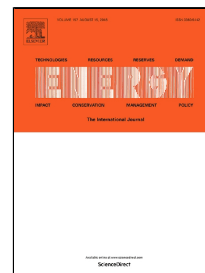


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Sources of Risk and Uncertainty in UK Smart Grid Deployment: An Expert Stakeholder Analysis

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Highlights:

- Stakeholders identified risk sources which might hinder growth of UK smart grids
- Risks linked to uncertainty in smart grid development are discussed
- Seven groups of risks and uncertainties are identified
- Stakeholders identified four cross-cutting issues as barriers to UK smart grids
- The smart grid is not a single endpoint, networks will become incrementally smarter

Abstract

The shift to increasingly smarter grids will require preparation and planning on the part of a diverse selection of current and future stakeholders. There are substantive sources of uncertainty that will impact on the adoption of smarter grid solutions. Risks and uncertainties are placed in one of seven categories: markets, users, data and information, supply mix, policy, investment conditions, and networks. Each of these has the potential to add risk to the planning profiles of the stakeholders involved. Here, UK stakeholders drawn from industry, government, regulators, and academia are canvassed about potential sources of uncertainty within the UK's electricity sector and the attendant risks that might be engendered by them.

Keywords: Broken value chain, Electricity networks, Energy market regulation, Risk and Uncertainty, Innovation, Smart Grid Policy

Introduction

This paper is concerned with a qualitative discussion of the many sources of uncertainty concerning the development of a smart grid (SG) provision within the UK's electricity industry. It builds on previous work to identify key issues likely to impact the need for a smarter grid, the most likely influencing factors for demand and to set out concerns arising from industry stakeholders. We use the definition of SG suggested 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" (European Commission, 2010).

47 This work synthesises knowledge from in-depth expert interviews and online
48 surveys forming part of a UKERC funded project to produce scenarios for the development
49 of SG in the UK. The scenarios (Balta-Ozkan et al., 2014) are the culmination of a multi-
50 stage process and have been used to inform the national debate about drivers, barriers, and
51 uncertainty of SG deployment. A key area of the process was the identification of the
52 principal elements of uncertainty and attendant risk arising from the many variables
53 inherent to SG which will be, to a lesser or greater degree, emergent. Questions have been
54 raised about the uncertainty of the potential benefits and risks of unforeseen issues for SG
55 (Kovacic and Giampietro, 2015). It was clear from the interviews in particular that an
56 extended discussion of these risks was warranted, and that risk and uncertainty need to
57 explicitly inform the considerations that underlie development and application of energy
58 policy and regulation. This paper aims to fulfil this gap by analyzing previously
59 unpublished data from this project with a particular focus on risk and uncertainties arising
60 from the UK context.

61 There have been very few broad assessments of the risks for the development and
62 deployment of SG. For example, although Rossebø et al. (2017), assessed many sources of
63 risk, their analysis concentrated on operational parameters expected to be important. In
64 their modelling, Zio and Aven (2011) explicitly recognized investment, environmental and
65 energy policy, and technical issues. Digmayer and Jakobs (2016) conducted a study of
66 experts and laymen into the risks associated with innovation in direct current grids. The risk
67 categories identified by Digmayer and Jakobs were technical, health-related, economic,
68 environmental, privacy, infrastructure, and landscape-related, approximately 80% of the
69 risks referenced were technical. Lastly, Tuballa and Abundo (2016) review some elements
70 of the deployment of SG.

71 The UK energy policy environment relating to carbon reduction and renewable
72 energy deployment is strongly influenced by EU commitments, though selection of
73 instruments rests with the UK. Security is primarily a national concern, while social issues
74 such as fuel poverty have both national and wider influences. Security of supply has
75 become significant in shaping the UK generation mix and this significance will continue to
76 grow while old coal and nuclear capacity are removed from the mix and the Government
77 attempts to incentivise sufficient new capacity to meet demand. This will be partially met
78 by new renewable capacity. EU policy requires 20% of energy consumption to come from
79 renewables by 2020 and the UK agreed an ambitious and legally obligatory target of 15%.
80 It is not clear what happens if any Member State fails to achieve their target (European
81 Commission, 2009) though substantial fines cannot be ruled out. Clearly the negotiated exit
82 of the UK from the EU is likely to impact substantially on the UK's commitments and any
83 consequences. A newer EU wide goal of 27% for 2030 is not a legal obligation but may
84 pressure continuing increases at the national level (European Commission, 2014). It is not
85 currently clear how the result of the UK referendum on leaving the EU will impact the
86 UK's position. The UK has seen steady growth in generation from renewable energy
87 sources of electricity (RES-E), particularly onshore and offshore wind and solar (DECC,
88 2015) and this is expected to continue, with a widening diversity of sources over time.
89 Decarbonisation of heat and transport via electrification may require a shift to greater
90 electrical demand, impacting on overall demand and demand volatility. The government
91 and regulator have acknowledged the challenges of integrating these technologies into
92 networks and markets and the need for new approaches to network management.

93 All GB distribution networks are owned by six distribution network operators
94 (DNOs). UK DNO R&D expenditure declined steadily following privatisation in 1990. The
95 continued evolution of policy and the emergence of a requirement for decarbonisation saw
96 Government and Ofgem come to view this as unacceptable in the face of the challenges
97 now faced for continued provision of reliable, secure and low carbon energy delivery
98 (Connor et al, 2014; Jamasb and Pollitt, 2008; Jamasb et al., 2008; Ofgem, 2009). This has
99 led to a number of policy initiatives to provide new incentives for investment.

