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The Internet of Things

Energy Consumption and Novel Social Experiences of IoT

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Summary

Practical measures to support better energy consumption

1. **A strategy to engage consumers with the energy system transition and energy management**

Australia's electricity grid is rapidly transitioning to a 'Future Grid' enabled by the Internet of Things (IoT). The Future Grid involves increasing distributed energy resources, demand response and emerging market arrangements. As part of this transition, recent research recommends household and community engagement initiatives that:

- Respond to the unpredictable, fast-changing and differentiated environment characterising the Future Grid
- Are nationally-coordinated and recognise the need for flexibility and adaptability
- Engage people through issues and concerns that already interest them (such as caring for children/pets).
- Are creative and innovative, as illustrated by the exemplar programs summarised in this Input Paper.

2. **Monitor and seek to influence the digital futures made possible by IoT-enabled devices**

It is important to consider the *digital* futures made possible by IoT-enabled devices (e.g. working from home), and their likely energy implications. Governments and industry should consider measures which seek to achieve lower-energy (or less 'peaky') digital lifestyles resulting from the integration of new IoT devices into people's lives.

3. **Consider the energy implications of 'non-energy policy'**

Non-energy policies include those from the health, education, defence and ICT (national broadband) sectors. While not specifically about energy, these policies can normalise or even require additional consumption, and therefore need to be considered as part of practical measures to support better energy outcomes.

4. **Provide energy leadership and coordination**

Australian households and communities want stronger energy and climate change policy at the federal level, to provide leadership for Australia's cities and regions, and to build trust and confidence in the Future Grid.

Future energy consumption risks

1. **Increased energy consumption risks in households**

IoT devices may increase energy consumption in people's homes (and for other consumer groups) by:

- The promotion of the energy-consuming lifestyle improvements made possible with IoT-devices (instead of or as well as the promotion of their energy efficiency/ management benefits).
- People's incorporation of IoT devices into their lives to deliver additional conveniences and comforts

- The multiplication of devices in use at any given time – resulting in additional energy consumption
- Additional *indirect* energy consumption resulting from the use of livestreaming and internet-enabled capabilities that depend on remote data centres.

2. Gender-related accessibility and violence risks

- The gender skills gap widens for girls and women where technologies are emerging – like many IoTs.
- Men are more likely to be interested in energy-related IoTs and smart home devices. Women may have less control over IoT-enabled appliances such as heating and cooling – even if spend more time at home.
- There are worrying trends that IoT and smart home devices may exacerbate domestic violence towards women. This includes locking occupants in and out of homes, or engaging in cyber-stalking.

3. Digital access, affordability and inclusion risks

- The potential benefits of IoT-enabled devices to reduce energy costs and manage demand are not equally accessible – because many people do not have the skills, money, Internet or data access on which participation relies. Those particularly at risk are regional, older, low-income or digitally excluded citizens.
- Automation and IoT are often not as easy, useful and acceptable as marketing suggests.
- Digital devices are not always considered desirable or productive in households with children.

Novel social experiences and interactions from energy use and IoT

1. New pet care and entertainment possibilities

- Australia has one of the highest rates of pet ownership in the world. More people are using IoT devices to provide care, comfort and entertainment for pets who stay at home during the day.
- Emerging pet care practices with energy implications include heating or cooling rooms and homes exclusively for pets during the day, monitoring pets with livestream security cameras or 'pet-cams', or providing IoT-enabled entertainment devices such as games and screen-based content.

2. Additional digital housekeeping and changing gender division of labour

- The integration of connected and smart devices into households is increasing the amount of 'digital housekeeping' – referring to the labour involved in installing, maintaining and operating this technology.
- Men are more likely to do digital housekeeping, often viewing it as a form of leisure rather than housework.
- Digital housekeeping could change the gendered division of labour in heterosexual coupled households, taking male digital housekeepers away from 'traditional' household chores, which are more likely to fall (back) to women.

3. E-changing and working from home

- Increased access to high-speed broadband in Australia's regions in resulting in some people making an 'e-change' to rural and regional communities.

