INSTRUCTIONS

for populating the Assessment Criteria Matrix from Score Cards

1) Follow the agreed naming convention
2) Populate column A on the Summary Page sheet with the agreed Ref name/number
3) Create a sheet (score card) for each technology, naming the sheet with the agreed Ref name/number
4) Score the technology in the respective score card
5) Create a "Return to Summary Page" hyperlink in cell A1 of each sheet (score card)
6) Create a hyperlink for each Ref name/number (column A) of the Summary Page sheet
7) Write "Done" in column G
8) Press F9 to copy through scores, the respective row should auto populate the scores and comments from the score card
9) Hide the comments or reveal them using the buttons in cells Z1 and CK1 respectively, in the Summary Page sheet

						Application					Scorecard	Total score	Subtotals						
Ref#	Class	Intervention	Technology	Min Performance Level/ Threshold	Notes	Domestic	Industrial / commercial	Generation	Distribution network				Technical	Environmental	Policy / Regulation	Monetary	Capacity/ Supply Chain	Consumer	Opportunities / risks
	Scoring																		
M1	**Monitoring, Sensors and in-built controls**		Smart meters - SMETS2			✓	✓				Done	102	26	7	12	10	20	27	
M2			Intelligent thermostat			✓	✓				Done	104	28	7	12	13	16	28	
M3			Intelligent lighting			✓	✓				Done	100	31	6	12	11	13	27	
M4			Power quality monitoring and intelligence systems						✓		Done	81	33	6	11	15	16	0	
P1	**Platforms / Analytics**		Customer energy use platforms			✓	✓				Done	88	25	7	12	7	16	21	
P2			Gaming of energy saving			✓					Done	102	28	9	11	16	17	21	
P3			Peer-to-Peer Energy Matching Platform			✓	✓		✓		Done	98	31	3	10	7	17	30	
Cn1	**Communication**		Whole home communication			✓	✓				Done	44	9	0	9	5	8	13	
Cn2			Internet of things mesh			✓	✓	✓	✓		Done	18	18	0	0	0	0	0	
Cn3			WiMax				✓	✓	✓		Done	7	7	0	0	0	0	0	
Cl1	**Control**		Smart Plugs			✓	✓				Done	111	30	6	14	15	14	32	
Cl2			Home Voltage Regulation			✓	✓				Done	105	28	8	14	15	11	29	
Cl3			Home energy management systems			✓					Done	115	27	8	15	18	17	30	
Cl4			Building Management System				✓				Done	113	27	8	15	14	19	30	
Cl5			Active Network Management						✓		Done	116	31	9	13	14	22	27	
Cl6			Microgrid Controller				✓		✓		Done	114	27	9	11	17	23	27	
Cl7			Generation Router Device					✓			Done	113	27	9	13	15	20	29	
R1	**Response**		Smart Appliances			✓	✓				Done	115	25	10	13	19	19	29	
R2			Demand Response			✓	✓				Done	110	28	10	11	17	19	25	
R3			Smart Invertor' or 'Virtual Oscillator'			✓	✓				Done	99	26	10	9	16	14	24	
R4			DER providing grid services					✓			Done	111	29	10	10	18	16	28	
S1	**Storage**		Electric batteries, domestic			✓					Done	90	26	5	12	11	14	22	
S2			Electric batteries - commercial / industrial				✓				Done	82	16	6	11	13	16	20	
S3			Heat batteries based on Phase Change Materials (PCMs)			✓	✓				Done	91	27	4	11	9	13	27	
S4			smart conventional heat storage			✓	✓				Done	87	25	8	12	12	17	13	
S5			Ice batteries			✓	✓				Done	82	27	6	9	12	8	20	

Smart meters - SMETS2

Provide a high level of data for network operators to use for better managing the network, as well as providing consumers with 'live' data on usage and opportunities for greater control

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	Dedicated smart meter network now live so SMETS2 meters (2nd generation smart meters with full functionality) can be installed
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	3	Depends on user interaction; moderate efficiency gains are possible but require user action.
Reliability	1 (low) to 5 (high) score	4	Subject to extensive specification and testing but limited experience to date of interactions with Smart Data Communications Company (DCC)
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	3	Requires replacement of dumb meters. Smart DCC now in place. Installation in some properties can be problematic, e.g. solid-walled tenements.
complexity of systems/ their integration	1 (complex) to 5 (simple) score	3	Simple interfaces but system behind them is highly complex. System is now live and SMETS2 meters can be installed, although very few have been
risk/severity of unintended consequences	1 (high) to 5 (low) score	4	SMETS2 meters should overcome many of the concerns associated with foundation meters, e.g. switchability, security but some concerns regarding consequences of those who choose not to switch.
		26	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	3	Moderate projected savings for consumers but network management benefits could be more significant and longer term potential may be higher
whole life environmental impact	1 (high) to 5 (low) score	4	Not addressed in DECC/BEIS Impact Assessment. Unsure of direct environmental impact of meters, no information on this. Must be some impacts from disposal of old meters, replacing with smart meters.
		7	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	Currently being rolled out in Scotland
compatibility with current regulation	1 (low) to 5 (high) score	5	Directly compatible
compatibility with current assessment methodologies	1 (low) to 5 (high) score	2	Smart meters don't feature in RdSAP
		12	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	3	Total cost of the whole smart meter rollout including the new dedicated network and meter installations estimated at £11bn GB-wide but smart meters due to be freely available to all by 2020. Cost score - depends if we are talking about direct cost to consumer or overall costs of smart meter network? Consumers don't pay anything up front and in theory suppliers save by not having to pay for meter readers. However, the meters effectively cost around £200 each (£11B cost, 53M to be fitted; NB many households getting 2 meters, gas & electricity)
life cycle costs	1 (high) to 5 (low) score	4	Not addressed in DECC/BEIS Impact Assessments. Assume relatively low but that depends on level of future proofing and when they might need to be replaced.
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	1	Total cost of rollout c£11bn, carbon saving (traded and non-) potential 30mtC02e. Implies carbon cost effectiveness of £367/tCO2e. Carbon cost effectiveness at individual building level has not been calculated. (According to old Guardian, article, building new wind power capacity, which costs £50-£79 for each tonne of carbon saved; https://www.theguardian.com/environment/2008/feb/20/energyefficiency.smartmeters - but same article says smart meters are more cost effective than wind on carbon saving). Combined meter saving forecast to be £11 in 2020; combined meter costs would be over £400, giving savings of 2.5% of meter costs.
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	2	Economies of scale already being achieved - GB-wide rollout. BUT the lack of area-based approach (supplier-led rather than, e.g. DNO-led) misses economy of scale opportunities.
		10	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	4	Good applicability, although Scotland does have a higher proportion of problematic properties than the rest of GB
existing Scottish capacity/skills	1 (low) to 5 (high) score	5	Already being rolled out by the energy suppliers
Scottish content	1 (low) to 5 (high) score	2	Suspect that no smart meters are being manufactured in Scotland but supply chain for the rollout is extensive, which will benefit many Scottish companies
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	5	Potential for integration with demand-side (network management) and supply-side (greater consumer control)
Scottish economic impact potential	1 (low) to 5 (high) score	4	Implementation of rollout likely to generate significant impact, particularly for installers
		20	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	4	Smart meters incorporate user-friendly in-home controls but research demonstrates that interaction with these is often short-lived
disruption	1 (high) to 5 (low) score	5	Little disruption in most cases. Simple meter replacements
customer acceptance	1 (low) to 5 (high) score	3	Benefit from significant promotional campaign but weighed against concerns around privacy of data
savings on bills	1 (low) to 5 (high) score	2	Projected to reduce the average household energy bill by £11 in 2020 and by £47 in 2030. (= Data from most recent Cost Benefit statement). The average dual-fuel non-domestic property is expected to realise bill savings of approximately £128 in 2020 and £147 in 2030
maintenance requirements	1 (high) to 5 (low) score	5	None
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	3	Allow more informed control of energy use but some concerns relating to vulnerable households. Long-term potential is high through greater interactivity
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	5	Being rolled out by the energy companies with extensive consumer protections in place, including code of practice for meter installation that all energy suppliers must comply with
		27	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		Level of future proofing and extension of applications to for example voltage limitation, time of use tariffs, real time information for distribution automation.
other relevant considerations/risks/opportunities	List/Describe		Some properties present technical challenges for installation. Smart DCC does not cover whole country
adaptability / future proofing	List / Describe		SMETS 2 meters have inbuilt functionality to talk to the DCC. Some concerns nonetheless that they won't be flexible enough for all potential uses.
		102	

References:

BEIS (2016) Smart meter rollout cost benefit analysis

CAG (2016) Smart Move: Taking stock of the smart meter rollout programme in Scotland Consumer Futures Unit Publication Series 2016: 1

Ofgem Factsheet - Smart metering - what it means for Britain's homes

Intelligent thermostat

Self-learning thermostats, adjust temperatures due to understanding of preferred temperatures, occupancy etc.

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	Already available, e.g. Nest thermostat gets to know the temperature you like when you're at home. And turns itself down when you're away. It learns how your home warms up or how draughty it is, so it only uses the energy it needs https://nest.com/uk/thermostat/meet-nest-thermostat; and Switchee http://switchee.co designed for social housing
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	3	In theory reasonably efficient with savings of >10% achievable.
Reliability	1 (low) to 5 (high) score	4	60 of 285 reviews on Amazon UK are critical
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	4	Compatible with a wide and expanding range of heating systems. See, for example, https://nest.com/uk/support/article/Which-heating-systems-are-compatible-with-the-Nest-Learning-Thermostat
complexity of systems/ their integration	1 (complex) to 5 (simple) score	4	Nest recommend professional installation
risk/severity of unintended consequences	1 (high) to 5 (low) score	4	Low risk, although Amazon reviews indicate operational problems in some instances with customers reporting control issues and cold homes as a result. Risk of breach of privacy - can indicate when someone is at home.
		28	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	3	One manufacturer (Tadoo) claim that consumers can save 27% on their heating bills. Nest trial across 42 US states showed on average the Nest Thermostat saved 10% to 12% on heating and 15% on cooling. Based on typical energy costs, they estimated average savings of $131 to $145 a year. However, savings will depend on baseline - CLEAResult report below suggests savings vary from 114kwH p.a. when replacing manual controller in gas heating system with no cooling, compared with 58kwH p.a. when replacing programmable controller.
whole life environmental impact	1 (high) to 5 (low) score	4	No data but can infer should be low due to adaptation of an existing function.
		7	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	No conflict
compatibility with current regulation	1 (low) to 5 (high) score	5	No conflict
compatibility with current assessment methodologies	1 (low) to 5 (high) score	2	Doesn't feature in RdSAP
		12	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	4	£200-300
life cycle costs	1 (high) to 5 (low) score	3	CLEARResult paper below suggests 10 year lifespan
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	4	Relatively high given low capital cost and assuming c.5-15% savings on energy bills
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	2	There are already an array of manufacturers and suppliers
		13	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	4	Good applicability - CLEAResult report suggests highest savings likely to be achieved in homes with electric heating, of which Scotland has a disproportionately high number
existing Scottish capacity/skills	1 (low) to 5 (high) score	4	Installation is not complex and can be carried out by competent plumber or electrician who is familiar with the product. E.g. Nest installer directory suggests 109 installers registered in Glasgow area and 8 in Inverness area.
Scottish content	1 (low) to 5 (high) score	2	Monitoring and control has reasonable share of UK market, according to Innovas data
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	3	Potential integration with other intelligent controls
Scottish economic impact potential	1 (low) to 5 (high) score	3	Principal benefit would be to local installers
		16	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	4	User-friendly interfaces, most linking to smartphone control
disruption	1 (high) to 5 (low) score	4	Requires some additional wiring at the boiler but low level of disruption overall
customer acceptance	1 (low) to 5 (high) score	5	Design is a major focus and key to marketing efforts
savings on bills	1 (low) to 5 (high) score	3	Moderate. Estimate around 5-15% depending on baseline
maintenance requirements	1 (high) to 5 (low) score	5	None
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	4	Intelligent functionality is intended to help ensure that home heating is adapted to lifestyle and usage, thereby increasing comfort
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	3	Would only be covered by standard consumer protections/product warranties. Some systems have installer networks but this is unlikely to provide much additional protection, e.g. terms & conditions of Nest Installation excludes any liability for property damage during installation
		28	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		
other relevant considerations/risks/opportunities	List/Describe		Consumer protection associated with installation appears limited
adaptability / future proofing	List / Describe		
		104	

