Review

Customer Privacy Concerns as a Barrier to Sharing Data about Energy Use in Smart Local Energy Systems: A Rapid Realist Review

Carol Vigurs 1*, Chris Maidment 2, Michael Fell 2 and David Shipworth 2

1 EPPI-Centre, Social Research Institute, UCL—University College London, London WC1H 0NR
2 UCL Energy Institute, Bartlett School of Environment, Energy and Resources, UCL—University College London, London WC1E 6BT, UK;
c.maidment@ucl.ac.uk (C.M.);
michael.fell@ucl.ac.uk (M.F.); D.shipworth@ucl.ac.uk (D.S.)
* Correspondence: c.vigurs@ucl.ac.uk; Tel.: +44-7859955570

Table S1. Abbreviations

| Abbreviation | Definition |
|--------------|------------|
| EnergyREV    | The EnergyREV (Energy Revolution) consortium has been formed to help drive forward research and innovation in smart local energy systems. EnergyREV is one of the three key components of the UK Industrial Strategy Challenge Fund’s Prospering from the Energy Revolution (PFER) programme. |
| EPPI-Centre  | Evidence for Policy and Practice Information Coordinating Centre. A research centre specializing in systematic reviews for policy and practice. Based in the Institute for Social Research, UCL. |
| GDPR        | General Data Protection Regulation. The European Union data protection regulations that came into force (2018). All entities that process personal data must comply with seven accountability and transparency principles: (1) lawfulness, fairness, and transparency; (2) purpose limitation; (3) data |
minimization; (4) accuracy; (5) storage limitation; (6) integrity and confidentiality; (7) accountability.

|   |   |
|---|---|
| PFER | Prosporing from the energy revolution. An investment by the UK government’s Industrial Strategy Challenge Fund (ISCF). |
| SLES | Smart Local Energy Systems. Future energy systems characterised by decentralized energy, requiring detailed customer energy use data to understand system performance in increasingly finer detail for grid balancing. |

Table S2. Search terms for energy sharing data studies in bibliographic databases

| 1. Terms for Privacy | 2. Near Terms for Data | 3. Terms of Data Sharing and Privacy Behaviours |
|----------------------|------------------------|-----------------------------------------------|
| Privacy              | Data                   | Behavior                                      |
| Private              | Information            | attitude                                      |
| personal             |                        | Calculus                                      |
| sensitive            |                        | concern                                       |
| secure               |                        | “tradeoff”                                    |
| security             |                        | trade-off                                     |
Anony* Intention
confidential preserv*
intimate issue*
safety Anxiet*
Data privacy Incentiv*
"risk perception"
Caution
Paradox
Trust
Barrier
Percept*
Perceived
"data sharing"
"willingness to disclose"
Table S3. Hypothesised contexts, mechanisms and outcomes for Guiding principle 1.

| Context                                      | Mechanism                                                                                                                                                                                                 | Outcomes                                                                                                                                                                                                 |
|----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Individual, Micro and meso system.           | Communication of a complete and relevant knowledge of risks and benefits to data sharing through usable privacy notices. Knowledge increases, and there is greater understanding and desire for benefits of sharing data | Active and sustained participation of customers in sharing data and involvement in active energy use behaviours                                                                                      |
| Meso system                                  | Recognition and communication of interdependence and mutual benefit. Partnership working with community groups, individuals, and business.                                                               | Customer achieve their benefits and SLES System achieves balance and resilience through real time data collection and responsive energy use behaviours of customers’                                                                 |
| Meso to micro                                | Resource. Outreach: Active and ongoing support, education and training                                                                                                                                 | Inclusion of all customers, including those that may be at risk of exclusion.                                                                                                                                  |

Guiding principle 1. Recognize the mutual benefits of data sharing for smart local energy systems and work with customers as partners.
Table S4. Hypothesised contexts, mechanisms and outcomes for Guiding principle 2.