100 The need to adopt new technologies and new approaches, potentially in different
101 locations for generation, network management and supply and provided by existing
102 companies and perhaps new market entrants creates substantial new sources of uncertainty
103 for all stakeholders. This paper explores these uncertainties with a view to identifying the
104 most important concerning future risk relating to solving the energy trilemma via smart
105 methodologies.

107 **Methodology**

108 We used a multi-step process as part of a wider programme of work carried out to inform
109 the development of SG scenarios for the UK (Balta-Ozkan et al., 2014). An extensive initial
110 literature review highlighted many areas of uncertainty and the specific issues arising from
111 them (Xenias et al., 2014). A list of UK stakeholder institutions was derived representing
112 regulators, consumers, and network operators. Eighteen semi-structured interviews were
113 conducted with experts representing these key organisations to identify emerging issues and
114 those factors thought to be the most important in shaping UK SG development. The
115 interviews fed development of a two-stage stakeholder online survey (n=77, n=44); broad
116 characteristics of the participants are given in Appendix A. We used a ranking system to
117 identify the factors considered to be most important in characterising UK SG development.
118 A Delphi Policy process (Turoff, 2002) identified the key transition points, with results
119 checked for credibility at an expert workshop with fifteen participants (Xenias et al., 2015).
120 The entire programme was overseen by an expert advisory group comprising ten
121 participants.

122 The interviews inform the writing throughout this paper and their content was added
123 to during the following stages of the applied methodology. The nature of the process,
124 drawing on additional information to add to a larger model, means more quantitative
125 assessments using tools such as NVivo is less appropriate since it would tend to militate
126 against factors emergent in the latter part of the process. The quantity and scope of the data
127 collected means that we focused on the main points arising from the whole process, with
128 the later elements of the method enabling us to select for perceived importance from expert
129 stakeholders.

130 While there it is always possible to overlook or misunderstand important
131 information, considerable effort was made to capture the widest possible information set,
132 with stakeholders asked to add to the list of considered factors at every stage. A framework
133 to organise the information was required as part of the scenario development process
134 (Balta-Ozkan et al., 2014) following the interview stage. Using information from our
135 literature review and the interviewees, and the views of our expert advisory group, we
136 developed a classification system as follows: markets, users, data and information, supply
137 mix, policy, investment conditions, and networks. This represents the most important
138 categories identified by the stakeholders. These seven groups were a convenient way of

139 ensuring consistency through the whole programme and we use them here for
140 categorisation. Many issues overlap categories and the categories should not be seen as
141 silos in this approach. Four cross-cutting issues emerged, and these are introduced first to
142 assist with laying out the evolving situation in the UK electricity sector.

143 While our method identified and ranked the areas considered most important for
144 dictating the likely direction of UK SG development to 2050, we qualitatively describe the
145 wider range of possible sources of uncertainty and the potential risk arising from them.

146

147 **Risks Raised by Stakeholders**

148 Independent of whether the interviewees and survey respondents considered an issue to be
149 a driver/barrier or benefit/pitfall of SG development, each has associated uncertainty. This
150 implies risk when companies are making decisions about investing in new capacity,
151 management or in bringing new services or technologies to market. The meanings of our
152 seven groups, whilst widely applicable, are conceived in the context of the SG scenarios
153 developed by Balta-Ozkan et al. (2014). We discuss the cross-cutting issues first, then
154 summarise the key risks, and their associated uncertainties and drivers in Table 1.

155

156 **Cross-cutting Issues**

157 Four issues were mentioned in multiple risk groups and warrant being discussed separately
158 from the categories discussed below.

159

160 *The Broken Value Chain*

161 The potential costs and value of smarter energy systems may be distributed across many
162 stakeholders. However, it is not always clear which stakeholders will benefit from which
163 actions and how value might be assigned (Hall and Foxon, 2014). This is a type of ‘split-
164 incentive’ problem with the UK smart meter (SM) roll-out a prime example. Suppliers are
165 bearing the cost for SM, but the usefulness to suppliers is largely limited to automated
166 collection of consumption data from consumers. The potential for more substantive
167 systemic benefit is in network management. However, this depends on the data that is
168 captured, who can access it and under what conditions, and the services that it might enable
169 should the network become more sophisticated. The benefits to suppliers are limited and
170 may threaten their business models (Balta-Ozkan et al., 2014; Bialek and Taylor, 2010;
171 Connor et al., 2014). This represents a systemic threat to the wider UK conception of the
172 SG. It has the potential to limit SG solutions for networks, inhibit innovation, reduce the
173 potential for dynamic pricing and negatively affect many more anticipated elements of the
174 smart grid.

175 Another issue raised was access to value generated from data. One supplier
176 interviewed emphasised that if the introduction of a time-of-use tariff (ToU) or significant
177 consumer behavioural change were to be achieved, then a challenge for their sector would
178 be to ensure the benefit went right across the value chain (Herold and Hertzog, 2015). This
179 has significant potential to alienate consumers. Stakeholders noted that supply companies
180 have the most established relationship with consumers and this might enable them to roll
181 out new SG services. However, it was noted that UK electricity supply companies are also
182 amongst the least trusted institutions and the Government has committed to ensuring that
183 data access does not expand from the current position (Edelman, 2016).