References:

https://www.uswitch.com/gas-electricity/guides/how-much-can-a-smart.thermostat-save/

https://nest.com/thermostat/real-savings/

http://ilsagfiles.org/SAG_files/Meeting_Materials/2015/6-23-15_Meeting/CLEAResult_Smart_Thermostat_WhitePaper_20150505.pdf

Intelligent lighting

Daylight and motion sensors connected into lighting controls, often combined with personal remote control from mobile phone / tablet

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	Commercially available, e.g. Phillips Hue
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	3	Efficiency will presumably depend on user interaction and correct initial configuration. Marketing data refers to the potential for saving electricity through automatic dimming schedules.
Reliability	1 (low) to 5 (high) score	4	The Phillips Hue Starter Kit attracts 13 critical reviews of 153 total reviews on Amazon UK. Small number of these refer to reliability issues
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	5	Can be installed anywhere with electric lighting and wi-fi
complexity of systems/ their integration	1 (complex) to 5 (simple) score	5	Straightforward DIY installation
risk/severity of unintended consequences	1 (high) to 5 (low) score	5	No obvious potential unintended consequences
		31	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	2	Not really part of the marketing of these products. As lighting becomes more efficient anyway, this diminishes the potential savings associated with smart controls. Ease of control and variety of settings available may also lead to increased use. However, an interview with Todd Manegold, senior director of Hue product marketing, by 'Slashgear' states that there is potential to reduce electricity use/carbon by automatically adjusting lighting depending on ambient light, avoiding unnecessary over-illumination, or tweaking the settings according to peak and off-peak energy periods. Research Philips has cited earlier even suggested that, by making the lighting temperature warmer, residents delayed turning up their physical thermostat.
whole life environmental impact	1 (high) to 5 (low) score	4	No data but can infer should be low due to adaptation of an existing function.
		6	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	No conflict
compatibility with current regulation	1 (low) to 5 (high) score	5	No conflict
compatibility with current assessment methodologies	1 (low) to 5 (high) score	2	Don't feature in RdSAP
		12	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	4	Starter pack, including three bulbs retails at c£250
life cycle costs	1 (high) to 5 (low) score	3	Bulbs have limited lifespan (15,000 hours) compared to other LED products
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	1	No data available but likely to be fairly small in most cases.
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	3	Likely to be potential for economies of scale as this appears to be still an emerging market in the domestic sector
		11	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	5	Applicable in all buildings with electricity and wifi
existing Scottish capacity/skills	1 (low) to 5 (high) score	3	As per intelligent thermostat, assume there are Scottish installers
Scottish content	1 (low) to 5 (high) score	2	Monitoring and control has reasonable share of UK market, according to Innovas data
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	2	Potential integration with other intelligent controls
Scottish economic impact potential	1 (low) to 5 (high) score	1	No data but unlikely, particularly given no professional installation required in domestic context
		13	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	5	Controlled via smartphone or other device
disruption	1 (high) to 5 (low) score	5	No disruption for basic system in domestic setting
customer acceptance	1 (low) to 5 (high) score	4	
savings on bills	1 (low) to 5 (high) score	2	As lighting becomes more efficient anyway, this diminishes the potential savings associated with smart controls. Ease of control and variety of settings available may also lead to increased use. However, an interview with Todd Manegold, senior director of Hue product marketing, by 'Slashgear' states that there is potential to reduce electricity use/carbon by automatically adjusting lighting depending on ambient light, avoiding unnecessary over-illumination, or tweaking the settings according to peak and off-peak energy periods. Research Philips has cited earlier even suggested that, by making the lighting temperature warmer, residents delayed turning up their physical thermostat.
maintenance requirements	1 (high) to 5 (low) score	5	None
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	3	May be limited benefits in terms of security and comfort
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	3	Would only be covered by standard consumer protections and warranties on individual products
		27	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		
other relevant considerations/risks/opportunities	List/Describe		
adaptability / future proofing	List / Describe		
		100	

https://www.slashgear.com/with-energy-star-nod-philips-hue-unlocks-smart-bulb-rebates-24461314/

Power quality monitoring and intelligence systems

Distributed monitoring systems to measure consumption at the local level and monitor the impact of low carbon technologies, allows higher integration of smart technologies as part of active management of networks

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	This is a well established technology
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	5	Not really relevant but assume low energy consumption translates to high efficiency
Reliability	1 (low) to 5 (high) score	4	monitor will capture information where possible, but the interpretation of that data is down to the engineer which can impact reliability. Restarts automatically, weather proof, low repair rates
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	5	
complexity of systems/ their integration	1 (complex) to 5 (simple) score	5	Industry standard bit of kit, can be easily integrated on to system for monitoring period and then uninstalled
risk/severity of unintended consequences	1 (high) to 5 (low) score	5	only risks are interpreting the data incorrectly
		33	

https://w

Environmental	Scoring	Score	
(in-use) carbon saving potential	1 (low) to 5 (high) score	2	monitoring does not lead to carbon savings, but better understanding of the network can make better utilisation of the network
whole life environmental impact	1 (high) to 5 (low) score	4	Should be low impact
		6	

Policy / Regulation	Scoring	Score	
compatibility with Scottish policy	1 (low) to 5 (high) score	5	Already in use by DNOs in Scotland
compatibility with current regulation	1 (low) to 5 (high) score	5	Already in use by DNOs in Scotland
compatibility with current assessment methodologies	1 (low) to 5 (high) score	1	Not applicable
		11	

Monetary	Scoring	Score	
capital costs	1 (high) to 5 (low) score	5	Reasonably low for the network operator
life cycle costs	1 (high) to 5 (low) score	5	Minimal
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	2	Not designed for savings per se, but can facilitate them
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	3	Devices are small and portable and can therefore be re-used on different areas of the network
		15	

Capacity/ Supply Chain	Scoring	Score	
applicability	1 (low) to 5 (high) score	4	Fits in with move to more active networks
existing Scottish capacity/skills	1 (low) to 5 (high) score	3	Not aware of any Scottish companies or manufacturers
Scottish content	1 (low) to 5 (high) score	3	Outram research have a close relationship with SP Energy Networks
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	3	
Scottish economic impact potential	1 (low) to 5 (high) score	3	
		16	

Consumer	Scoring	Score	
user friendliness / practicality	1 (low) to 5 (high) score		This is not something used by an energy consumer - it would be installed and used by the network operator
disruption	1 (high) to 5 (low) score		
customer acceptance	1 (low) to 5 (high) score		Customer is unaware
savings on bills	1 (low) to 5 (high) score		Does not lead to direct savings on bills although indirectly could reduce the need for system reinforcement
maintenance requirements	1 (high) to 5 (low) score		
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score		
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score		
		0	

Opportunities / risks	Scoring	Score	
Critical success factors/watch points	List/Describe		
other relevant considerations/risks/opportunities	List/Describe		improved monitoring of the network can lead to improved modelling and analysis, and better understanding of what is happening in real life - when compared with assumptions made in design of the network
adaptability / future proofing	List / Describe		
		81	

Customer energy use platforms

Provide information on energy use and bills, make energy use suggestions

Used in conjunction with Smart Meters

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	8	the most basic platforms are at 9, but the full potential is yet to be reached
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	4	Not particularly relevant but low consumption
Reliability	1 (low) to 5 (high) score	3	Not reported, assume average
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	3	Needs to be compatible with smart meters, may need add-ons to do so
complexity of systems/ their integration	1 (complex) to 5 (simple) score	4	Not complex
risk/severity of unintended consequences	1 (high) to 5 (low) score	3	Too early to understand any unintended consequences. Main risk is that platforms are under-used.
		25	

Environmental	Scoring	Score	
(in-use) carbon saving potential	1 (low) to 5 (high) score	3	Could help to provide users with better understanding of energy use
whole life environmental impact	1 (high) to 5 (low) score	4	indirect savings over lifetime of use
		7	

Policy / Regulation	Scoring	Score	
compatibility with Scottish policy	1 (low) to 5 (high) score	5	
compatibility with current regulation	1 (low) to 5 (high) score	5	
compatibility with current assessment methodologies	1 (low) to 5 (high) score	2	Assessment methodologies do not take into account behavioural effects
		12	

Monetary	Scoring	Score	
capital costs	1 (high) to 5 (low) score	2	
life cycle costs	1 (high) to 5 (low) score	2	
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	2	
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	1	One device per user
		7	

Capacity/ Supply Chain	Scoring	Score	
applicability	1 (low) to 5 (high) score	4	would be applicable to Scottish energy consumers
existing Scottish capacity/skills	1 (low) to 5 (high) score	4	not aware of specific existing Scottish capacity or skills but strong ICT sector so potential for transferability
Scottish content	1 (low) to 5 (high) score	1	
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	3	
Scottish economic impact potential	1 (low) to 5 (high) score	4	Good, Scotland has a lead in ICT
		16	

Consumer	Scoring	Score	
user friendliness / practicality	1 (low) to 5 (high) score	3	Specific to brands, evolving
disruption	1 (high) to 5 (low) score	2	Low
customer acceptance	1 (low) to 5 (high) score	3	like demand response or other smart technologies, those who want to be more proactive will be more accepting that those who do not
savings on bills	1 (low) to 5 (high) score	4	can provide savings if consumers are more aware of energy use when, would integrate better with time of use tariffs
maintenance requirements	1 (high) to 5 (low) score	3	unknown
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	3	unknown
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	3	unknown
		21	

Opportunities / risks	Scoring	Score	
Critical success factors/watch points	List/Describe		
other relevant considerations/risks/opportunities	List/Describe		
adaptability / future proofing	List / Describe		
		88	

Gaming of energy saving

Offering up household appliances for central network control, in the form of a "game". Win points and prizes for making in-use appliances (energy) available for reduction

