncertainty over future demand changes and whether energy efficiency programmes will prove effective. Some assessments suggest UK energy decarbonisation will only be possible with programmes to electrify both heat (i.e. through heat pumps) and transport provision [21–23]. One UK overview of scenarios for decarbonisation via electrification suggested a doubling in peak demand by 2050 [24]. Demand, of course, is also dependent on public acceptance and uptake of electric transport and heat options, which is not assured and may prove more difficult than anticipated [25]. Such changes, if they happen, would mean substantial challenges for DNOs and the SO. Smart technologies, with their potential to allow greater controllability and knowledge across networks are essential to allowing DNOs to actively manage networks and prevent sudden load shifts leading to grid failures. The scale of new stressors on the networks makes smarter approaches essential in countries like the UK.

Addressing these issues the UK government introduced a SG routemap [26], building on the earlier Electricity Networks Strategy Group routemap [27], which had already been partly superseded by the introduction of RIIO [28,29] and the ongoing Electricity Market Reform (EMR) [29,30]. The DECC routemap sets out three key stages in UK SG development as foreseen by the UK Government [24]: 2014–2020: Development (including smart meter rollout); 2020–2030: Rollout; and 2030–2050: Developed Phase (where IP exploitation and consumer benefits are realised). This model requires initial innovation but seems limited on continuous innovation beyond the initial phases. It notes, but does not explore, the risks and uncertainties of the evolution of the UK's future ESI. National Grid [31] goes further in considering the different elements that will increase smartness across the functions of the UK ESI and in identifying the political, economic, social, and technological uncertainties that will influence their development. Their assessment implies a different picture and timeframe for network change, with both (a) evolving system demands and (b) corresponding continuing innovation, extending to 2050. Other work explores SG development in the context of energy system change [e.g. 32].

While these efforts to define SG uncertainties and map future development are important, they give little attention to behavioural or spatial dynamics or to the range of stakeholder perspectives on energy system change. Our project aimed to address these important deficits in the current literature by producing a detailed, interdisciplinary examination of SG development, incorporating evolving system demands and innovation, through a robust stakeholder elicitation methodology.

1.3. Smart grid stakeholders

The wide and fluid definition of what can be included in SGs creates a wide net of stakeholders that must be considered as likely to impact or be impacted by SG development. Organisations already active in generation, supply, transmission and distribution will be central to any reshaping of their sectors. The networks and SO will be most strongly impacted by the changes, since they will have to manage the changing demands on the system, deal with increased risk, and manage increased investment in innovation.

Many energy consumers (industry excepted) currently take a passive role in overseeing and managing their energy use. Many