184

185 *Public Perception and Media Representation*

186 A number of stakeholders raised the risk of negative public reaction to smart energy
187 technologies and services. Low levels of consumer trust in utilities and media criticism of
188 utility operations and profits were noted by many respondents. It was perceived that if the
189 media were critical of new and emerging technologies or applications, it could inhibit
190 uptake. Possible negative coverage might object to perceived cost, effectiveness, intrusion
191 into the home and risk of health effects (regardless of evidence). The latter has already seen
192 negative headlines in some territories and to some extent in the UK (Buchanan et al., 2016;
193 Hess, 2014; Raimi and Carrico, 2016). This risk of lack of public acceptance may affect the
194 cost effectiveness of SM, data and information availability, and reduce the consumer base
195 for new markets and services.

196

197 *Skill Shortages*

198 Participants stated that the risk arising from a lack of appropriate skills was widespread in
199 the industry. Uncertainty concerning which technologies will dominate affects investment
200 in particular skillsets (Jagger et al., 2013). A shortage of skills would tend to reduce options
201 for network operators and push up costs. Some action was noted e.g. the Power Academy, a
202 scheme to encourage graduates into electrical engineering appropriate to the power sector,
203 but this was thought unlikely to be sufficient due to the ageing profile of many DNO
204 engineers. Other shortfalls included modelling skills amongst DNOs.

205

206 *Institutional Issues*

207 Stakeholders were asked about the institutional barriers to UK SG development and the
208 roles and effectiveness of the Department of Energy and Climate Change¹ (DECC), the
209 Office of Gas and Electricity Markets (Ofgem) and the body they jointly support, the Smart
210 Grid Forum. There was concern about the absence of high-level plans for moving the UK
211 forward to its wider energy targets, the electricity sector reform and the necessity and scope
212 for SG within this framework. The need for more leadership from Government was cited,
213 specifically to identify and implement steps necessary to achieving long-term SG goals.
214 This linked to a widespread concern as to the importance of effective co-ordination of the
215 system-wide changes necessary to facilitate smarter energy delivery. To ensure different
216 elements moved forward concurrently, for example, to ensure policy and regulatory change
217 keep pace with technology.

¹ In 2016 the Department of Business Innovation, and Skills and the Department of Energy and Climate Change were merged to form the Department of Business, Energy, and Industrial Strategy.

Category	Key Uncertainty	Risk	Impact
Markets	Commonality across the UK	Lack of co-operation between suppliers and DNOs	SG functionality
	Rate of market development	Lack of access to markets for small generators and aggregators	New energy services
	Changing policy	Supply market concentration	Competition
	Value for money for the consumer	Lack of customer engagement	Demand management
Users	Level of behaviour change	Lack of customer buy-in re demand-side response	Demand management
	Customer engagement	Failure of smart meter roll-out	SG functionality
Data and Information	Level of aggregation and availability	Lack of data protection and security	New energy services
	Level of public trust and acceptability	Lack of transparency	New energy services
	Commonality across the UK	Inadequate smart meter technology	Equality of outcome for consumers
	Level and timeliness of access	Lack of access for system operators	Cost reduction
Supply Mix	Planning for reinforcement	Curtailed network access	RES-E targets
	Planning	Lack of public acceptability of RES-E	RES-E targets
Policy	Changing policy	Policy instability	RES-E targets
	Changing policy	Lack of long-term planning	CO ₂ reduction target
	Misaligned aims and objectives	Lack of coordination between Ofgem and BEIS	Competition
Investment Conditions	Rate of return	Lack of access to capital	CO ₂ reduction target
	Future price controls	Continued under-investment	SG functionality
	Rate of return	Lack of innovation	SG functionality
Networks	Rate of increase in RES-E	Low rate of decarbonisation	RES-E targets
	Rate of SG deployment	Industry inertia	Cost reduction
	Rate of SG deployment	Intelligence used as a temporary fix	Cost reduction

Table 1. Summary of the principal sources of uncertainty and risk identified by interviewees and survey participants.

218 **Markets**

219 'Markets' refers here to both the continuance of old and the provision of new energy services, by
220 existing and new actors. This includes tariffs and business models which may be premised on the
221 use or mediation of energy technologies.

222 Accessing future lower cost tariffs using demand-side response (DSR) may require
223 consumers to make available a service to an energy company. This depends on the willingness
224 and ability of consumers to change their energy-use behaviour sufficiently to deliver an
225 aggregated, cost effective benefit to demand management. The risk is in customer willingness to
226 accept that it is worthwhile to spend time and resources to access tariffs linked to load-shifting.
227 Both the willingness and capability to engage with DSR technology would be telling in terms of
228 which consumers benefit. A key source of risk suggested by some respondents is consumers
229 rejecting DSR technology, thus rejecting behavioural change as this would appear trivial in terms
230 of energy and thus cost savings.

231 Owen and Ward (2010) and Owen et al. (2012) suggest that a typical UK household
232 demand might be able to shift 9% of demand. Although the UK Energy Demand Research
233 Programme found up to 10% short-term savings in 1-2 person households, the (limited) longer-
234 term evidence suggested 3% or less (Aecom, 2011). This has the potential to increase with
235 adoption of technology. Consumers without 'shiftable' load may come to subsidise those with
236 such load, since the latter may eventually be able to take better advantage of dynamic pricing. It
237 was noted that some new household tariffs might be regressive and that tariff structures
238 rewarding shiftable load might add to this since access to new and expensive technology may be
239 limited to wealthier households. Energy efficiency programmes might most usefully be aimed at
240 those without shiftable load. Since shiftable load may dictate access to lower tariffs political
241 repercussions may arise if some consumers can access lower tariffs while others cannot. Getting
242 the right tariffs to incentivise consumers was also cited as important i.e. a tariff that works for the
243 consumer rather than just bringing complex tariffs to market. It was also noted that a current UK
244 political trend of simplifying consumer tariffs may be at odds with increasing complexity arising
245 from dynamic pricing or ToU tariffs. (Moylan, 2017; Richards and White, 2014)

246 Load-shifting by industry is already commonplace with large consumers having bespoke
247 contractual arrangements. Some sectors have high uptake of energy efficiency. Involvement in
248 demand side activity might be determined by processes specific to each industry. It was
249 suggested there may be little value in shifting for some industries and little opportunity in others,
250 while some might benefit.