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	8	Northern Powergrid currently running a feasibility trial, which has had difficulties recruiting participants
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	4	Given that it's an app, the efficiency should be high.
Reliability	1 (low) to 5 (high) score	3	No data, but given nature of the app, unlikely to be problems with reliability
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	5	Just requires smart plug and smartphone app to participate
complexity of systems/ their integration	1 (complex) to 5 (simple) score	4	Smart plug allows integration with all electronic devices
risk/severity of unintended consequences	1 (high) to 5 (low) score	4	Hard to imagine any unintended consequences; users respond to notifications that encourage them to reduce energy use. Potential for vulnerable customers to be encouraged to reduce energy consumption in a way that may impact on their wellbeing
		28	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	4	Could be considerable; according to those involved in Northern PowerGrid/Open Energi's 'The GenGame', if the same number of people played GenGame as Pokemon GO, it would free up 500MW of capacity, enough to power more than a million homes. The DNO's website states that, "With over 100 homes signing up within the first three days of going live across the electricity distributor's patch and surprising levels of engagement in order to win, with people allowing their games consoles, TVs, and even hot tubs to be turned off whilst in use, the project is on track to be a major success."
whole life environmental impact	1 (high) to 5 (low) score	5	Minimal; the games are usually apps.
		9	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	No conflict
compatibility with current regulation	1 (low) to 5 (high) score	5	No conflict
compatibility with current assessment methodologies	1 (low) to 5 (high) score	1	Buildings assessment does not take into account behavioural change
		11	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	3	Total project costs for the GenGame feasibility trial is £1.75m. Aim was to get up to 2,000 households
life cycle costs	1 (high) to 5 (low) score	4	No data but likely low
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	4	ACE project as a whole estimated to save 346,000tCO2. Total cost of project is £7m, costing a reasonable £20/tCO2 . (NB Not all of this would be through games; these form a key part of the project but it also involves other interventions)
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	5	If trial is successful there could be very significant economies of scale from a large-scale rollout
		16	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	5	Wide applicability
existing Scottish capacity/skills	1 (low) to 5 (high) score	4	Strong ICT sector
Scottish content	1 (low) to 5 (high) score	3	No known Scottish content to-date but good link in with Scottish gaming sector re IP and design.
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	2	Link to smart plugs which are installed to make appliances available to the grid operator and to allow self-control by customers.
Scottish economic impact potential	1 (low) to 5 (high) score	3	Scotland has a lead in ICT and a thriving gaming sector. Gross value may not be high compared to other sectors with more manufacturing and more uptake.
		17	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	4	Engagement via smartphone app
disruption	1 (high) to 5 (low) score	5	No disruption involved
customer acceptance	1 (low) to 5 (high) score	2	Northern Powergrid trial suggests intensive recruitment efforts needed. Open Energi website suggests 400 households recruited
savings on bills	1 (low) to 5 (high) score	3	Estimated £33/year for participating households according to Northern Powergrid's LCNF submission for ACE, the successor to the GenGame
maintenance requirements	1 (high) to 5 (low) score	4	No data but once an app is established, maintenance should be minimal.
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	3	No obvious benefits in terms of health, wellbeing or comfort
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score		
		21	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		
other relevant considerations/risks/opportunities	List/Describe		
adaptability / future proofing	List / Describe		
		102	

References:

Norther Powergrid (2015) NIA Project Registration and PEA Document - http://www.smarternetworks.org/NIA_PEA_PDF/NIA_NPG_005_3137.pdf

Northern Powergrid (2016) Network Innovation Allowance Progress Report - http://www.smarternetworks.org/NIA_PEA_PDF/NIA_NPG_005_PR_5245.pdf

http://www.openenergi.com/news-posts/gengame-partnership-demonstrates-power-gamification-drive-domestic-dsr-success/

https://www.thegengame.com/

https://www.theenergycheck.co.uk/single-post/2016/11/25/New-mobile-game-%E2%80%98helping-manage-UK-power-demand%E2%80%99

Low Carbon Network Fund full submission proforma; activating customer engagement, Norther Power Grid https://www.ofgem.gov.uk/ofgem-publications/75317/npg-ace-isp-pdf

Peer-to-Peer Energy Matching Platform

Cloud-based data platform to match business energy demand with local renewable energy resources

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	Currently available via Open Utility's Piclo product, in partnership with Good Energy. Available to business consumers only
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	4	
Reliability	1 (low) to 5 (high) score	4	No data, although this is a matching service so shouldn't be subject to any major reliability issues
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	5	Simply requires signing up with a partner electricity retailer
complexity of systems/ their integration	1 (complex) to 5 (simple) score	4	Little data on this but appears to be a straightforward energy matching service
risk/severity of unintended consequences	1 (high) to 5 (low) score	5	No unintended consequences envisaged
		31	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	1	Allows individual business consumers to reduce their carbon footprint but does not reduce emissions from the network overall
whole life environmental impact	1 (high) to 5 (low) score	2	As a trading service this would presumably be low
		3	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	No conflict
compatibility with current regulation	1 (low) to 5 (high) score	5	No conflict
compatibility with current assessment methodologies	1 (low) to 5 (high) score		N/A
		10	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	5	No direct to consumers other than potentially higher tariff when switching to a partner retailer
life cycle costs	1 (high) to 5 (low) score		N/A
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	1	Allows individual business consumers to reduce their carbon footprint but does not reduce emissions from the network overall
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	1	Having a higher number of generators signed up could enable a wider range of tariffs to be offered but savings likely to be marginal
		7	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	2	applicable only to businesses currently
existing Scottish capacity/skills	1 (low) to 5 (high) score	5	The high levels of renewable generation in Scotland make it particularly relevant to the Scottish context
Scottish content	1 (low) to 5 (high) score	3	Links to strong ICT sector.
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	4	Links formed between generation and demand sectors
Scottish economic impact potential	1 (low) to 5 (high) score	3	Scotland has a lead in ICT. Gross value may not be high compared to other sectors with more manufacturing and more uptake.
		17	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	5	Simply requires signing up with a registered energy retailer and specifying required energy mix
disruption	1 (high) to 5 (low) score	5	No disruption
customer acceptance	1 (low) to 5 (high) score	4	A May 2016 article refers to 37 different participants from across the country buying and selling renewable-generated electricity between themselves. Rosie Frankland, commercial manager at the National Trust, said that the pilot had been a "great experience". "It has provided a transparent, easy to use mechanism for the Trust to offer its renewable energy to consumers wanting to source from a renewable generator.
savings on bills	1 (low) to 5 (high) score	3	The Eden Project said that initial analysis of the project's results had shown that the site could save as much as £20,000 each year through reduced Distribution Use of System (DUoS) charges by prioritising locally-generated electricity. These kind of savings will be highly variable depending on location, but generally energy matching should save on peak demand related charges.
maintenance requirements	1 (high) to 5 (low) score	5	None required
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	3	No impact
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	5	Energy still provided by retailer so covered by energy market protections
		30	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		
other relevant considerations/risks/opportunities	List/Describe		
adaptability / future proofing	List / Describe		
		98	

http://www.solarpowerportal.co.uk/news/good_energy_and_open_utility_piclo_trial_brings_renewable_tariffs_to_583

Whole home communication

Home Area Networks for machine to machine communication. The Xsilon solution uses power lines in the home as the conduit.

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9		Unclear. Www.xsilon.com gives the impression that the product has been developed but there is no information on how the product can be acquired
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score		Not relevant
Reliability	1 (low) to 5 (high) score		No data
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	5	Technology fits inside a standard 13-amp plug so can be retrofitted to any appliance
complexity of systems/ their integration	1 (complex) to 5 (simple) score	4	System communicates via existing mains wiring
risk/severity of unintended consequences	1 (high) to 5 (low) score		No data
		9	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score		No data
whole life environmental impact	1 (high) to 5 (low) score		No data
		0	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	3	May undermine the smart meter rollout as it could potentially provide more useful in-home information for householders than a smart meter in-home display
compatibility with current regulation	1 (low) to 5 (high) score	5	No conflict
compatibility with current assessment methodologies	1 (low) to 5 (high) score	1	Not in RdSAP
		9	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score		No data
life cycle costs	1 (high) to 5 (low) score		No data
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score		No data
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	5	Likely to be very high if the product is shown to be commercially and technically viable
		5	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	5	In theory, should be applicable in all homes
existing Scottish capacity/skills	1 (low) to 5 (high) score		N/A
Scottish content	1 (low) to 5 (high) score		No data
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	2	Potential for linkages with other in-home communication and control technologies
Scottish economic impact potential	1 (low) to 5 (high) score	1	No obvious wider economic impact potential
		8	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	3	Described as 'plug and play' but no in-use evidence
disruption	1 (high) to 5 (low) score	4	Product description indicates that it would simply require changing plus on devices
customer acceptance	1 (low) to 5 (high) score	1	No evidence as yet
savings on bills	1 (low) to 5 (high) score		No data
maintenance requirements	1 (high) to 5 (low) score		No data
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	2	Product description suggests that the system would allow remote control of appliances but no other apparent comfort/health/wellbeing benefits
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	3	Would just be covered by standard consumer protections/warranties
		13	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		
other relevant considerations/risks/opportunities	List/Describe		
adaptability / future proofing	List / Describe		
		44	

Internet of things mesh

allow different people, cities and councils to share data from smart devices and allow them to link to existing information networks as easily as possible

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	8	London, Bristol and Milton Keynes have acted as testbeds for the application of the IoT at City level - HyperCat City. At a more local level, Moixa Gridshare allows households and businesses with smart batteries installed to share their battery energy. The latter is a commercially available product
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score		No data
Reliability	1 (low) to 5 (high) score	3	No published evaluation of HyperCat City but British Standards have issued a PAS specification - PAS2012. Moixa Gridshare products have 5 year warranty.
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	2	No data on this but the publication of the PAS specification should help to enable better integration in future. Moixa Gridshare requires households and businesses to have smart batteries installed first.
complexity of systems/ their integration	1 (complex) to 5 (simple) score	3	At a basic level (individual or groups of businesses/households), relatively simple, particularly once smart meters have been installed but complex at a wider level
risk/severity of unintended consequences	1 (high) to 5 (low) score	2	Obvious risks in terms of cyber crime
		18	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score		
whole life environmental impact	1 (high) to 5 (low) score		
		0	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score		
compatibility with current regulation	1 (low) to 5 (high) score		
compatibility with current assessment methodologies	1 (low) to 5 (high) score		
		0	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score		
life cycle costs	1 (high) to 5 (low) score		
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score		
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score		
		0	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score		
existing Scottish capacity/skills	1 (low) to 5 (high) score		
Scottish content	1 (low) to 5 (high) score		
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score		
Scottish economic impact potential	1 (low) to 5 (high) score		
		0	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score		
disruption	1 (high) to 5 (low) score		
customer acceptance	1 (low) to 5 (high) score		
savings on bills	1 (low) to 5 (high) score		
maintenance requirements	1 (high) to 5 (low) score		
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score		
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score		
		0	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		
other relevant considerations/risks/opportunities	List/Describe		
adaptability / future proofing	List / Describe		
		18	

WiMax

Radio-based telecommunications for relaying data required as part of a smart network