| Context                  | Mechanism                                                                 | Outcomes                                                                 |
|--------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Individual; and Micro system | Individual sense of autonomy, choice and control, self-efficacy, locus of control. | Active or passive resistance or active and continued use                  |
|                          | Active involvement in the design increases sense of control               | Trusted devices and technologies are adopted and used                     |
|                          | Tailoring of technologies or service to meet personal goals:              | Devices and technologies perceived to be compatible with personal values are adopted and used |
|                          | whether saving money, or “going green”                                   |                                                                          |
| Meso system              | Ease of integration, into existing technologies and ways of living.       | Devices and technologies perceived to be useful are adopted and used     |

Guiding principle 2. Involve people in the design of data sharing technologies from the start.
Table S5. Hypothesised contexts, mechanisms and outcomes for Guiding principle 3.

| Context                      | Mechanism                                                                 | Outcomes                                                                                           |
|------------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| Micro through to meso systems | Existing familiarity of privacy choices and controls.                      | Sharing or not sharing data can depend on existing knowledge, and how similar or different the privacy notices are compared to what people have already experienced. |
|                              | Usable privacy is accessible and relevant                                  |                                                                                                   |
| Micro systems                | Having a choice over which third parties to share data with creates trust   | Blocking sharing data can be a default position, where the third parties are unknown               |

Guiding principle 3. Give people a say on the third parties that they are happy to share data with

Table S6. Hypothesised contexts, mechanisms and outcomes for Guiding principle 4

| Context                      | Mechanism                                                                 | Outcomes                                                                                           |
|------------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| Individual and Micro through to macro | Privacy is relational and contextual. Control over information settings should allow for the setting of boundaries around what is acceptable or not acceptable for each context and time. | Empowerment over the control flow of information.                                                   |

Guiding principle 4. Empower people to set the boundaries around the flow of information about themselves
Table S7. Hypothesised contexts, mechanisms and outcomes for Guiding principle 5

| Context          | Mechanism                                                                 | Outcomes                                                                 |
|------------------|--------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Micro to meso    | Ambivalence that people will see any real benefit to themselves          | Lack of trust in the extent and purpose of data collection inhibits take up |
| Micro system     | Anticipating benefits or unanticipated consequences of being “flexible”  | Resistance or disappointment to unanticipated perceived intrusions into daily life |
| Micro system     | Understanding and knowledge of privacy conditions                        | Withdrawal of consent as a default safety mechanism                       |

Guiding principle 5. Ensure that the purpose and value of the data collected is transparent and fair

Table S8. Hypothesised contexts, mechanisms and outcomes for Guiding principle 6

| Context                        | Mechanism                                                                 | Outcomes                                                                 |
|--------------------------------|--------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Meso system                    | Resource: Methods of accounting and billing allows for multiple account holders. | People who affected by energy use monitoring give their informed consent to the extent and depth of energy data collection. |
| Individual, Micro and Meso system | Values and beliefs of the household, differing priorities of members of the household, assumptions made about the use of monitoring technology. Assumptions of service providers about capacity of customers to receive and understand information about technology and services. | Over-monitoring, energy use data used as a vector of control. |
|                                |                                                                          | Including or excluding groups of people from decision making around the benefits of data sharing, including financial benefits and efficiencies, or other “off label” benefits. |
Meso and macro systems

- Principle: gent problem over investment and benefit. Resource: Incentives for investments and ongoing support
- People affected by data sharing are excluded from decision making leading to passive resistance and use of technology is not sustained.
- SLES access to data is limited and declines over time.

Guiding principle 6. Ensure that everyone that is affected by sharing of data is involved in giving their informed consent.