251 Electric vehicles (EVs) *may* be able to offer bulk energy and ancillary services (such as
252 frequency support) to distribution networks. If properly managed and incentivised EVs might act
253 as a key element of demand shifting and enhanced flexibility, but this would require the
254 integration of numerous elements including willingness on the part of EV owners, DNOs and
255 economics favouring adoption for both. Peterson, et al. (2010) and Bishop et al. (2013) present
256 evidence that the economics of battery degradation makes the provision of vehicle-to-grid (V2G)
257 services unlikely, though this may change with technological innovation. The emergence of
258 widespread EV adoption may also not emerge on the same timeframe as storage is needed,
259 Relying on V2G as an important element of SG thus presents a risk (Nezamoddini and Wang,
260 2016).

261 Other issues considered by interviewees and respondents to be important were the risk of
262 continued sector fragmentation, lack of co-operation between suppliers and DNOs, lack of
263 opportunities for aggregators, lack of access to markets for small generators, and supply market

264 competition and concentration. Also highlighted was the slow development of markets for
265 storage, DSR, EVs, and heat. Uncertainty concerning uptake rates is likely to be highly
266 significant as regards network planning and investment. Risk potential includes over and under
267 investment in networks, with respective impacts on cost, return to networks or retardation of
268 growth in renewables.

269

270 **Users**

271 ‘Users’ here predominantly means residential, commercial, and small industrial consumers.
272 Large industrial users already manage their risks in more advanced ways. The risks identified
273 emerge mainly from the role and engagement of consumers.

274 Many stakeholders emphasised that the lack of a substantial uptake of DSR and consumer
275 involvement was a risk to realising full SG potential, and in particular what might be achieved by
276 demand management. It was also noted that current potential to shift demand will be limited if
277 the “...visibility of advantages...” is not apparent. Customer awareness of SG and what it means
278 for them was summed-up by one respondent as “*The degree to which people can understand and*
279 *want a more complex relationship with their energy suppliers*”. When asked about consumer
280 engagement stakeholders had concerns as to whether groups of consumers would benefit equally
281 from SG. The extent to which consumers engage with smart technologies and products such as
282 time-varying tariffs will impact on the provision of new services and system management
283 methods (CSE, 2014). Uncertainty as to the level of engagement might only be resolved once
284 action is taken to open up markets (Balta-Ozkan et al., 2014) with one respondent suggesting that
285 success may depend on the implementation strategy.

286 Stakeholders noted the degree to which residential consumers will tolerate high prices
287 rather than take action, seeing the unknowns arising from this as a significant risk to the uptake of
288 demand side measures. The concern of many utility and other stakeholders was that consumers
289 would decline to become more proactive and that this put a key element of systemic flexibility at
290 risk. Uncertainty arises in the uptake of new services and tariffs; Darby et al. (2015) suggest
291 novelty and behaviour change diminish in a few weeks. Consumer rejection of DSR might be
292 partially mitigated by the development of automated DSR measures, with this dependent on
293 whether and when these develop and if they can find a route to market. The uncertainty arises
294 from the potential complexity faced by the residential consumer; commercial consumers with
295 energy management capability may be better able to take advantage of the new energy services
296 SG will offer. Consumer disengagement or resistance (scepticism) was considered by survey
297 respondents as the biggest perceived barrier to the smartening of the networks. Further work is
298 needed to determine the consequences of increased complexity of decision making on consumer
299 engagement. Additional uncertainty about DSR arises from the rate at which automated and non-
300 automated technologies emerge and the scope of what each can achieve (Redpoint and Element
301 Energy, 2012). Respondents identified a lack of common technical standards as a risk to
302 widespread deployment and interoperability, highlighting the need for coordination (Sato et al.,
303 2015; Tao et al., 2015).

304 An additional near-term risk is the scheduling of the UK’s SM rollout. Approximately 53
305 million gas and electricity meters are to be replaced in domestic and small commercial GB
306 premises by 2020 (DECC, 2014). However, the rollout has already faced repeated delays and
307 may be at significant risk of overrun, with the potential to become a “*costly failure*” without
308 Government intervention (ECCC, 2015). Delays to the rollout completion presents risk to the
309 emergence of opportunities for demand side response, and to addressing the lack of temporal

310 knowledge about electricity consumption needed to improve network management. One
311 respondent called for “*Joined up thinking between smart metering and smart grid*
312 *programme[s]*” though this reflected the opinion of numerous stakeholders. This echoes a wider
313 call from many stakeholders for greater levels of coordination relating to UK SG development,
314 and particularly for UK Government to take a stronger role.

315

316 **Data and Information**

317 This section is concerned with both historical and real-time data generation, collection,
318 aggregation, accessibility and billing information. We consider the establishment of a technically
319 and economically effective system for managing large volumes of data, and the limitations to SM
320 and sensors (due to Government cost-setting). The three most frequently cited areas for risk by
321 the survey respondents were data protection and security, privacy guarantees, and public trust and
322 acceptability (Xenias et al., 2015).