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9		Subject of a broadly successful trial by Western Power Distribution in 2015
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score		No data
Reliability	1 (low) to 5 (high) score	4	In the Western Power Distribution Falcon project, the network is said to have had a 'reasonably reliable level' throughout the project. States that 'the network broadly 100% available throughout'.
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	3	FALCON project demonstrated integration with existing network architecture but requires clear line of sight between installations
complexity of systems/ their integration	1 (complex) to 5 (simple) score		
risk/severity of unintended consequences	1 (high) to 5 (low) score		
		7	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score		
whole life environmental impact	1 (high) to 5 (low) score		
		0	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score		
compatibility with current regulation	1 (low) to 5 (high) score		
compatibility with current assessment methodologies	1 (low) to 5 (high) score		
		0	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score		FALCON report suggests that 'WiMAX has proved to be a suitable radio technology for this application yielding a low overall installation and operational cost solution'
life cycle costs	1 (high) to 5 (low) score		
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score		
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score		
		0	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score		
existing Scottish capacity/skills	1 (low) to 5 (high) score		
Scottish content	1 (low) to 5 (high) score		
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score		
Scottish economic impact potential	1 (low) to 5 (high) score		
		0	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score		
disruption	1 (high) to 5 (low) score		
customer acceptance	1 (low) to 5 (high) score		
savings on bills	1 (low) to 5 (high) score		
maintenance requirements	1 (high) to 5 (low) score		
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score		
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score		
		0	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		
other relevant considerations/risks/opportunities	List/Describe		
adaptability / future proofing	List / Describe		
		7	

Only info available is from WPD Falcon project. This included new telecomms systems but other components too; information not really broken down.
http://www.smarternetworks.org/Files/FALCON_160503095823.pdf

Smart Plugs

Plugs for appliances that facilitate control either or by both of grid operator and customer

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	Commercially available in many forms and from multiple vendors
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	4	Smart plug has no efficiency penalty and the device can lead to more energy efficient connected appliance use but depends on user and method of control
Reliability	1 (low) to 5 (high) score	4	High reliability assumed from highly tested and matured products in marketplace
(level of) Compatability with existing systems	1 (low/poor) to 5 (high/good) score	4	Very high compatibility with electrical appliance connections and low power wireless comms to 'control hub points' - wider system compatibility varies
complexity of systems/ their integration	1 (complex) to 5 (simple) score	5	Can buy off the shelf for some devices and use with smart phone apps
risk/severity of unintended consequences	1 (high) to 5 (low) score	4	Fairly low risk associated with the device other than controlling any critical appliances inappropriately
		30	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	3	Unknown: some vendors claim significant energy (and so carbon) savings on decently robust but no independent evidence
whole life environmental impact	1 (high) to 5 (low) score	3	unknown: little published information on through life impacts - most information is on annualised savings
		6	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	An important part of the flexibility and demand side agenda
compatibility with current regulation	1 (low) to 5 (high) score	5	All appears to be aligned or straightforward from regulation perspective
compatibility with current assessment methodologies	1 (low) to 5 (high) score	4	Most likely to come under auspices of general Building Energy Management Systems standards for automated and manual supervisory control of energy consumption
		14	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	5	Low costs per device and relative to appliance costs and energy costs for end users
life cycle costs	1 (high) to 5 (low) score	4	No ongoing lifecycle costs for devices or services
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	3	Unknown: linked to energy saving and marginal carbon intensity of energy consumption reduction
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	3	Can buy smart hub type kits, but savings are marginal because the cost is reasonably low already
		15	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	5	wide opportunity for applicability at the majority Low Voltage energy consumption locations (residential, public estate and commercial)
existing Scottish capacity/skills	1 (low) to 5 (high) score	2	Some research in universities, not aware of any Scottish companies
Scottish content	1 (low) to 5 (high) score	1	Unknown but assumed low: not clear from evidence if any supply chain components or final assemblies are sourced in Scotland
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	4	Opportunity for cross-sector participation/benefit similar to recent CF/LED lighting programmes
Scottish economic impact potential	1 (low) to 5 (high) score	2	Low opportunity for wholesale/retail activity from any wider roll-out campaign/programme
		14	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	5	plug and play with smartphone devices
disruption	1 (high) to 5 (low) score	5	very low impact on energy amenity at point of use
customer acceptance	1 (low) to 5 (high) score	4	Similarly to other demand response programmes, clear customer benefits and ease of use are essential for wide take up
savings on bills	1 (low) to 5 (high) score	4	Moderate overall savings but potential significant savings for applications where appliances are left in service unnecessarily
maintenance requirements	1 (high) to 5 (low) score	4	Low maintenance expected
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	5	More user control of energy appliances and use in both local and remote applications
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	5	Basic electrical safety certification in place but few standards cover user features and operation
		32	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		Wider consumer focused campaigns and application by building energy managers are likely to enhance uptake and successful use
other relevant considerations/risks/opportunities	List/Describe		Further development of the devices and their integration into wider building management systems and beyond could lead to providing services to the system and DNOs e.g. peak reduction, voltage regulation etc.
adaptability / future proofing	List / Describe		Low cost, therefore upgrades or new models easily replaced. Could be superseded by devices with in-built controllability.
		111	

Home Voltage Regulation

Maintains voltage at set point in the home, saving energy and extending life of appliances and light bulbs - average incoming voltage is 245V but appliances generally use 220V, excess lost as heat.

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	Products commercially available in marketplace
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	3	Expected gains to consumer and wider system efficiency but more robust evidence required
Reliability	1 (low) to 5 (high) score	3	Unknown on a large scale and while a mature technology it still seems in the early stages of deployment and utilisation
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	5	Plug and play, similar to smart plug devices
complexity of systems/ their integration	1 (complex) to 5 (simple) score	5	Plug and play, similar to smart plug devices
risk/severity of unintended consequences	1 (high) to 5 (low) score	3	More stable and lower consumption voltage is potentially useful but this may lead to some higher losses from higher currents in constant power load types and potential additional losses in the voltage regulator itself
		28	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	4	6 - 18 tonnes of CO2 equivalent savings over 20 years
whole life environmental impact	1 (high) to 5 (low) score	4	Expect this to be minimal as it is a small device
		8	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	Energy saving and promotes smart grid technology
compatibility with current regulation	1 (low) to 5 (high) score	5	No reason why it couldn't be installed today
compatibility with current assessment methodologies	1 (low) to 5 (high) score	4	the ND NCM already recognises and makes allowance for voltage regulation (power correction factor) and AMT (automatic monitoring and targeting) – see para 168 at: http://www.gov.scot/Resource/0048/00486061.pdf. Not common in domestic context so not currently part of SAP.
		14	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	5	£549 including installation
life cycle costs	1 (high) to 5 (low) score	4	Potential low parasitic loss of additional interposing electrical equipment
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	3	No data, need to convert energy savings to carbon savings
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	3	Higher savings from larger deployments and lower costs expected if relatively simple devices gain mass market scale
		15	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	3	At current costs, most likely to benefit commercial office spaces- larger commercial and industrial facilities may already have such power conditioning equipment for power factor correction or voltage regulation
existing Scottish capacity/skills	1 (low) to 5 (high) score	2	No information on development or deployment in Scotland
Scottish content	1 (low) to 5 (high) score	1	current manufacturer based on Bristol
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	3	Part of building management systems and energy services sector
Scottish economic impact potential	1 (low) to 5 (high) score	2	Expected moderate energy efficiency gains (and some avoided equipment damage) per customer uptake but not expected to be a major economic driver at a wider scale
		11	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	5	No user interaction required
disruption	1 (high) to 5 (low) score	5	Minimal beyond initial installation
customer acceptance	1 (low) to 5 (high) score	3	Early adoption profile at present, but could pick up depending on incentives
savings on bills	1 (low) to 5 (high) score	5	£75-£135 saving on annual energy bill
maintenance requirements	1 (high) to 5 (low) score	4	Minimal
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	3	No impact
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	4	Similar to other electrical on-site equipment
		29	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		Campaigns targeted to facilities managers for commercial sector deployments or large cost reduction and residential uptake
other relevant considerations/risks/opportunities	List/Describe		Potential to be included as part of larger building management systems, or connected to a service which would provide voltage support to DNO?
adaptability / future proofing	List / Describe		Can it communicate with wider network through comms? Could interact with grid services in future?
		105	

Home energy management systems

starting at remote controls e.g. thermostats, light and other appliance remote controls, and ranging to whole home controls

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	3	Efficiency depends on system configuration or user interaction
Reliability	1 (low) to 5 (high) score	4	Depends on the particular tool, but no significant problems noted
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	3	If using multiple types of control device, there may be interoperability issues combining different brands
complexity of systems/ their integration	1 (complex) to 5 (simple) score	3	If using multiple types of control device, there may be interoperability issues combining different brands
risk/severity of unintended consequences	1 (high) to 5 (low) score	5	Low risk other than possible cyber security vulnerabilities to internet and wireless based technologies
		27	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	4	Energy savings of around 30% quoted in reference sources
whole life environmental impact	1 (high) to 5 (low) score	4	Minimal
		8	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	Energy saving and promotes smart grid technology while empowering customers
compatibility with current regulation	1 (low) to 5 (high) score	5	No reason why it could not be installed today
compatibility with current assessment methodologies	1 (low) to 5 (high) score	5	Yes - can improve home energy efficiency
		15	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	5	Starts at £150 for individual device, options for subscription solutions (£60 per year)
life cycle costs	1 (high) to 5 (low) score	4	Depends on scale of solution. Ongoing subscription costs are low, minimal maintenance costs
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	4	30% savings on energy use, and relatively low cost so relatively high carbon saving projected
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	5	The more energy there is to manage, the more there is to gain from this solution. It is not expected that costs will reduce significantly with market scale but there will likely be some moderate gains on Internet of things/wireless adapters and competitive pressure on the energy management application software and hardware.
		18	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	4	promotes energy saving and smart grid technologies to wide spectrum of home energy users
existing Scottish capacity/skills	1 (low) to 5 (high) score	2	No record of numbers deployed (are likely already some homes in Scotland) or Scottish supply chain participation in deployments
Scottish content	1 (low) to 5 (high) score	3	Not aware of any Scottish technology developers in this area but generally strong sector identified by Innovas
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	4	Works with smart plugs and combines other types of smart controls to increase efficiency of home system. Good potential for wider energy services, on-site generation and grid/market interaction.
Scottish economic impact potential	1 (low) to 5 (high) score	4	Good potential for altering the energy and financial flows as consumers become more efficient and also procure and provide services related to home energy management
		17	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	5	Varies per vendor system
disruption	1 (high) to 5 (low) score	4	Little disruption other than behaviour and user up-skilling required in some cases
customer acceptance	1 (low) to 5 (high) score	4	Likely high acceptance based on the growth of apps and smart technology
savings on bills	1 (low) to 5 (high) score	4	No figures report but savings in the region of 30% on total energy use
maintenance requirements	1 (high) to 5 (low) score	5	Likely negligible maintenance required as per consumer electronic devices and applications
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	5	likely to enhance overall wellbeing and comfort by more carefully controlling energy use in homes
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	3	Some potential for uncertainty with sophisticated combination of data, privacy, multiple devices, international vendors
		30	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		annual review of energy use before and after installation, reduction in energy bills assessed for specific users and also widely reported and tested to build confidence.
other relevant considerations/risks/opportunities	List/Describe		potential to link to renewable resources e.g. pv panels on house. Cyber threats and suspicions over data privacy are likely to be a factor in uptake.
adaptability / future proofing	List / Describe		modular so it can be expanded and changed in future and with opportunity to update software relatively easily.
		115	

https://www.greentechmedia.com/articles/read/hems-the-nuts-and-bolts-of-the-subscription-model