Table S9. Hypothesised contexts, mechanisms and outcomes for Guiding principle 7.

| Context               | Mechanism                                                                 | Outcomes                                                                                       |
|-----------------------|---------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| Micro and meso systems| Balance of power in a household. The visibility revealed by the use of energy monitoring data can shift this balance. Peer pressure to monitor behaviors. Resource: Methods of accounting and billing allows for multiple account holders and permissions to change granularity of data granted to those on the account. | Over monitoring, energy use data used as a vector of control. Multiple account holders should reduce the potential for the use of energy data to be used for gaslighting, or coercive control. |
| Meso and macro systems| Ethical design principles. Innovative use of detailed energy use data by household may generate unintended consequences. | Minimise the impact of unintended consequences.                                               |

Guiding principle 7. Recognize that technologies for revealing and monitoring behaviours in the home can be used in unexpected and unwanted ways.
Table S10. Hypothesised contexts, mechanisms and outcomes for Guiding principle 8.

| Context                        | Mechanism                                      | Outcomes                                           |
|-------------------------------|------------------------------------------------|----------------------------------------------------|
| From micro to macro systems   | Open channels of communication                  | Swiftly address the impact of unintended consequences |
|                               | Resources: outreach for stakeholder identification and involvement to include different perspectives into ethical design principles | Establish an ongoing process of evaluation |

Guiding principle 8. Ensure there are channels of feedback and ongoing communication to continuously improve service delivery.

Table S11. Data sharing technologies and systems in each domain.

| Data sharing technologies in the individual domain | These are usually operated by one person at a time, or one person has sole responsibility, they are usually password protection. Smart devices, Electric vehicles, personal computers, Apps. |
|---------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Data sharing technologies in the Micro domain     | These are technologies that are in the home. Users interact with sensors, Internet of things, Home networks, smart meters, smart appliances, smart home |
| Data sharing technologies in the Meso domain      | These are technologies related to the local energy system and community based services. EV charging, Smart grid, Data storage servers, Smart local energy systems, Community based energy. |
| Data sharing technologies in the macro domain     | These technologies at this level tend to be outside of the individual control and influence. This includes, internet, Cellular communications, powerline communications. Data protection policies, cloud storage. |