323 A significant source of uncertainty is whether data (or information) will reach where it
324 can best be used. The level of aggregation, availability, and how rapidly it gets to stakeholders,
325 will largely determine what services can be made available. This includes what network operators
326 know about demand and the rapidity with which they can respond to network issues.

327 All data generated by SM will be passed to the Data Communications Company (DCC)
328 for handling and passing on to stakeholders with access rights (currently suppliers only). This
329 will allow suppliers to transfer data to and from consumers. The UK SM implementation strictly
330 limits access to data to maximise customer privacy. Third party data access is strictly limited,
331 with DNO access effectively disallowed in the supplier-led rollout. There was a supposition
332 amongst many respondents that the frequency of data collection via SM and data aggregation was
333 likely to become freer over time, with consequent implications for network services. The rate of
334 change in data access will be a key determinant in how, when and which potential SG features
335 become available (Balta-Ozkan et al., 2014) but this is subject to many factors including political
336 will and public buy-in, making the rate of change unpredictable. Pullinger et al. (2014) conclude
337 that the current UK SM specifications may mean missed opportunities and that data resolution
338 may prohibit some prospective uses of SM.

339 The supplier-led nature of the rollout also emphasises upfront cost saving against SM
340 capability. Reduced capability risks a loss of future flexibility; one respondent suggested “*There*
341 *is a real danger of installing a system which cannot deal with better than half hourly signals ...*
342 *and that would limit smart grids and require a second system to go in in 5-6 years.*”

343 A further source of uncertainty is that the three UK areas (North, Central, South) see
344 communications provided by two service providers using two different communications
345 technologies (DCC, 2015). The risk is that different levels of performance may engender
346 different outcomes for consumers.

347 Smart meter data has a broad range of possible uses for DNOs as well as other existing
348 and potentially emergent stakeholders. Balta-Ozkan et al (2014) and Hall and Foxon (2014) noted
349 that there was a substantive risk for the UK in not recasting DNOs as DSOs or at least allowing
350 them to adopt some of the characteristics. This evolution to DSO operations is being considered
351 and may move ahead (BEIS and Ofgem, 2017; ENA, n.d). The need is for DNOs to have greater
352 responsibility, and the tools, for system balancing. Denial of increased access to the SM
353 generated datasets might lower the potential value for SM in aiding systemic cost reduction.

354 There was disagreement over the exact form of SM data outputs that might be usefully
355 made available. Some respondents cast doubt on the need for real-time data, claiming that many

356 key benefits were in greater volumes of data which need only be available on an aggregated or
357 delayed basis. Understanding the usage landscape is the key point. There was general agreement
358 that restrictions will be relaxed over time but uncertainty arises from stakeholders not being clear
359 as to what data will be available, when, and how much control an individual stakeholder may
360 exert to limit access. The risk lies in the lack of signals to trigger investment in new service
361 provision, particularly for DNOs but also in uptake of usable options as they emerge in other
362 national contexts.

363 The curtailment of data access arises from the need to protect consumer privacy. The UK
364 default is to strongly protect privacy, but it is possible not all consumers will require this level of
365 protection and may support some level of reduced privacy in return for potential tariff reduction.
366 Consumer perception may dictate the rate of revised data access, but decisions will sit with
367 Government and the regulator (Britton, 2016; Brown, 2014; Elam, 2016). Furthermore, a lack of
368 transparency about data exploitation was considered a risk for public opinion and media
369 treatment of energy issues. One respondent considered the key point to be “*Consumer confidence*
370 *in data relating to their energy use*”.

371 Security is a key issue for SM rollout, and closely linked to privacy (Herold and Hertzog,
372 2015). Stakeholders had specific concerns about the vulnerability and consumer perception of
373 vulnerability of SM and other ‘internet of energy’ systems to remote or physical interference. The
374 risk of a lack of data security was raised by many respondents. This contrasts with access, giving
375 rise to potential conflicts and therefore uncertainty about priorities. It is not possible to estimate
376 how many consumers might allow third party access to their data and under what circumstances.

377 378 **Supply Mix**

379 This section is concerned with the evolving roles of flexible, variable, and inflexible generation.
380 There was an expectation that shifting demand will be an essential element of the future grid
381 responsiveness to rapid shifts in output from intermittent RES-E generation and that should
382 consumers decline to do so in bulk it would require alternatives that would be costly and
383 potentially more difficult.

384 Some UK counties are effectively sterilised for new distributed generation above the
385 domestic scale since reinforcement would have to be so extensive that costs are prohibitive. The
386 key uncertainty for DNOs is when, where and to what extent reinforcement of networks should
387 occur. This is predicated on many variables including growth in demand for generation
388 connection, uptake and location of heat pumps (HPs) and EVs. Approaches used so far by DNOs,
389 include prioritised constraint of generators on a ‘last in, first out’ basis and wind farms
390 contracting to shut down when local PV output is high, that is, curtailment risk is transferred to
391 the generator. This displaces smart solutions which many respondents considered would be
392 cheaper than traditional reinforcement in the long run. Uncertainty in planning for SG arises from
393 the unknown volume of RES-E resulting from current policy as well as from the types of
394 technology that may be deployed. Offshore and onshore wind energy was looking likely to be
395 most significant, but further deployment of onshore wind appears halted (Hansard, 2015).