Building Management System

Commercial, industrial

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	Mature technology widely available from multiple vendors and widely deployed
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	3	Efficiency depends on user interaction, correct initial configuration and interactions across management system components and energy equipment
Reliability	1 (low) to 5 (high) score	4	Depends on the particular tool, but no significant problems noted (other than misconfiguration so efficiencies not forthcoming as expected)
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	3	Most BMS products are mature and come with integration, interface and interoperability options.
complexity of systems/ their integration	1 (complex) to 5 (simple) score	3	As above
risk/severity of unintended consequences	1 (high) to 5 (low) score	5	Low risk but there are many reported cases of underperforming BMS
		27	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	4	Can reduce operating costs by up to 20% so energy reduction and better management can contribute to carbon emission reduction
whole life environmental impact	1 (high) to 5 (low) score	4	Minimal
		8	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	Energy saving and promotes smart grid technology
compatibility with current regulation	1 (low) to 5 (high) score	5	No obvious barriers or reasons why it could not be installed today
compatibility with current assessment methodologies	1 (low) to 5 (high) score	5	It can help improve the efficiencies of devices installed on or around the home
		15	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	2	£2-5 PER SQ FOOT
life cycle costs	1 (high) to 5 (low) score	4	It will depend on the scale of the solution, ongoing license/maintenance agreements, and whether the management of the scheme is in-house, or by a third party
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	3	Due to high costs, effectiveness will be greater for larger properties e.g. office buildings
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	5	The more energy there is to manage, the more there is to gain from this solution. Can integrate with Demand Response schemes
		14	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	3	would benefit commercial office spaces, large factory premises with energy intensive operational processes
existing Scottish capacity/skills	1 (low) to 5 (high) score	4	Strong sector identified by Innovas. Example - 'MCE Scotland - engineering firm specialising in HVAC Control and Building Energy Management Systems with offices located throughout Scotland.
Scottish content	1 (low) to 5 (high) score	5	BMS installer companies with offices located in Scotland
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	4	Can be integrated with generation technologies to create self-sufficient sites e.g. minimise supply from grid.
Scottish economic impact potential	1 (low) to 5 (high) score	3	Not knowing the baseline makes the additional economic impact from additional deployment difficult to gauge
		19	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	5	Mature products in marketplace with good usability features
disruption	1 (high) to 5 (low) score	3	Adjustment period required to get balance right on site/factory processes and tune system to maximise gains
customer acceptance	1 (low) to 5 (high) score	4	Already a mature, customer accepted solution deployed at new build and retrofit stages
savings on bills	1 (low) to 5 (high) score	4	Savings in the region of 20% on total energy use reported but more robust evidence required in this significant, mature sector of energy efficiency
maintenance requirements	1 (high) to 5 (low) score	4	Requires regular audit and maintenance to ensure no negative impacts on business operations and that benefits are secured and plant changes are reflected in system configuration
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	5	Reflected in BMS technology/products already
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	5	Reflected in commercial contractual arrangements for BMS implementation and services
		30	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		annual review of energy use before and after installation, BMS configuration checks, reduction in energy bills, improved efficiency in processes
other relevant considerations/risks/opportunities	List/Describe		potential to link to renewable resources e.g. pv panels, CHP, GSHP
adaptability / future proofing	List / Describe		modular so it can be expanded and changed in future
		113	

http://blogs.intel.com/iot/2016/06/20/costs-savings-roi-smart-building-implementation/

http://www.mcescotland.com/

Active Network Management

Through Control and Communications infrastructure, management of DER connected within a network area to manage constraints on the network

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	Accepted as a technologically mature solution
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	5	Makes efficient use of DER assets and existing network capacity while lowering costs of grid and market integration
Reliability	1 (low) to 5 (high) score	4	Reliability is dependant on the communication, control hardware and DER responsiveness so end-to-end system reliability is able to be enhanced through system tuning
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	5	Is compatible with existing DNO networks and control systems (communicating through a number of comms channels/protocols) and interfacing to a number of customer energy assets
complexity of systems/ their integration	1 (complex) to 5 (simple) score	3	Degree of complexity involved due to security of information transfer and mission critical nature of network and energy asset control
risk/severity of unintended consequences	1 (high) to 5 (low) score	5	Low risk to system
		31	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	5	Increases network losses through higher utilisation but increases the connection of renewables to the network and utilisation of the network assets
whole life environmental impact	1 (high) to 5 (low) score	4	Increases network losses through higher utilisation but increases the connection of renewables to the network and utilisation of the network assets
		9	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	Facilitates renewable connections and smart grids
compatibility with current regulation	1 (low) to 5 (high) score	5	Business as usual for DNOs and aligns with major flexibility, 'unlocking capacity' and QMEC regulatory initiatives
compatibility with current assessment methodologies	1 (low) to 5 (high) score	3	Not relevant
		13	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	2	£5-10k for a single energy asset solution, growing to £500,000 for an entire scheme controlling multiple generators/DER against multiple constraints in a regional power network area
life cycle costs	1 (high) to 5 (low) score	3	ongoing license costs
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	4	carbon emissions benefit is directly linked to the operation to the renewable energy assets that ANM controls
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	5	Wide area ANM can provide a reduction in cost per MW (but must be led by DNOs)
		14	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	4	applicable to all DER assets integrating to grid system and energy/system services markets
existing Scottish capacity/skills	1 (low) to 5 (high) score	5	ANM vendor Smarter Grid Solutions head office in Glasgow
Scottish content	1 (low) to 5 (high) score	5	Invention from Scotland university sector and commercial ANM provider and technology developer based in Scotland
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	4	As a system wide and all energy asset management solution ANM provides opportunities to work across developers, power network companies, energy suppliers, system operator, consultancies and public sector
Scottish economic impact potential	1 (low) to 5 (high) score	4	See above
		22	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	4	Not really used by an energy consumer, but by a DER Developer and power network company but usability features becoming more prominent
disruption	1 (high) to 5 (low) score	4	Commissioning typically takes place during energy asset connection
customer acceptance	1 (low) to 5 (high) score	5	High when it can facilitate higher export potential, or faster and cheaper connection to the grid
savings on bills	1 (low) to 5 (high) score	3	Flexible connections are cheaper than firm connections requiring grid reinforcements, therefore this reduces network upgrade costs (savings are passed on to the consumer)
maintenance requirements	1 (high) to 5 (low) score	4	updates as and when required, minimal disruption
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	3	No impact - additional power system operation and maintenance procedures already updated to account for new solution
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	4	Overseen by regulation of power network companies operating ANM schemes with customer participation
		27	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		Capacity of generation able to connect through managed connections, growth in connections in constrained parts of the distribution network, requirements and markets for managing system flexibility
other relevant considerations/risks/opportunities	List/Describe		Transition to DSO, enhancement of SO roles, new markets for flexibility
adaptability / future proofing	List / Describe		Flexible software based solution that can be upgraded as technology changes and system/user requirements change
		116	

Microgrid Controller

Local controller that would allow an islanded network to be created following disconnection from the main grid. This would require the control platform to balance supply and demand within the islanded network to maintain power supply to critical infrastructure within the islanded grid. Can apply to industrial estates or within neighbourhoods e.g. domestic scale

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	Commercially deployed solutions growing
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	4	Makes more efficient use of local grid and energy assets and, while energy technology neutral, provides opportunity for greater renewable
Reliability	1 (low) to 5 (high) score	4	Reliability is dependant on the Comms installed
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	5	Is compatible with existing DNO networks, and can communicate with a number of communications protocols
complexity of systems/ their integration	1 (complex) to 5 (simple) score	3	Degree of complexity involved due to data, security, control and operation requirements within microgrid and between microgrid and power system
risk/severity of unintended consequences	1 (high) to 5 (low) score	2	Moderate risks to local dependents on microgrid operation of maloperation or energy resource inadequacy
		27	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	5	Can increase local renewable penetration and reduce transport losses of electricity
whole life environmental impact	1 (high) to 5 (low) score	4	Increases local network losses but increases the connection of renewables to the network - might be efficiency loss with any battery storage
		9	

Policy / Regulation	Scoring	Score	Comments
compatability with Scottish policy	1 (low) to 5 (high) score	5	Can facilitate renewable connections, provide rural or islanded communities with the potential to have greater control over renewable resources in the area
compatability with current regulation	1 (low) to 5 (high) score	3	Depending on the scheme, some areas of DNO regulation which does not permit generation to continue exporting when there are outages. It may have to operate on a private network.
compatibility with current assessment methodologies	1 (low) to 5 (high) score	3	Not relevant
		11	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	3	Ranges from $25/kW to $200/kW (http://www.sustainablepowersystems.com/wp-content/uploads/2016/10/UMC-Frequently-Asked-Questions-Rev-1.pdf) depending on manufacturer and scale of grid
life cycle costs	1 (high) to 5 (low) score	4	Minimal for the microgrid controller, but there would be life cycle costs associated with a private network
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	5	carbon emissions benefit is directly linked to the operation to the renewable energy assets that ANM controls
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	5	Increasing the number of elements in the scheme, can spread the costs of central controller but individual units will still be required over device
		17	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	5	particularly relevant for some of the island communities with weak interconnections to mainland grid
existing Scottish capacity/skills	1 (low) to 5 (high) score	4	Lots of work at Scottish Universities, but other than ANM vendor, not aware of Scottish specific companies manufacturing microgrid controllers
Scottish content	1 (low) to 5 (high) score	4	Lots of work at Scottish Universities, but other than ANM vendor, not aware of Scottish specific companies manufacturing microgrid controllers
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	5	Working with developers, DNOs, consultancies, public sector
Scottish economic impact potential	1 (low) to 5 (high) score	5	Could have impact on islanded and rural communities, reduce energy bills and increase the use of local renewable generation
		23	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	4	Not really used by an energy consumer, but by a Developer
disruption	1 (high) to 5 (low) score	4	Commissioning can take place during connection, but sometimes outages required for upgrades
customer acceptance	1 (low) to 5 (high) score	5	High when it can facilitate higher export potential, better security of supply
savings on bills	1 (low) to 5 (high) score	4	can reduce import from national grid and ensure local demand is met by local generation.
maintenance requirements	1 (high) to 5 (low) score	4	updates as and when required, minimal disruption
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	3	No impact - additional power system operation and maintenance procedures already updated to account for new solution
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	3	would be overseen by network regulator, all solutions would be grid compliant with existing industry standards
		27	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		ability to facilitate connections in remote and rural areas of the network with weak grid infrastructure
other relevant considerations/risks/opportunities	List/Describe		
adaptability / future proofing	List / Describe		Flexible, can be upgraded as technology changes
		114	

Generation Router Device

a 'box' that communicates with energy management platform and instructs generation response e.g. Broderson RTU or Origami Energy Router

Forms part of the DER Management/ANM system (Cl5)

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	5	Used to control generation and make more efficient use of existing connection assets, using standard comms protocols
Reliability	1 (low) to 5 (high) score	4	Reliability is dependant on the Comms installed
(level of) Compatability with existing systems	1 (low/poor) to 5 (high/good) score	5	Is compatible with existing DNO networks, and can comminicate with a number of comms protocols
complexity of systems/ their integration	1 (complex) to 5 (simple) score	3	Degree of complexity involved due to security of information transfer etc
risk/severity of unintended consequences	1 (high) to 5 (low) score	1	Hacking in to systems can enable generation or demand to be removed from the system
		27	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	5	Improves flexibility of the network and therefore improves provision of renewable energy on the network
whole life environmental impact	1 (high) to 5 (low) score	4	Improves use of renewables, improves balancing of the network
		9	