- Greater internet connectivity and access to IoTs is also enabling more people to work from home and engage in new forms of mobility and collaboration.
- These emerging work location trends have potential implications for the energy needs of cities and regions, and the changing energy demand profile of households.

4. Holidaying and 'resorting' at home
- Some middle- or high-income households with highly mobile lifestyles are viewing their homes as a place to experience entertainment services and other 'luxury' opportunities.
- While often sporadically or only occasionally used, these services can involve high energy consumption.

5. Energy sharing and charging
- Australian households and businesses are demonstrating an emerging interest in peer-to-peer energy trading, similar to AirBnB or other sharing economy platform models.
- It is likely that a variety of platforms to share or trade energy will emerge in the near future, enabling householders and businesses to share or donate excess locally-generated energy to people within their distribution network or community.

6. Mobility and transport trends
- Private Electric Vehicle (EV) ownership: Australia has an existing private car ownership culture, and it is likely that that this will persist in future EV adoption. Provision of infrastructure to enable charging during the day (e.g. when parked while at work) will be critical to help balance electricity supply and demand.
- Mobility as a Service (MaaS): If householders begin to use MaaS fleet EVs (sometimes envisaged as autonomous driving cars or pods) these are likely to be shared vehicles, charged at public or private charging stations, potentially reducing peak demand in households, and creating possibilities for energy trading.
- A key issue for consumers is what has come to be referred to as battery 'range anxiety', which refers to concerns regarding the distance an EV can travel without needing to be recharged.

Input Paper

Practical measures to support energy consumption in Australian cities and regions

1. A ***strategy to engage consumers*** with the energy system transition and energy management

Australia's electricity grid is rapidly transitioning to a two-way system in which energy consumers are also producers of electricity. The 'Future Grid' is enabled by the Internet of Things (IoT) and involves increasing distributed energy resources, demand response and emerging energy market arrangements. For households and businesses in Australian cities and regions this includes:

- Technologies such as rooftop solar PV systems, battery storage, automated control of hot water systems, pool pumps, smart or IoT-enabled appliances and air conditioning

- Demand response programs that ask households and businesses to vary the timing of their consumption in response to variable pricing, incentives, rewards or other appeals
- Community-scale projects such as micro-grids
- A two-sided energy market involving third party platforms and vendors, such as demand response aggregation and peer-to-peer trading (as part of the sharing economy).

One of the key challenges for the Future Grid is balancing supply and demand from distributed resources, battery storage and different types of consumers (residential, commercial, industrial) using energy at different times. Key challenges include:

- Managing peak electricity demand which, in Australia's temperate Southern states, normally occurs in the late afternoon and early evening on hot summer (or winter) days (as a result of increased air conditioning load from residential and commercial buildings, and to which battery charging could contribute as electric vehicle (EV) adoption increases)
- Utilising 'spare' energy available at specific times due to increasing renewable generation

Consumer response is critical to maximise potential benefits from the energy system transition (including reliable, more affordable and cleaner energy). Various IoT-enabled devices and automation have been proposed for the Future Grid, both in Australia and internationally (CSIRO 2013; CSIRO & ENA 2017; National Grid 2018).

Most industry and policy reports assume that IoT will improve household management of their energy consumption, production and storage in the Future Grid, including enabling a positive response to demand response programs and variable pricing tariffs (that charge more during peak periods and less during off-peak periods). It is widely expected and/or desired that consumers will increase or decrease energy use at key times, including by installing technologies which automate their response ('set and forget'), and/or agreeing to external monitoring and control of their energy production, storage and appliances.

Low levels of energy consumer engagement and trust undermines the potential benefits of IoT-enabled devices and automation in the Future Grid. Frustration with energy price increases, low levels of confidence in the energy system and market, conflicting narratives about renewables and other energy issues, and perceived lack of planning and policy have all contributed to energy consumer disengagement and distrust in the energy sector (AEMC 2019; Energy Consumers Australia 2019a; Nicholls et al. 2019).