396 Political, geographical, market, social or technical factors create uncertainty in how RES-
397 E technologies are adopted across the UK. The political imperative for RES-E is currently an
398 important enabler but this does not imply certainty into the future. Respondents expressed
399 concern over political commitments as well as continued rates of deployment as a major source
400 of uncertainty. They also questioned whether it was possible to adequately support both RES-E
401 and nuclear power from the public purse, citing the potential for conflict over policy frameworks

402 and the flexibility issues around large-scale use of nuclear. The funding of these two technology
 403 groups from a single source, the ‘Levy Control Framework’, adds to potential uncertainty as to
 404 rates of expansion, with each requiring different approaches to network investment and future
 405 system balancing. It was noted that regardless of the comparative economics, RES-E will be
 406 impacted by decisions such as the UK Government’s to provide greater support to nuclear fission
 407 than to the more mature RES-E technologies. Furthermore, protests against RES-E occur in many
 408 nations for reasons including cost and landscape impacts (Hall et al., 2013; Cohen et al., 2014;
 409 Stigka et al., 2014; Newbery, 2015; Raimi and Carrico, 2016).

410 The political narrative may change, implying potential variance in support for the
 411 different technologies expected to impact the grid. This might mean:

- 412 1. growing support, as has essentially been the case in most of Europe in the last decade,
- 413 2. reduced support as with some EU Member States following the 2008 economic downturn,
 414 or
- 415 3. rejection of one or more renewable energy technologies in favour of more general support
 416 for CO₂ emission reduction and low carbon technology without the RES-E emphasis.

417
 418 This might favour increasing gas generation due to concerns over security and reliability
 419 of supply, or other policy initiatives, for example nuclear generation. The potential for different
 420 mixes of electrical generation – not just of RES-E – was cited as a major source of uncertainty in
 421 planning degrees of smartness (Xenias et al., 2014).

422

423 **Policy**

424 Respondents highlighted the risks due to ineffective policy and in particular policy instability, not
 425 just in terms of changing what is required from the grid but in terms of the policy framework for
 426 smarter approaches to dealing with them. The impacts of policy on uncertainty and risk can be
 427 highly varied. Arguably, longevity is one element of good policy but this is too simplistic in
 428 terms of the selection process to achieve specific goals, possible failure of that instrument, and
 429 potential changes in broader policy aims with political and public agendas. The failure to create
 430 political certainty may impact on overall installed capacity of low carbon technologies, and the
 431 timeframe over which commissioning occurs. This uncertainty applies to all RES-E technologies
 432 and existing or emergent competing technologies (such as gas, nuclear and CCS).

433 A point raised by many respondents was consistency of approach to long-term planning,
 434 particularly between Ofgem and DECC. Furthermore, the risk of not aligning the goals,
 435 objectives, and strategies of DECC and Ofgem was raised frequently with one respondent saying:
 436 *“Both must agree on common aims and objectives”*, another accentuating the need for *“Linkage*
 437 *across price controls i.e. incentives for networks to work with each other to deliver optimal*
 438 *benefits to GB plc”*. *“Regulatory boundaries for network operators, must liaise better with the*
 439 *customer”* typifies the opinion of many respondents. The absence of more effective coordination
 440 was seen by many respondents as potentially restricting the development of smarter energy
 441 solutions and their integration into the wider electricity system. Two areas of risk were identified
 442 1) a failure by Government and other stakeholders to develop the mechanisms and institutions to
 443 coordinate SG development, and 2) a failure to do so effectively, by selecting inappropriate
 444 policy instruments. Despite the formation of the Smart Grid Forum by DECC and Ofgem there
 445 were numerous calls for greater future coordination, and especially for DECC to take a much
 446 stronger role. Comments such as *“Certainty of legislation and regulation so that investments are*

447 *secure*” summed-up the main issue. The regulatory system emerging from RIIO creates a new
 448 operational environment for DNOs.

449 The changes to UK policy in support of large-scale RES-E have been manifold (Connor,
 450 2003; Connor et al., 2014; Kern et al, 2014; Mitchell, 2007, Pearson and Watson, 2012). They
 451 exemplify some of the wide range of factors which could impinge on the total volume of
 452 intermittent generation that will be developed on (and off) the UK network, the type of
 453 technology and thus the spatial variation in where it might occur. Each undermines the ability of
 454 the networks to plan for the future. The risk of lack of clear Government policy and leadership
 455 was summed-up by two typical comments from respondents “*We need a clear, consistent and*
 456 *steady policy on energy production*” and “*Government policy for example, a clear position on*
 457 *electrification as key (or not) to carbon reduction*”. Furthermore, one respondent specifically
 458 mentioned targets: “*Changing targets driven by the EU and /or national politics*” as indicative of
 459 the risk of unclear policy governance.

460 Concerning UK regulatory policy, the Government and Ofgem acknowledged that the
 461 RPI-X² system of network regulation introduced with privatisation in 1990 was incapable of
 462 delivering the innovation needed to integrate smarter grid management and thus decarbonisation
 463 (Ofgem, 2010a, 2010b). They took steps to address this by:

- 464 1. introducing the RIIO³ system for network incentivisation and
- 465 2. incentivising DNOs to invest in R&D via Registered Power Zones (RPZ.), the Innovation
 466 Funding Incentive (IFI) (both 2005-2010), the Low Carbon Network Fund (LCNF, 2010-
 467 2015) and most recently the Network Innovation Competition (NIC) and Network
 468 Innovation Allowance (NIA).