Policy / Regulation	Scoring	Score	Comments
compatability with Scottish policy	1 (low) to 5 (high) score	5	supports active management of both demand and generation devices, increase use of renewable generation
compatability with current regulation	1 (low) to 5 (high) score	5	Already in use in Scotland
compatibility with current assessment methodologies	1 (low) to 5 (high) score	3	Not relevant
		13	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	3	£4000 - £5000 for Broderson RTU32 (used for ANM systems)
life cycle costs	1 (high) to 5 (low) score	4	minimal for the controller
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	5	carbon emissions benefit is direclty linked to the operation to the renewable energy assets that router controls
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	3	Always need one router per device/site
		15	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	5	Particularly relevant for some of the island communities with weak interconnections to mainland grid
existing Scottish capacity/skills	1 (low) to 5 (high) score	4	No records of numbers deployed, but they are used by Smarter Grid Solutions (based in Glasgow)
Scottish content	1 (low) to 5 (high) score	1	Not aware of any Scottish technology developers in this area
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	5	Working with developers, DNOs, consultancies, public sector
scottish economic impact potential	1 (low) to 5 (high) score	5	
		20	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	4	Not really used by an energy consumer, but by a Developer or aggregator
disruption	1 (high) to 5 (low) score	4	Commissioning can take place during connection, but sometimes outages required for upgrades
customer aceptance	1 (low) to 5 (high) score	5	High when it can facilitate higher export potential,better security of supply, improving revenue through participation in services
savings on bills	1 (low) to 5 (high) score	4	Increase revenue for developers - not really a saving on consumer bills. Perhaps marginally through improved efficiency in balancing
maintenance requirements	1 (high) to 5 (low) score	4	updates as and when required, minimal disruption
health/wellbeing/comfort	1 (high negative imapct) to 5 (high positive impact) score	3	No impact
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	5	support through the vendor of the equipment
		29	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		increased participation of demand and generation in energy services, will increase as this is rolled out at distribution level
other relvant considerations/risks/opportunities	List/Describe		Increased flexibility of renewable generation, enhanced control which can be local control or centralised (via DNO/DSO)
adaptability / future proofing	List / Describe		Flexible, can be upgraded as technology changes
		113	

Smart Appliances

Smart appliances are able to respond to signals e.g. price information, direct control signals, and/or local measurements of electricity supply, and where the response leads to a change in when the appliance uses electricity. Using smart appliances to automatically adjust demand at peak times without any customer participation.

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	3	Could improves efficiency of devices around the home but very much depends how smart functionality is used
Reliability	1 (low) to 5 (high) score	3	Still in trial stages, reliability to be demonstrated for sustained period
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	4	Typically manufactured with 'smart' capabilities, and are installed the same was as standard appliances; possible to retrofit with a smart plug.
complexity of systems/ their integration	1 (complex) to 5 (simple) score	3	Can buy some devices with it readily integrated, retrofitting the device would be more complex
risk/severity of unintended consequences	1 (high) to 5 (low) score	3	Disconnecting fridges or heating devices can lead to high levels of customer dissatisfaction
		25	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	5	If all refrigerators were 'smart', this would provide significant levels of flexibility to national grid
whole life environmental impact	1 (high) to 5 (low) score	5	Smart appliances have the potential to greatly reduce the carbon impact of some devices e.g. fridge/freezers
		10	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	Supports energy efficiency drivers
compatibility with current regulation	1 (low) to 5 (high) score	3	Fully regulated industry so no issues here but smart devices need time of use tariffs and these are hampered by lack of half hourly settlement for domestic consumers.
compatibility with current assessment methodologies	1 (low) to 5 (high) score	5	Yes
		13	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	4	Small cost increase over conventional devices if buying built in smart capability. Around £100 more expensive
life cycle costs	1 (high) to 5 (low) score	5	Minimal
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	5	say 20% more expensive than standard device, with the potential to reduce energy consumption at peak times AND in future, provide services to the grid
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	5	The more devices that are installed nationwide, the greater level of flexibility available to operators
		19	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	5	Would benefit homes, potential to deploy in council housing/sheltered housing scenarios
existing Scottish capacity/skills	1 (low) to 5 (high) score	3	no records of numbers deployed but likely to be in some homes. Not that common yet
Scottish content	1 (low) to 5 (high) score	3	Not aware of Scottish manufacturers
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	5	Can be compatible with new markets for demand response if created under DSO Vision (all DNOs)
Scottish economic impact potential	1 (low) to 5 (high) score	3	Unless sales are via a Scottish company, minimal impact. Could potential be savings on energy bills but not clear
		19	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	3	Can be complex, but users tend to be more interested in learning how to use these things if they have an interest in being more efficient with their devices
disruption	1 (high) to 5 (low) score	4	Some time to learn best way to use device
customer acceptance	1 (low) to 5 (high) score	4	BEIS Consumer Panel found that, of their existing non-smart appliances, people would be most willing to use washing machines (79%), tumble dryers (71%), dishwashers (68%), and chargers (68%) flexibly with a smart tariff. The public are less willing to use fridges (45%) and freezers (43%) flexibly, largely due to a view that they need to run constantly to ensure food safety. Some customers can reject devices with more control, assuming them to be more complex/no interest in smart devices
savings on bills	1 (low) to 5 (high) score	4	Potential to reduce energy use of individual appliances and therefore reduce overall energy costs
maintenance requirements	1 (high) to 5 (low) score	5	Same as standard maintenance requirements for appliances
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	4	Consumer override is typically included - particularly for heating devices
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	5	regulated appliances, consumer protection provided by heavily regulated industry
		29	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		Number of appliances deployed, capability of aggregator capacity to support network
other relevant considerations/risks/opportunities	List/Describe		creation of flexibility markets, aggregation of capacity, creation of local services.
adaptability / future proofing	List / Describe		increase in residential DSR participation)
		115	

https://www.theguardian.com/environment/2009/apr/27/carbon-emissions-smart-fridges-environmentally-friendly-appliances

Demand Response

enables reduction/shift of electricity load from buildings through their existing building management systems (BMS) in response to signal from DNO. To facilitate this need aggregation of load shedding and communication between DNO and BMS.

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	8	Technology trials for DSR, but the market is to be developed
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	5	A number of devices already on the market which can provide Demand Response, but there is no wide scale market at the moment
Reliability	1 (low) to 5 (high) score	4	Reliable technology, but customers can override settings and reduce reliability
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	4	New devices to be installed in some cases
complexity of systems/ their integration	1 (complex) to 5 (simple) score	3	Can be complex to adapt user behaviour, but integration of tools is straight forward
risk/severity of unintended consequences	1 (high) to 5 (low) score	4	Low
		28	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	5	0.87Mt for domestic and 0.25Mt for non-domestic
whole life environmental impact	1 (high) to 5 (low) score	5	increased flexibility demand in homes and in large buildings, and able to reduce demand at peak hours
		10	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	Aligns with both Scottish, and UK Wide policy
compatibility with current regulation	1 (low) to 5 (high) score	3	Early stages for regulation of Demand Response, TBC
compatibility with current assessment methodologies	1 (low) to 5 (high) score	3	Improved energy efficiency in the home and C&I buildings, although will not impact on building energy efficiency
		11	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	4	Capital costs are associated with the technologies required for DR (smart meters, smart appliances)
life cycle costs	1 (high) to 5 (low) score	3	Settlement and billing costs
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	5	Can reduce CO2 through peak shifting, energy reduction, additional system balancing
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	5	The more participants in DR, the greater the benefits are for users and the wider system
		17	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	5	Lots of participants that could use DR
existing Scottish capacity/skills	1 (low) to 5 (high) score	4	Lots of large C&I buildings that could participate
Scottish content	1 (low) to 5 (high) score	1	Not Scotland specific
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	4	Combination of DR and local generation could balance locally i.e. maximise wind export through use of demand response
Scottish economic impact potential	1 (low) to 5 (high) score	5	Potential to reduce building energy costs
		19	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	4	Can be managed via a central controller (as part of BMS), or through individual appliances
disruption	1 (high) to 5 (low) score	3	Requires a change in attitude towards demand use
customer acceptance	1 (low) to 5 (high) score	3	Some users are opposed to demand response, preferring to have their own control over energy consumption. This is not an issue for C&I use
savings on bills	1 (low) to 5 (high) score	4	Can reduce energy use, participation in Time of Use tariffs (where available) could increase savings potential
maintenance requirements	1 (high) to 5 (low) score	4	Low
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	4	Some users argue that there is reduced comfort by not using energy whenever you like e.g. overriding storage heater settings but for the most part this is not the case (may only be relevant for young children or elderly)
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	3	Unknown?
		25	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		Numbers of participants, particularly at domestic scale, increase in C&I participation, local energy markets or balancing
other relevant considerations/risks/opportunities	List/Describe		If there is creation of markets for demand response at distribution level, this will increase participation/potential
adaptability / future proofing	List / Describe		
		110	

https://www.surrey.ac.uk/ces/files/pdf/1011_WP_Bradley_et_al_DemandResponse_3.pdf

Smart Invertor' or 'Virtual Oscillator'

A new technique known as virtual oscillator control allows smart solar inverters to sense and adjust to grid disturbances, such as a sudden change in frequency or voltage. As distributed solar grows and big power plants are retired, VOC will help keep the grid stable.

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	7	Still under development
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	5	Greatly improves operation of invertor connected generation
Reliability	1 (low) to 5 (high) score	3	To be determined through trials
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	5	Appears to be compatible with existing systems - that's one of the aims of the development and trials
complexity of systems/ their integration	1 (complex) to 5 (simple) score	3	Could be complex to integrate - to be determined
risk/severity of unintended consequences	1 (high) to 5 (low) score	3	If configured incorrectly it could trip generation or cause issues on the network
		26	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	5	improves the efficiency of the network
whole life environmental impact	1 (high) to 5 (low) score	5	minimal
		10	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	4	Nothing specific about technology in Scottish Policy, but would improve performance of PV plant and therefore increase renewable generation export
compatibility with current regulation	1 (low) to 5 (high) score	2	Unsure - there may be changes required to grid codes to integrate these systems
compatibility with current assessment methodologies	1 (low) to 5 (high) score	3	Not applicable
		9	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	5	Relatively low cost compared with the cost of the solar panels £100-£900 depending on spec?
life cycle costs	1 (high) to 5 (low) score	5	Low
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	5	Small additional cost to PV panel, to increase export potential
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	1	One inverter per device
		16	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	5	Potential to be developed in Scotland, and deployed in areas with large PV deployment (housing developers?)
existing Scottish capacity/skills	1 (low) to 5 (high) score	1	Not aware of any work being done in Scotland on this
Scottish content	1 (low) to 5 (high) score	1	Research is being led by NREL in the US
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	3	Potential to work with suppliers, developers, and PV manufacturers to install smarter systems
Scottish economic impact potential	1 (low) to 5 (high) score	4	Increase PV export
		14	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	3	not applicable
disruption	1 (high) to 5 (low) score	5	once installed there's no interruption
customer acceptance	1 (low) to 5 (high) score	3	minimal disruption but not well known
savings on bills	1 (low) to 5 (high) score	3	might increase PV export but not enough to notice substantial saving on bills/increase revenue from panels
maintenance requirements	1 (high) to 5 (low) score	4	minimal
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	3	not applicable
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	3	unknown
		24	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		Use monitoring data from the device to determine if performance improvements
other relevant considerations/risks/opportunities	List/Describe		
adaptability / future proofing	List / Describe		Ability to incorporate with flexibility markets or grid services in the future
		99	

https://www.nrel.gov/grid/virtual-oscillator-controls.html

DER providing grid services

The PV power plants were able to provide variability smoothing through automatic generation control, frequency regulation for fast response and droop response, and power quality control.