Type of data sharing technologies in each domain.
| Short Title | Country | Type of study | Number of participants | Type of intervention | Components of intervention | Aim of intervention | Users of data |
|-------------|---------|---------------|------------------------|----------------------|---------------------------|---------------------|--------------|
| S1. Bailey (2015) | Canada | Observational | 1470 CPEVS survey \( n = 530 \) in discrete choice experiments | Smart charging of PEVs | • Alternative energy source  
• Budget information | To allow load management, reduce system costs, subsidize PEV market, increase use of renewables | • Energy provider |
| S2. Begier (2014) | Poland | Observational | 4 focus groups, 302 interview participants total: 963 persons) | Smart meters | • Communication  
• Email information  
• Home computer  
• In home displays  
• Information  
• Internet access  
• Personal visit by representative  
• Variable rates | Main technical purposes of smart metering, like energy saving, reducing total energy consumption, especially reducing peak demand of energy | • Criminals  
• Energy provider |
| S3. BEIS (2018) | Great Britain | Review | NA | Regulation Regulatory framework | • Communication  
• Smart meter  
smart metering Data Access and Privacy Framework. | The Framework establishes sector-specific provisions relating to the processing of energy consumption data, which are designed to complement, but not replace, wider data protection legislation [e.g. GDPR] | • Consumers  
• Energy network operator  
• Energy provider  
• Third party organizations |
| S4. Choe (2012) | USA | Observational | 11 couple households | In Home sensors | • Diary  
• Home computer  
• Sensor lights  
• Technology education session | Sensors can help make decisions about energy efficiency. | |
| Study Reference  | Location | Study Design | Data Collection Method | Key Findings | Study Objectives | Methodological Notes |
|------------------|----------|--------------|------------------------|--------------|------------------|---------------------|
| 55. Citizens Advice Bureau (2019) ++/++ | Great Britain | Observational | Survey, process evaluation | 3008 online interviews, 213 face to face interviews, Smart appliances, Smart meters, Smart meter | Smart meters and smart devices aim in part to facilitate a more flexible electricity system | Corporations, Energy provider |
| 56. Da Silva (2012) +/- | Multiple locations | Observational | Survey | Not clear end prosumers of electricity in the residential sector | Real time information | Energy provider “retailer” |
| 57. Delmas (2014) +/- | USA | Experimental | Quasi | 66 rooms, 102 participants | Email information, home energy monitoring device, In home displays, Information posters, Real time information | (To) test the efficacy of detailed private and public information on electricity conservation. | Not stated |
| 58. Fell (2015) +/- | Great Britain | Observational | Survey | 2159/2302 people full omnibus study | Electric heating | Demand side response (DSR) Simply defined as “change in electricity consumption patterns in response to a signal” (Element Energy 2012, 9), DSR offers the ability to sculpt demand for electricity to fit the available supply. | Not stated |
| 59. Giordano (2011) +/- | Europe | Observational | Survey | Not clear | Authentication, Authorization, Certification, Encryption | (to). foster greater consumption awareness taking advantage of Smart Metering systems and improved customer information, in order to allow consumers to | Criminals, Market analysts, Insurance companies |
| Study Code | Country | Study Design | Sample Size | Energy System Components | Findings |
|------------|---------|--------------|-------------|--------------------------|----------|
| S10. Guerreiro (2015) | Portugal | Observational | 515 residents in the city of Évora | Smart meters | Ensures integrity and confidentiality; modifies their behavior according to price and load signals and related information. |
| S11. Hansen (2017) | Denmark | Observational | 20 households | Smart grid, Electric vehicles (n = 17), Geothermal Heat pump, Hybrid air/water HP, Home energy monitoring device, Internet access, Photovoltaics PVs, Real time information, Sensors, Smart meter, Sun Wells | Smart meters permit smart grids, including by giving people feedback on their energy use so they can alter consumption patterns. |
| S12. Hess (2014) | Canada, USA | Observational | 75 organizations or information sites | Smart meters | Smart meters can help achieve “more resilient and sustainable electricity consumption”. |
| S13. Hmielowski (2019) | USA | Observational | 1035 | Smart meters | To support/inform the installation of smart meters to increase energy efficiency, reduce costs and greenhouse gases. |
| Study ID | Authors | Year | Location | Methodology | Case Study | Observational | National | Smart meters | Incentives | Products | Energy Provider | Other Comments |
|----------|---------|------|----------|-------------|------------|---------------|---------|--------------|------------|----------|----------------|---------------|
| S14.     | Hoenkamp | 2012 | The Netherlands | Case study | National | Smart meters | Compulsory roll out, In home displays, Real time information, Smart meter | Smart Meters play a crucial role in reaching the energy efficiency goals of the 20-20-20 targets of the EU Climate and Energy Package | Not stated |
| S15.     | Horne   | 2015 | USA | Survey | Study 1 (S1) 353 Study 2 (S2) 355 | Smart meters | Real time information, Smart meter | Smart Meters contribute to the technical capacity of utility companies to manage demand (through demand response programs), incorporate renewable sources of electricity into the system, and increase the overall efficiency and reliability of the system | • Energy provider • Third party organizations |
| S16.     | Huang   | 2016 | Not stated | Model | Mixed strategy Nash Equilibrium game | NA | Incentives | Alternative energy source, PV, Battery, Smart meter | the goal of our price-based incentive approach is to allow both parties, namely consumers and the electricity provider, to negotiate consumption and data sharing such that all parties can potentially profit from interactions. | • Energy provider |
| S17.     | Jakobi   | 2017 | Germany | Observational | Focus group, Interviews | K3 | Smart thermostats | An App, Dashboard, Diary, home log book, Feedback, Information, Internet access, remote controls, Sensors, Smart meter, Smart plugs, Smartphone, Web Portal, Z wave | Products mainly address issues of security, energy savings and comfort. Monitoring and saving energy by avoiding standby consumption, automated switching off of devices and appliance-based measurement of energy consumption as well as visualization of consumption. | Not stated |
| Study (Year) | Country | Type | Methods | Findings | Participants | Incentives | Impact | Additional Notes |
|------------|---------|------|---------|----------|-------------|-----------|-------|-----------------|
| Jakobi (2019) | Germany | Observational ethnographic case study | survey: 34/200 App: 205 | Smart meters - An App for Android, Customer choice of level of disclosure, Information, Internet access, Smart meter | (smart) meters are designed to collect information on power consumption and send it to third parties. | | | Advertisers, Consumers, Third party organizations |
| Kapade (2017) | Not stated | Model | 1000 modelled households. | Incentives - Area networks, Smart meter | To incentivize consumers via a credit-based system to share power consumption data that is beneficial to industries. | | Data Collectors, Third party organizations, Unethical individuals |
| Melville (2017) | United Kingdom | Observational | 1st interview (prior to installation): 12 respondents. 2nd interview (after intervention period): 7 of these 12 respondents. Subsequent focus group: 5 of these 7 respondents. | Community demand response (DR) - Consumption data, Feedback, Incentives | To influence individual consumption behavior through community accountability, (not just price signals), in an electricity demand response scheme. | | Peers |
| Moere (2011) | Australia | Experimental Quasi experimental study | Intervention 6 - Control 5 | Smart meters - Feedback, Internet access, Outside home display, Sensors, Wireless network | Providing comparative feedback may have a positive effect on behavior change by triggering feelings of competition, social comparison or social pressure [26]. | | Consumers |
| Naus (2015) | The Netherlands | Observational | Focus Group - 12, Survey = 171 | Smart grid - Consumption, Domestic production, Energy meter | Government bodies at different levels have formulated targets to promote a transition to a low-carbon economy. Households are increasingly positioned as | | Energy provider |
| Study | Country | Methodology | Sample Size | Data Collection | Data Analysis | Findings |
|-------|---------|-------------|-------------|----------------|--------------|----------|
| +/++  | Great Britain | Observational | 62 in four groups | Half-hourly settlement | Smart meter | Half-hourly settlement uses more fine-grained electricity consumption data from smart meters. It could allow more innovative energy products to be commercialized. |
| S23. Ofgem Year 9 (2018) | Great Britain | Deliberative workshops | 62 in four groups | Half-hourly settlement | Smart meter | Half-hourly settlement uses more fine-grained electricity consumption data from smart meters. It could allow more innovative energy products to be commercialized. |
| S24. Pournara (2016) | Germany | Model | data on 6000 participants | Incentives | Authorization | A Smart Grid project that studies the impact on electricity consumption of residential and enterprise consumers in Ireland. |
| S25. Sexton (2018) | England | Observational | 5 in Energy case study interviews | Energy governance | Consumption data | Consumption data sharing, linking and re-use (secondary use) of government administrative data |
| S26. Snow (2014) | Australia | Observational | 23 households s235 households | Smart meters | Feedback | The emerging standard of visible and sharable electricity consumption information empowers families with multiple avenues to measure, share, discuss and learn how to better manage and reduce their usage |
| +/-   | +/-     | +/-         | +/-         | +/-            | +/-         | +/-      |