469 While these were seen by the majority of respondents as positive changes a key criticism
 470 from various stakeholders was summed-up by one respondent as “*Regulatory incentives e.g.*
 471 *LCNF encourages piecemeal solutions without a clear UK strategy*”. There was also some
 472 concern that while these mechanisms might assist in creating new network options, there may not
 473 be sufficient capital available to the DNOs to roll them out across the networks. A recent review
 474 of the LCNF agrees that there is no clear path to wider rollout. (Rhodes et al, 2016)

475 Ofgem introduced RIIO as the main instrument for incentivising the Transmission System
 476 Operators (TSOs) and the DNOs to invest in innovation and then deploy new approaches more
 477 deeply into network operations, something which RPI-X was unable to do. The aim was to allow
 478 greater flexibility for network investment. Stakeholder opinion varied as to its likely success and
 479 the extent to which it might achieve this aim. It is notable that many respondents did not consider
 480 that the failure of RIIO would rule out smarter networks (Balta-Ozkan et al, 2014).

482 **Investment Conditions**

483 By *investment conditions* we mainly consider the trade-off between the cost of capital (cheap or
 484 expensive) and the regulatory investment framework (obstructive or helpful). The issues raised
 485 by participants indicated as most important were uncertain return on investment (ROI), new
 486 modes of financing and business models, and new value delivery mechanisms (e.g. flexibility).
 487 Also mentioned as significant risks were the elevated levels of investment required and the lack
 488 of access to capital. An overarching and recurring theme was long-term regulation and policy
 489

² Price cap regulation of the form Retail Prices Index (RPI) minus expected efficiency savings (X).

³ RIIO, Revenue = Incentives + Innovation + Outputs UK price controls

490 (un)certainty. Issues surrounding the impact of regulation on investment has been explored by
 491 Moisés Costa et al. (2017).

492 A specific risk raised was under-investment by DNOs. Historically DNOs have focussed
 493 on incremental improvements to reduce costs, with the old RPI-X system of incentivisation set up
 494 to reward this and effectively ruling out more risky approaches. The SG transition presents a far
 495 more complex task.

496 Participants agreed that both National Grid and the DNOs will need to take more risks
 497 and that more innovation was required. This will increase costs and require a correspondingly
 498 greater ROI. Several respondents linked ROI to policy, for example “*Certainty of ROI – not*
 499 *government policy, but legally binding contracts*” was a typical comment. The level of additional
 500 risk that Ofgem will tolerate will be significant in determining the outcomes of future distribution
 501 price control reviews (DPCR). There is a risk Ofgem’s perspective on allowable risk may remain
 502 more conservative than the DNOs, either collectively or individually, retarding innovation. A
 503 number of stakeholders referred to the issue of whether Ofgem would allow investment ahead of
 504 need, notably the allowance of investment which would not pay off until after the end of the ED1
 505 DPCR in 2023. ED1 states this is permitted, but what Ofgem tolerates and what DNOs believe it
 506 will tolerate, is a source of uncertainty.

507 The RPZ, IFI, LCNF and NIA schemes aimed to address the fall in DNO R&D activity
 508 and have been credited with driving significant steps in revitalising the environment of driving
 509 investment in innovation (Jamas and Pollitt, 2015). However, participants criticised the
 510 piecemeal approach. One stakeholder criticised the IFI for ignoring operational innovation, and
 511 focussing too much on technical solutions.

512 The location where intellectual property rights rests was raised as a risk arising from the
 513 LCNF and its antecedents with the potential to deter investment. There was general agreement
 514 that the involvement of third-party companies in innovating system services was desirable. This
 515 has the potential to conflict with Ofgem perspective of capturing the benefit for the public of
 516 investment from regulated network funds. There was concern that Ofgem’s approach needs to
 517 ensure these third-party businesses can benefit from their own side of the investment. The risk is
 518 whether RIIO can deliver the levels of innovative practice required and the adoption of new
 519 methods; failure may retard growth in multiple areas of enhanced network smartness.

520 A source of uncertainty raised by some stakeholders (notably those with an interest in
 521 distribution but not attached to a DNO) arose from doubts that the DNOs lack the structure to
 522 innovate. It was suggested that some UK DNOs may not have the intellectual capacity, capable
 523 personnel, or the will to drive innovative approaches. This is linked to issues such as skills
 524 shortages, but may go wider and present an institutional or cultural barrier. The institutions will
 525 need to evolve but at what rate will they need to invest in changes and what will an effective
 526 strategy look like?

527

528 **Networks**

529 We categorised networks as passive, partially active, and fully active. Much of what has already
 530 been reported here outlines sources of uncertainty for networks. Government decarbonisation
 531 policy drives increases of intermittent and firm distributed generation, and new volatile sources
 532 of distributed demand. However, uncertainty as to their capacity and location presents difficulties
 533 for TNO/DNOs when making investment decisions. Although not confined to network operators,
 534 industry inertia and resistance was identified as a source of risk with one respondent commenting
 535 “*It's comfortable to stay with BAU, least risk, least effort, pleases the owners*”. A key uncertainty

536 is whether to deploy smarter alternatives ahead of immediate requirements or to minimise
537 spending by reacting ad hoc. A respondent said that DNOs have a “*conservative nature*”; whilst
538 this approach may appear as risk averse in the near-term, it may be a risky stance for the future,
539 in an environment where many respondents regarded change as essential and with no possibility
540 of a lasting status quo.

541 Many respondents highlighted the difficulty of making meaningful predictions for
542 network needs after the 2020-2025 period i.e. the 2015-2023 RII0-ED1 operating period. Many
543 respondents identified a lack of a long-term vision for network development as a major risk to the
544 successful deployment of SG. Some stakeholders said that while the Government has a vision for
545 the system in the medium and long-term, it does not appear to have a staged-plan for
546 implementation. Another stakeholder suggested Ofgem was allowing an open marketplace to “*let*
547 *a thousand flowers bloom*” but questioned whether this was an optimal approach. Their view was
548 that Ofgem should cut the options and engender a more specific route forward.