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	7	Market needs to be created, but DER is ready
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	5	Would improve flexibility of the network
Reliability	1 (low) to 5 (high) score	4	Through the use of other technologies (ANM, generation router, controllers) this can respond in real time - but will be reliant on Comms technology
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	5	Technology exists to allow this, but there are no existing markets for this at LV level
complexity of systems/ their integration	1 (complex) to 5 (simple) score	4	participation via an aggregator will simplify things
risk/severity of unintended consequences	1 (high) to 5 (low) score	4	Fail safes can be installed to ensure there are no negative impacts of non-responsive generation
		29	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	5	Greater flexibility, increase use of renewable generation when the resource is available
whole life environmental impact	1 (high) to 5 (low) score	5	Greater flexibility, increase use of renewable generation when the resource is available
		10	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	4	Closely aligned with Scottish policy proposals and plans under energy strategy
compatibility with current regulation	1 (low) to 5 (high) score	3	Market does not exist, and therefore difficult to rank this.
compatibility with current assessment methodologies	1 (low) to 5 (high) score	3	Not applicable
		10	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	5	Low
life cycle costs	1 (high) to 5 (low) score	3	Administration, subscription costs for aggregator - participants may need to pay for participation in the service, as they do at Transmission)
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	5	improves flexibility of the system, better use of available renewable resources
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	5	The more participants in DER services, the more competitive the market and therefore potential to lower costs
		18	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	5	large volume of DER connected generation in Scotland that could participate in such services
existing Scottish capacity/skills	1 (low) to 5 (high) score	5	Lots of DER installed that could participate IF the market was created
Scottish content	1 (low) to 5 (high) score	1	No trials by Scottish DNOs at the moment for Market services, but maybe in future?
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	1	
Scottish economic impact potential	1 (low) to 5 (high) score	4	DER has the potential to increase revenue through participation in balancing services
		16	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	4	depends if the develop is participating as part of an aggregator or not. Likely to be aggregator if small capacity
disruption	1 (high) to 5 (low) score	3	creation of markets is likely to create disruption in the energy market, lots of discussions with DER would need to take place first to establish rules and regulation
customer acceptance	1 (low) to 5 (high) score	5	customer would only participate if they wanted to - not a requirement
savings on bills	1 (low) to 5 (high) score	5	can increase revenue
maintenance requirements	1 (high) to 5 (low) score	5	low
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	3	not applicable
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	3	Unknown
		28	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		Market for DER participation must first be created. Then monitor participation, improved balancing costs, system flexibility, increase revenue potential for DER (which could encourage more development due to lack of subsidies)
other relevant considerations/risks/opportunities	List/Describe		
adaptability / future proofing	List / Describe		markets can be flexible and therefore capability of DER may develop in the future
		111	

Electric batteries, domestic

Electrical energy converted to chemical energy where it is stored, and then discharged as electrical energy to be used at another time. In behind the meter applications, the battery remains in the same place but stores energy generated at one time for use at another time. In a domestic setting, typically used in conjunction with renewable energy (PV).

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	Lithium ion most commonly used for light weight and longer life
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	5	Round trip charge to discharge efficiency 98%
Reliability	1 (low) to 5 (high) score	4	Generally good if handled and sited correctly (i.e. not robust to all environmental conditions due to hazardous chemicals)
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	3	Compatible with relatively large PV systems but difficult to keep fully charged if small amount of excess and will not be sufficient to power more than lights, fridge and TV / laptop. In winter mode may not be sufficient to power much.
complexity of systems/ their integration	1 (complex) to 5 (simple) score	2	Higher costs / complexity for installation in a domestic setting. Too heavy for installation on a floor i.e. needs to be ground level?
risk/severity of unintended consequences	1 (high) to 5 (low) score	3	Potential for hazard (e.g. fires) if not properly sited and maintained.
		26	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	3	If combined with renewable energy then saving mostly low carbon energy although sometimes need to charge from the mains to complete charge cycle and maintain battery health.
whole life environmental impact	1 (high) to 5 (low) score	2	Hazardous chemicals are a threat to the environment, and metals need to be mined. Recycling rates can be quite high if there is a market to recover certain elements (e.g. lead).
		5	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	Scotland's ambitious renewable energy targets will need storage and / or import / export from neighbouring markets.
compatibility with current regulation	1 (low) to 5 (high) score	4	At domestic level no real conflicts
compatibility with current assessment methodologies	1 (low) to 5 (high) score	3	Consultation on proposed changes takes batteries into account but some stakeholders do not believe these go far enough
		12	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	2	$890-1476 /kWh (Lazard) for residential application of lithium ion
life cycle costs	1 (high) to 5 (low) score	2	No data. Lithium not considered toxic or persistent in the environment, but some battery chemistries may have more toxic materials (e.g. cobalt). Limited recycling infrastructure.
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	3	No data per t C saved, but some data to suggest manufacturing of cathode materials and wrought aluminium is carbon intensive.
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	4	High potential for economies of scale, but concerns about scarcity of some cathode elements
		11	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	2	Limited applicability, largely those with renewable energy installations and suitable space and conditions
existing Scottish capacity/skills	1 (low) to 5 (high) score	3	Some support infrastructure for installation, limited UK-manufacturing but none Scotland-specific
Scottish content	1 (low) to 5 (high) score	1	Raw materials largely imported. Historical lead and zinc mining in Scotland.
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	4	Significant links to renewable energy and microgeneration installation, as well as smart grid more generally
Scottish economic impact potential	1 (low) to 5 (high) score	4	Innovas data shows high market value by percentage (Scotland has nearly 12% of UK market value)
		14	

Consumer	Scoring	Score	Comments	
user friendliness / practicality	1 (low) to 5 (high) score	4	Difficult to know but no obvious issues	
disruption	1 (high) to 5 (low) score	2	"Typical domestic systems vary from being the size of a small computer to the size of a washing machine."	BRE
customer acceptance	1 (low) to 5 (high) score	4	Again difficult to know but no particular reason why they wouldn't be accepted, comparable to electric vehicles which are readily accepted.	
savings on bills	1 (low) to 5 (high) score	3	Moderate for domestic use	
maintenance requirements	1 (high) to 5 (low) score	3	Not without maintenance requirements (e.g. to fully charge and winter mode) but more and more semi-automated	
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	3	Neutral on wellbeing and comfort, probably makes little difference unless off-grid	
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	3	General consumer protection but as emerging technology it is inevitably emerging area	
		22		

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		Lifecycle issues with materials used to manufacture, need better recycling
other relevant considerations/risks/opportunities	List/Describe		
adaptability / future proofing	List / Describe		Good scalability and potential for adaptation to future
		90	

REFERENCES

NYSERDA, December 2014,

BRE, 2016. Batteries and solar power, guidance for domestic and small commercial customers

Lazard, 2016. Lazard's levelized cost of storage. Version 2

Electric batteries - commercial / industrial

Electrical energy converted to chemical energy where it is stored, and then discharged as electrical energy to be used at another time. In behind the meter applications, the battery remains in the same place but stores energy generated at one time for use at another time. In a commercial setting, typically used in conjunction with renewable energy or for peak management / demand response. Assume installed in an industrial setting such as a shipping container or similar.

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	8 to 9	8 are near-commerical variants (advanced lead acid, vanadium redox (flow), zinc bromide (flow), sodium nickel chloride), 9 are commercial (lead acid, lithium ion, sodium sulphur, nickel cadmium)
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	3	Round trip charge to discharge efficiency ranges from 60 (nickel cadmium / zinc bromide) to 98 (lithium ion)%
Reliability	1 (low) to 5 (high) score	3	Generally good if handled and sited correctly (i.e. not robust to all environmental conditions due to hazardous chemicals). Some better technically than others for different circumstances - for example some hold charge better than others.
(level of) Compatability with existing systems	1 (low/poor) to 5 (high/good) score	4	Compatible with existing electrical systems, in a technical sense and can have superior ability to support electrical stability. May need some updates to electrical standards.
complexity of systems/ their integration	1 (complex) to 5 (simple) score	3	Installation costs can double total cost, depending on the circumstances, finding right location for battery (which is heavy) can be difficult
risk/severity of unintended consequences	1 (high) to 5 (low) score	3	Potential for hazard (e.g. fires) if not properly sited and maintained.
		16	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	4	Data hard to come by but storage essential for large-scale integration of low carbon technologies. Depends variously on carbon intensity of grid electricity, electrical energy charging the battery, frequency of use.
whole life environmental impact	1 (high) to 5 (low) score	2	Hazardous chemicals are a threat to the environment, and metals need to be mined. Recycling rates can be quite high if there is a market to recover certain elements (e.g. lead).
		6	

Policy / Regulation	Scoring	Score	Comments
compatability with Scottish policy	1 (low) to 5 (high) score	5	Scotland's ambitious renewable energy targets will need storage and / or import / export from neighbouring markets.
compatability with current regulation	1 (low) to 5 (high) score	3	Some challenges in charging regime for storage, although work underway to address these
compatibility with current assessment methodologies	1 (low) to 5 (high) score	3	Consultation on proposed changes takes batteries into account but some stakeholders do not believe these go far enough
		11	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	2	Installed energy cost $800-2500 per kWh for "single use" (NYSERDA); levelised cost $515 to 1350 for available use (Lazard)
life cycle costs	1 (high) to 5 (low) score	3	No data. Lithium not considered toxic or persistent in the environment, but some battery chemistries may have more toxic materials (eg cobalt). Limited recycling infrastructure for lithium ion and others. Good recycling structure for lead acid batteries.
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	3	No data per t C saved, but some data to suggest manufacturing of cathode materials and wrought aluminium is carbon intensive.
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	5	Significant, most commentators show costs reducing with scale across all of the battery types
		13	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	3	Extended applicability compared to domestic batteries, but still limited to renewable energy matching and / or microgrid and offgrid applications.
existing Scottish capacity/skills	1 (low) to 5 (high) score	3	Some support infrastructure for installation, limited UK-manufacturing but none Scotland-specific
Scottish content	1 (low) to 5 (high) score	1	Raw materials largely imported. Historical lead and zinc mining in Scotland.
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	5	Significant links to renewable energy and microgeneration installation, as well as smart grid more generally
scottish economic impact potential	1 (low) to 5 (high) score	4	Innovas data shows high market value by percentage (Scotland has nearly 12% of UK market value)
		16	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	3	
disruption	1 (high) to 5 (low) score	2	
customer aceptance	1 (low) to 5 (high) score	4	
savings on bills	1 (low) to 5 (high) score	2	High initial cost and limited use cases at the moment mean moderate bill savings.
maintenance requirements	1 (high) to 5 (low) score	2	Need to maintain optimim charge conditions, winter mode etc
health/wellbeing/comfort	1 (high -ve) to 5 (high +ve) score	4	
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	3	
		20	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		Costs need to come down further, and / or multiple use opportunities arise. Technically improved energy density, longer life and lower self-discharge rates. Environmentally, improved recycling infrastructure.
other relvant considerations/risks/opportunities	List/Describe		
adaptability / future proofing	List / Describe		
		82	