- Real time information
- Variable rates
- active participants with a responsibility to act as 'change agents'
| Study Reference | Country | Study Type | Sample Size | Data Sources | Findings | Users of data |
|-----------------|---------|------------|-------------|--------------|----------|--------------|
| S27. Horne (2019) | USA | Observational - Experimental vignette survey | S1 - 100 per condition, n = 300; S2 300 per condition, n = 1200 | Smart meters | An App | In its transition to a sustainable, reliable, efficient ‘smart grid,’ the system is integrating increasing amounts of ICT. |
| S28 Toft (2015) | Denmark | Observational - Interviews | 24 households | Smart grid | Geothermal Heat pump | One of the key elements of the Smart Grid is that electricity consumers make some of their consumption available as flexible capacity to balance the grid. Consumers’ flexible capacity is only available to the grid if the consumers adopt Smart Grid technology (SGT) that establishes the link between the electric system and the consumer. |
| S29. Valor (2019) | Multiple locations | Review - Exhaustive review | k = 100+ | Interactive feedback (via displays, apps, web portals etc.) | An App; In home displays; Web Portal | To design domestic energy/eco feedback displays that are "more effective in creating the desired household behavioral change to maximize energy conservation." |
| S30. Van Aubel (2019) | The Netherlands | Observational - Case study | National | Smart meters | Central administration; home energy monitoring device; In home displays | To discuss the how and why certain choices have been made in the Netherlands, in relation to roll out of smart meters |
| S31. Vermont Trasco LLC (2014) | USA | Observational - Case study | Reliant 600,000; ENO 150,000; SVE 21,000; CMP 600,000 | Smart grid | Advertising; Community outreach; Critical peak rebate; Customer training; Day ahead; Email information; Incentives; In home displays | Smart Grid Investment Grant projects (aim to) modernize the electric grid, strengthen cybersecurity, improve interoperability, and collect data on smart grid and customer operations. |
| Dataset | Methodology | Study Region | Key Findings | Examples |
|---------|-------------|--------------|--------------|----------|
| S32. Walter (2018) | Review, Multiple locations, Germany | • Partnerships with local organizations • Programmable Communicating Thermostat • Phone calls • Public meetings • Smart meter • SMS Messaging • Social Media • Software tools • trained customer • Variable rates • Web Portal | • Partnerships with local organizations • Programmable Communicating Thermostat • Phone calls • Public meetings • Smart meter • SMS Messaging • Social Media • Software tools • trained customer • Variable rates • Web Portal | Enabled by numerous connected sensors, new cars offer new functionalities, provide higher security levels and promise to enhance the comfort of travelling. |
| S33. Winter (2015) | Observational, Multiple locations, USA | • Event data recorder (EDR) • Informative intelligent speed adaption (ISA) | • Event data recorder (EDR) • Informative intelligent speed adaption (ISA) | Smart meters allow a utility to send commands to the meter, such as turning off the power due to nonpayment of tariffs or reducing the amount of energy consumed. |
| | Survey | | | | Ambulance. • App providers • Breakdown service • Car manufacturer • Family • Garage • Police • Hotels • Insurance companies • Traffic control center • Third party organizations |