549 The different low carbon technologies present different risks to networks. One uncertainty
550 identified was the uncoordinated charging of high numbers of EVs. Not only is the EV adoption
551 rate unpredictable, but it may be gradual or may suddenly change as price parity is achieved
552 (BNEF, 2016). Once EVs are present they imply risk in terms of impacts on overall demand
553 profiles, in terms of creating new peaks, exacerbating existing ones or causing rapid changes in
554 demand (Clement-Nyns, et al. 2010; Papadopoulos, et al., 2012). The key uncertainty is the rate
555 of emergence and of dissemination of technical network solutions but geographical distribution
556 may also present issues. Balta-Ozkan et al. (2014) identified that the rate of deployment is
557 influenced by policy, success in trials, availability of finance, and whether the technology can be
558 applied equally in urban and rural settings. This was summed-up by one respondent as making
559 SG “*Complicated from the design perspective*”. These criteria increase the risk of over and under
560 investment in different locations.

561 Demand-side management, DSR, and storage (amongst other solutions) are proposed as
562 tools to enhance network management. Respondents suggested potential for conflict in trading
563 for usage on markets for capacity and balancing. For example, the potential for National Grid to
564 be in conflict over access to capacity produced from demand reduction which was contracted to
565 other service providers.

566 The ‘utility death spiral’ (Pérez-Arriaga and Bharatkumar, 2014), describes a possible
567 situation of reducing network use and increasing volumetric charges, pushing users to seek
568 alternatives and thus creating a vicious circle of reducing asset utilisation. Increasing the capacity
569 of distributed generation and introducing smart technologies risks reducing asset utilisation, and
570 therefore reducing income for TNOs and DNOs.

571

572 **Conclusions and policy implications**

573 This research emerges from work to build SG scenarios to 2050, taking an approach which
574 identifies the main events which will shape them. Although primarily concerned with the UK
575 many of our observations of uncertainty and attendant risks will be relevant to other nations and
576 territories, though the specifics of any emergent SG will be unique.

577 Present UK electricity systems are passive, and many risks we identified are a
578 consequence of increasing complexity of potential solutions. A repeated theme in our collected
579 data was the need to think in terms of systems of steadily increasing smartness presenting SG not
580 as a single artefact or endpoint, but as an ongoing process. Most outcomes dependent on multiple
581 coordinated (or potentially uncoordinated) policy and regulatory changes. The key risk for the

582 UK was seen by many to be the lack of long-term vision. There was difficulty even in predicting
583 past 2020 and this uncertainty is the key source of risk for the many stakeholders involved. In
584 terms of policy, the risk of continuing inconsistency of aims and objectives between DECC (now
585 BEIS) and Ofgem was the most important. Many stakeholders highlighted the need for regulation
586 – and the regulator – to evolve with technology and market services. Long-term regulation and
587 policy certainty is a necessary condition for investment, and critical for the success of smartening
588 the grid.

589 The drivers of the requirement for higher degrees of grid smartness are major sources of
590 uncertainty in terms of the extent and pace of change required, as well as factors such as spatial
591 variation in uptake. These drivers include greater volumes of intermittent generation on both
592 transmission and distribution networks and greater volumes of RE sourced in areas not adjacent
593 to the current network, the level and geographical spread of domestic consumers with distributed
594 generation, and the potentially wide-scale but unpredictable uptake of HPs and EVs.

595 One of the most significant and difficult to mitigate risks was the so-called ‘broken-value
596 chain’. Across several aspects of SGs there may be economic and other benefits in terms of wider
597 societal goals such as facilitating renewable energy. In a number of cases there is no obvious way
598 to monetise new technology and services for whichever stakeholder pays for it, or would like to
599 pay for it. A similar issue was supplier concern arising from additional network costs pushing up
600 overall costs, and the impact on consumer bills. Suppliers are considerably less concerned about
601 demand-side management so long as supply is not interrupted. The decision to favour a supplier-
602 led SM rollout was widely seen as having the potential to substantively delay evolution of the
603 SG. Gradual relaxation of restrictions on access to data – most notably for DNOs and other
604 parties – is expected, but may be slow to occur. Creating value from consumer data may be
605 problematic and undermine consumer buy-in.

606 The need to act to enable the factors that will allow for a smarter grid is imperative, and it
607 was widely accepted that the status quo cannot continue. As one stakeholder put it “*Doing*
608 *nothing is the worst response – it guarantees failure.*” We emphasise that current assumptions
609 about the network will stop applying, and current solutions will become less effective and more
610 expensive. Assumptions must be questioned repeatedly by all relevant stakeholders with a view
611 to identifying the continued evolution of the sector and maximising public benefit.

612

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617

619 **Appendix A**

620 The participants in the two survey rounds are characterised in Table A.1. and Table A.2.

621

Sector	Round 1	Round 2
Academic	33%	25%
Consultant	9%	0%
Consumer / community interest group	13%	5%
Generator	2%	2%
Network Operator	19%	25%
Policy	5%	2%
Regulator	2%	2%
Supplier	8%	9%
Other	11%	30%
	100%	100%

622

623 Table A.1. Summary of the sectors which survey respondents represent.

624

625

Expertise		
Business	28%	18%
Economics	3%	11%
Engineering	34%	41%
Social Science	19%	16%
Other	16%	14%
	100%	100%

626

627 Table A.2. Summary of the self-identified area of expertise of the survey respondents.

628

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