REFERENCES

NYSERDA, December 2014,

Heat batteries based on Phase Change Materials (PCMs)

Based on the technology used for re-useable hand warmers, but optimised for storage of excess renewable energy and smoothing of demand

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	8	Available to purchase and some demonstration projects, but not widely used
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	4	Marketed as more efficient than electrical batteries, although needs more data
Reliability	1 (low) to 5 (high) score	4	Experience using PCMs to manage heat of Lithium Ion batteries suggests improved reliability but not enough experience on batteries with PCM as heat store. Intention is for it to be reliable.
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	4	Designed to work with combi boiler, PV, CHP and heat pumps - needs validating with more experience. Not clear how fits with domestic load, charge / discharge requirements of battery.
complexity of systems/ their integration	1 (complex) to 5 (simple) score	3	Seems relatively simple
risk/severity of unintended consequences	1 (high) to 5 (low) score	4	Not toxic materials like batteries so potential seems lower
		27	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	4	Should be good based on estimated bill savings
whole life environmental impact	1 (high) to 5 (low) score		No data
		4	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	Storage highly compatible with Scottish policy on low carbon energy
compatibility with current regulation	1 (low) to 5 (high) score	4	At domestic level no real conflicts
compatibility with current assessment methodologies	1 (low) to 5 (high) score	2	Consultation on proposed changes takes batteries into account but some stakeholders do not believe these go far enough, and probably have electrical batteries in mind
		11	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	2	Around £1700 for 5kWh system, £340/kWh
life cycle costs	1 (high) to 5 (low) score		?
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	3	Still quite expensive, needs more experience, carbon savings depend on context
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	4	In so far as it is relatively new technology should be scope for economy of scale
		9	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score		Unknown, depends on properties of battery - can it partially charge or must it fully charge and discharge?
existing Scottish capacity/skills	1 (low) to 5 (high) score	3	http://www.sunamp.com/ is only provider we could find, based in East Lothian, working with Edinburgh university.
Scottish content	1 (low) to 5 (high) score	4	Basically unknown for materials but high for IPR
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	4	Potential for a flexible technology used across domestic and commercial sectors. Also has a track record for use in absorbing excess heat from Li ion batteries in EVs
Scottish economic impact potential	1 (low) to 5 (high) score	2	Low in near to medium term simply because its relatively new and small industry
		13	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	4	based on claims
disruption	1 (high) to 5 (low) score	4	Low, small and wall mountable
customer acceptance	1 (low) to 5 (high) score	4	
savings on bills	1 (low) to 5 (high) score	4	Manufacturers claim that Berwickshire housing association shows 45-60% savings on bills in combination with heat pumps - need more experience
maintenance requirements	1 (high) to 5 (low) score	4	Not clear
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	4	
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	3	Newish technology so will need experience
		27	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		
other relevant considerations/risks/opportunities	List/Describe		
adaptability / future proofing	List / Describe		
		91	

https://www.sunamp.com

smart conventional heat storage

Conventional heat storage using bricks or water augmented by smart(er) controls

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	Established technology with an update for smart controls and improved efficiency
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score		
Reliability	1 (low) to 5 (high) score	2	
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	5	Excellent compatibility given existing technology, and potential to readily integrate into modern demand response
complexity of systems/ their integration	1 (complex) to 5 (simple) score	4	
risk/severity of unintended consequences	1 (high) to 5 (low) score	5	Well known and understood
		25	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	4	study by DNV KEMA, which estimated that retrofitting the storage heaters in ~14m EU homes with 'smart storage' (new generation heaters with digital controls) could lead to efficiency savings of around 20% . Glen Dimplex quote 15% energy savings and 30% financial savings during a pilot project in 140 Irish homes.
whole life environmental impact	1 (high) to 5 (low) score	4	
		8	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	5	
compatibility with current regulation	1 (low) to 5 (high) score	3	Needs more sophisticated time of use tariffs for domestic customers
compatibility with current assessment methodologies	1 (low) to 5 (high) score	4	SAP incorporates 'automatic charge control' for electric storage heaters, which includes a degree of smart functionality.
		12	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	3	£800 for a 1kW Quantum heater.
life cycle costs	1 (high) to 5 (low) score	3	
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	3	Claims up to 30% saving on bills
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	3	
		12	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	5	
existing Scottish capacity/skills	1 (low) to 5 (high) score	4	Good for installers and operation, but unknown re manufacture
Scottish content	1 (low) to 5 (high) score	2	
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	3	
Scottish economic impact potential	1 (low) to 5 (high) score	3	
		17	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	3	Not got a good reputation on user friendliness but modern updates have potential to change this.
disruption	1 (high) to 5 (low) score		
customer acceptance	1 (low) to 5 (high) score	3	68% of the GB respondents with storage heating surveyed in 2012 said they were satisfied with it (compared with 91% of respondents with gas central heating), while 25% were dissatisfied. An earlier survey of British public opinion on energy issues found that storage heating was the least popular option for shifting electricity load (water heating was the most popular) and that only 35% of respondents thought there would probably be a growth in the use of electric storage heaters. Interestingly, younger respondents were more likely to be interested in adopting storage heating than the older ones. Scottish respondents – that is, those from the coldest regions of GB – were the least enthusiastic. - significant potential to improve image of storage heating with smarter alternatives.
savings on bills	1 (low) to 5 (high) score	4	Project in Ireland shown that Quantum has the potential to deliver a 30% economic saving to individual homeowners (€37,000 saving across 140 units per year or €264 saving per home)
maintenance requirements	1 (high) to 5 (low) score		
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	3	
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score		
		13	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		Need better developed time of use tariffs (and half hourly settlement for domestic customers) to really tap demand response potential
other relevant considerations/risks/opportunities	List/Describe		
adaptability / future proofing	List / Describe		
		87	

REFERENCES

Consumer Focus. From devotees to the disengaged. A summary of research into energy consumers' experiences of Time of Use tariffs and Consumer Focus's recommendations. (2012)

IpsosMORI Energy Issues 2009. Survey of British public opinion. (2010) https://www.ofgem.gov.uk/sites/default/files/docs/2010/06/mori-energyissuesreport- final.pdf

Darby, SJ, 2016. Balancing the system comfortably? Electric storage heating and residential demand response. BEHAVE 2016 4th European Conference on Behaviour and Energy Efficiency Coimbra, 8-9 September 2016. http://www.realvalueproject.com/images/uploads/documents/Darby-coimbra_916.p

http://www.glendimplex.com/news/view/glen_dimplex_group_launches_revolutionary_quantum_heating_system

Ice batteries

Makes ice during the charge cycle, powered by excess renewable energy or off peak grid electricity, delivers cooling for air conditioning units as the discharge

Technical	Scoring	Score	Comments
Technology readiness	TRL score 1-9	9	Commercially available and in use in the US
Efficiency (product / technology efficiency)	1 (low) to 5 (high) score	3	Less use but more efficient in colder climates
Reliability	1 (low) to 5 (high) score	4	Good reliability in trial
(level of) Compatibility with existing systems	1 (low/poor) to 5 (high/good) score	4	Replaces the compressor unit of HVAC systems, some teething problems with existing thermostat in trial
complexity of systems/ their integration	1 (complex) to 5 (simple) score	3	Needs some modification for UK application (currently sold from the US); longer charge times due to lower domestic voltage in UK than US
risk/severity of unintended consequences	1 (high) to 5 (low) score	4	
		27	

Environmental	Scoring	Score	Comments
(in-use) carbon saving potential	1 (low) to 5 (high) score	3	charges (freezes) in off-peak times and replaces energy intensive compressor unit of AC to provide cooling. In lower ambient temperatures of UK does not meet its full potential for energy saving. Main benefit in the trial was peak lopping, which saves carbon indirectly through reduced need for peaking plant.
whole life environmental impact	1 (high) to 5 (low) score	3	Refrigerant needs to be properly managed and disposed of
		6	

Policy / Regulation	Scoring	Score	Comments
compatibility with Scottish policy	1 (low) to 5 (high) score	4	
compatibility with current regulation	1 (low) to 5 (high) score	3	No particular barriers but storage generally not well incentivised
compatibility with current assessment methodologies	1 (low) to 5 (high) score	2	Consultation on proposed changes takes batteries into account but some stakeholders do not believe these go far enough, and probably have electrical batteries in mind
		9	

Monetary	Scoring	Score	Comments
capital costs	1 (high) to 5 (low) score	3	$1500-2500/kW; 'Of total cost installation 65%, ice bear unit 28%, shipping 7%. Current price high due to low pound, but on high end of per kW for generation.
life cycle costs	1 (high) to 5 (low) score	3	Add 1.5-2% of capital cost for maintenance, plus cost of disposal
carbon cost effectiveness (£ per tCO2 saved)	1 (low) to 5 (high) score	2	No data. But in the Thames Valley trial the project could find no suitable participants to self fund installation from 194 buildings due to lack of customer benefits and no market incentivisation. The DNO ended up funding 3 units themselves and installing them at volunteer locations.
(potential for) economy of scale (to drive down costs)	1 (low) to 5 (high) score	4	Assumed significant potential due to low market penetration at present.
		12	

Capacity/ Supply Chain	Scoring	Score	Comments
applicability	1 (low) to 5 (high) score	2	Not strong demand for air conditioning based on cooling in Scotland
existing Scottish capacity/skills	1 (low) to 5 (high) score	1	Product marketed mainly in US
Scottish content	1 (low) to 5 (high) score	1	
potential for cross-sector involvement/benefit	1 (low) to 5 (high) score	3	Part of an air conditioning and even BMS
Scottish economic impact potential	1 (low) to 5 (high) score	1	Based on low applicability
		8	

Consumer	Scoring	Score	Comments
user friendliness / practicality	1 (low) to 5 (high) score	3	Not much data but no adverse reports in the trial
disruption	1 (high) to 5 (low) score	2	Some disruption from civil and mechanical works to place and connect the unit. Commissioning of 7kW units took 1-2 days. Installation 11 days.
customer acceptance	1 (low) to 5 (high) score	3	Scepticism on whether it would be worthwhile
savings on bills	1 (low) to 5 (high) score	2	Limited savings unless a particularly high and constant need for cooling
maintenance requirements	1 (high) to 5 (low) score	3	
health/wellbeing/comfort	1 (high negative impact) to 5 (high positive impact) score	3	
existing consumer protection? (adequacy?)	1 (low) to 5 (high) score	4	
		20	

Opportunities / risks	Scoring	Score	Comments
Critical success factors/watch points	List/Describe		Along with thermal and electrical storage needs appropriate incentives
other relevant considerations/risks/opportunities	List/Describe		Low applicability to Scotland due to low ambient temperatures
adaptability / future proofing	List / Describe		
		82	

REFERENCES

https://www.ice-energy.com/technology/

http://www.smarternetworks.org/Files/Thames_Valley_Vision_150916140427.pdf

http://www.thamesvalleyvision.co.uk/wp-content/uploads/2017/05/NTVV-Learning-Outcome-Report-LV-Network-Storage-Cold-Thermal-Storage.pdf