The rapid uptake of rooftop solar and reductions in energy use by a subsection of households has largely been a response to consumer concerns about rising energy prices rather than ongoing engagement with complex energy issues or interest in taking energy demand into account when going about daily life, e.g. when cleaning, cooking or heating/cooling the home. **Neither governments nor the energy sector have devised or implemented a coordinated strategy to build the trust and engagement needed for most consumers to participate in the ways expected to deliver benefit in the Future Grid.**

There is no consensus on best practice (household) engagement towards the Future Grid. Recent research funded by Energy Consumers Australia, found that innovative engagement initiatives are underway and emerging, but most engagement in the Australian energy sector is still based on traditional understandings of households as bill-paying customers (Strengers et al. 2019c). Following an extensive international literature review and research with Australian households and energy sector stakeholders, the research team recommended Future Grid engagement approaches that:

- Respond to the unpredictable, fast-changing and differentiated environment characterising the Future Grid
- Recognise the need for flexibility and adaptability across different scenarios and possibilities, acknowledging that a 'one size fits all' approach is neither possible nor desirable
- Recognise the ways that people value engaging with energy in ways that extend beyond its role as a market commodity (e.g. as a community asset, shared responsibility or common good)
- Change the terminology and thinking away from 'customers' and 'consumers' and onto people as 'partners', 'flexible opportunists', 'carers' and other meaningful roles that better reflect how people think about and engage with energy as part of their everyday lives
- Engage people through the issues, concerns and everyday practices that already interest them (such as caring for their children or pets)
- Are creative and innovative, as illustrated by 14 exemplar engagement program ideas in the Future Grid Engagement Strategy (Strengers et al. 2019c). These included:
    - Memes to engage young people
    - Community splash parks for people living in heat-vulnerable areas with poor quality housing and/or low incomes
    - Fun mascots to communicate the changing needs and of the electricity grid
    - Free or discounted pet heating and cooling technologies for heat vulnerable pets as an alternative to air conditioning and heating
    - Free activity vouchers that incentivise people to leave the home and do something else with their time during periods of peak electricity demand (which normally fall on hot days).

2. Consider the ***digital futures*** made possible by IoT-enabled devices, including new ways to ***use more energy***

In addition to considering the emerging *energy* futures enabled by IoT, it is equally important to consider the *digital* futures made possible by IoT-enabled devices and their likely energy implications.

For example, and as discussed further below (under 'Risks'), **IoT is enabling enhanced comfort, convenience, security and entertainment in ways likely to require *increased* energy consumption**. Likewise, IoT is enabling new working and living arrangements, such as the ability to work and care for others at home, with a range of connected devices and technologies.

In addition to seeking ways to deliver IoT-enabled *energy* futures, **governments and industry should consider measures which seek to achieve lower-energy *digital lifestyles*** resulting from the integration of new IoT devices into people's lives. These could include promoting or incentivising 'lifestyle' technologies that are likely to result in lower energy practices than other available alternatives.

3. Consider the energy implications of **non-energy policy**

Understanding and responding to changing digitally-enabled lifestyles and practices necessitates paying attention to non-energy policy. This includes health, education, defence and ICT (national broadband) policy – which although not specifically about energy (Royston et al. 2018) can significantly impact how and when energy is consumed, and encourage new practices that normalise or even require certain types of consumption (Røpke, I. 2012).

For example, education policy requiring school children to have and/or use digital technologies for homework and in school activities has impacted home energy use as children have become more reliant on digital devices and the practices reliant on connectivity (even where parents' preference is to minimise or avoid screen usage by children).

Another example of non-energy policy comes from the health sector which often promotes 'staying home' and running the air conditioner in hot weather, which counteracts energy sector messages to curb usage during peak periods (Nicholls and Strengers 2018).

4. Provide **energy leadership and direction**

There are clear indications that **Australian households and communities want stronger energy and climate change policy at the federal level**, to provide leadership and direction for Australia's cities and regions (The Australia Institute 2019; Nicholls et al. 2019).