| Dataset | Methodology | Study Region | Key Findings | Examples |
|---------|-------------|--------------|--------------|----------|
| S32. Walter (2018) | Review, Multiple locations, Germany | • Partnerships with local organizations • Programmable Communicating Thermostat • Phone calls • Public meetings • Smart meter • SMS Messaging • Social Media • Software tools • trained customer • Variable rates • Web Portal | • Partnerships with local organizations • Programmable Communicating Thermostat • Phone calls • Public meetings • Smart meter • SMS Messaging • Social Media • Software tools • trained customer • Variable rates • Web Portal | Enabled by numerous connected sensors, new cars offer new functionalities, provide higher security levels and promise to enhance the comfort of travelling. |
| S33. Winter (2015) | Observational, Multiple locations, USA | • Event data recorder (EDR) • Informative intelligent speed adaption (ISA) | • Event data recorder (EDR) • Informative intelligent speed adaption (ISA) | Smart meters allow a utility to send commands to the meter, such as turning off the power due to nonpayment of tariffs or reducing the amount of energy consumed. |
| | Survey | | | | Ambulance. • App providers • Breakdown service • Car manufacturer • Family • Garage • Police • Hotels • Insurance companies • Traffic control center • Third party organizations |

- **Dataset**: Reference to the study or dataset.
- **Methodology**: Method used in the study.
- **Study Region**: Region where the study was conducted.
- **Key Findings**: Main findings or results.
- **Examples**: Examples of findings or applications.
| Study characteristics of included primary studies. |
|---------------------------------------------------|

| Reference | Country | Study Type | Sample Size | Key Features | Objectives |
|-----------|---------|------------|-------------|--------------|------------|
| S34. Yao (2019) | USA | Observational Action research | 25 | Smart homes • An App • Co-design • Hardware devices • Policy / regulation • Sensors • System modes | To create smart home designs that address users’ privacy concerns. | • Car manufacturers • Third party organizations |
|           |         |            |             |              |            | • Unethical individuals |