Recent research recommends a nationally coordinated approach to household energy engagement – underpinned by an energy and climate change plan and policy – that provides the Australian community with leadership and understanding about where the energy sector is heading and why (Strengers et al. 2019c).

A **robust, clear, long-term national plan** is likely to improve trust and confidence in energy policy within the Australian community, and increase consumer willingness to utilise digital technologies that assist with demand management and increase efficiency of the energy system (Energy Consumers Australia 2019b).

Future energy consumption risks

1. *Increased energy consumption risks*

There is a growing body of research demonstrating that **IoT devices can increase direct energy consumption in people's homes** (Hargreaves & Wilson 2017; Røpke et al. 2010, Strengers & Nicholls 2017). This is because new technologies enable additional opportunities to consume energy, and can increase standards and expectations for existing practices and services (Shove & Walker 2014). This is similar to the history of other technologies and appliances that have become embedded into everyday life, many of which have led to increased expectations of 'comfort, cleanliness and convenience' which constitute 'the environmental hot spots of consumption' (Shove 2003).

While many digital technologies have *potential* energy-saving benefits, actual energy outcomes are highly dependent on how they are designed, marketed, used and the context into which they are introduced.

Companies typically emphasise the energy-consuming lifestyle improvements made possible with these devices, rather than their energy-saving benefits. Where energy-saving benefits are mentioned, these are generally secondary to others (Strengers et al. 2017). Research investigating the lifestyle visions discussed by smart home proponents in popular newspaper, magazine and online articles found a unified vision of 'pleasance' – which promises 'comfort, romance and peace-of-mind' (Strengers & Nicholls 2017). These lifestyles improvements – if incorporated into people's homes and lives – are likely to *increase* energy demand, even if energy-saving benefits and efficiencies are also possible.

Smart homes and smart home devices provide new conveniences and comforts that may result in increased energy consumption, as demonstrated in several studies conducted with Australian householders (Jensen et al. 2018, Nicholls et al. 2017, Strengers & Nicholls 2017, Strengers et al. 2017, Strengers et al. 2019a). For example, an IoT-enabled air conditioner can allow householders to pre-cool or pre-warm their homes before arriving home, thereby creating a new opportunity to consume more energy.

Smart thermostats use IoT to take weather forecasts, household occupancy, and other data into account to automate heating and cooling. Smart thermostats promise significant energy savings but product testing showing 'overall' energy savings in United States homes also shows *increased* energy consumption in over 30% of homes (Nest Labs 2015). While energy reductions are achievable in large, climate-controlled homes, typical Australian households whose residents use heating and cooling only 'as needed' may find that smart thermostats *increase* energy use by moderating and thermally regulating home temperature more often (and potentially across a larger volume of space) than previously experienced or possible with other types of heating and cooling appliances. **Smart thermostats could therefore undermine active, manual energy management practices (e.g. 'only using heating and cooling as needed') in ways that increase energy use from heating and cooling appliances**.

Technologies that reduce or eliminate the need for consumers to actively conserve energy can have carry over effects – diminishing energy management awareness and practices. For example, young adults moving out of a family home in which automation managed their energy use for them (via sensor lighting, smart thermostat, automated windows and shading) may struggle to manage energy use in a less technologically advanced home.

IoT-enabled devices can also contribute to the multiplication of devices in use at any given time, providing additional ways to consume energy (Røpke et al. 2010). For example, people can monitor their home, pets, or people they are caring for via a live-streaming video feed whilst simultaneously engaging in other activities both in and out of the home (Richardson et al. 2017).

While most digital devices have low *individual* energy use, this may not always result in reduced energy consumption overall if new interdependencies between higher energy use devices emerge. For example, gaming consoles rapidly became commonly used in homes (sometimes involving several devices), and social resistance to switching these devices off when not in use resulted in considerable additional energy use (Delforge and Horowitz 2014).

Likewise, substantial initiatives to reduce household standby power use through provision of free powerboards with automated standby power control have been undermined by household unwillingness to lose settings and data in set top and other media boxes, or risk having a TV turn off part-way through watching a show. After installation, these devices were rejected by households on a large scale because they were considered inconvenient. **Standby power of entertainment devices remains a significant and growing issue.**

Energy-related research on IoT typically doesn't consider these potential risks, focusing instead on opportunities to save and shift energy demand in isolation of other possibilities to consume it. As a result, **current estimates of IoT benefits may significantly overestimate the opportunity for energy reduction and/or load shifting.**

IoT devices can also increase *indirect* energy consumption through the use of livestreaming and internet-enabled capabilities that depend on remote data centres (Morley et al. 2018). While many (but not all) data centres have committed to 100% renewable energy targets, current demand for data is growing at a faster rate than can be met by renewable supplies (Cook et al. 2017).

2. Gender-related accessibility and violence risks

There are considerable and unique risks posed to girls and women as part of the current gender divide in digital skills. These were recently detailed in a major global report published by the UNESCO EQUALS Skills Coalition (West et al. 2019). The gender skills gap widens for girls and women where technologies are emerging or new – as is the case for many IoTs.

Men are more likely to be interested in energy-related IoTs and smart home devices more broadly, as found in our research with Australian households (Strengers 2013, Strengers et al. 2019a). They are also more likely to be the instigators and installers of these technologies into the home. In some cases, women in heterosexual coupled households are not fully aware of how to operate these devices or how they are being used in their homes. As such women may have less control over IoT-enabled appliances such as heating and cooling – even if they are the ones spending more time at home.

There is a risk that **energy industry strategies to engage consumers assume that householders will act like a masculine 'Resource Man'** – who is interested in managing and monitoring his energy demand and supply using a range of emerging technologies (Strengers 2013). In contrast, **women still carry out the majority of domestic activities in homes that consume energy** and are more likely to be interested in other ways of enacting environmental responsibility (Fartboko 2017). Strategies to engage consumers in IoT-enabled energy futures need to take these gendered considerations into account.

An emerging body of research is demonstrating **worrying trends towards the use of IoT and smart home devices in exacerbating domestic violence towards women in the home** (Bowles 2018, Leitão 2018, Strengers et al. 2019a). This includes locking occupants in and out of homes, or monitoring their movements and engaging in cyber-stalking.

3. ***Digital access, affordability and inclusion risks***

The potential benefits promoted for IoT to reduce energy costs and manage demand are not equally accessible – because many people do not have the skills, money, Internet or data access on which participation relies. This risk has parallels with the shift towards Internet banking and the closure of regional bank branches and post offices, which have left rural and older Australian's who don't always have access to computers, Internet or digital skills, with limited capacity to do banking or pay bills (Parliament of Australia 2004).

Planning and policy is typically delivered by urban, digitally-skilled professionals, and does not always take into account **unintended and unforeseen impacts on the regional, older, low-income or digitally excluded citizens**.

ABS data indicates that about 20% of people aged 55-64 years, and about 40% of those over 65 years do not use the Internet, and that usage is significantly higher in cities (ABS 2018). Of those that do, it is likely that a significant proportion are not sufficiently 'tech-savvy' to utilise IoT devices for energy purposes.

In the energy sector there is a considerable emphasis on the widespread rollout of 'cost-reflective' electricity pricing (higher charges at peak times) and use of automation to shift appliance usage to lower price periods. While this might benefit the system as a whole, **households without Internet, time or digital skills may be financially disadvantaged during this transition.**

Automation and IoT are often not as easy, useful and acceptable as marketing suggests. We conducted a small household trial of market-leading, self-install smart light bulbs and 'smart plugs' to provide automation and smart phone app-mediated control of appliances (Nicholls et al. 2017). Key findings included:

- A quarter of trial households were not sufficiently interested or digitally confident to attempt to install the devices
- A quarter of trial households tried to install the devices but could not get them working
- A quarter of households installed the devices but later abandoned use due to product failures they could not resolve, inconvenience or other reasons
- Only a quarter of households installed the smart devices and, 3-6 months later, were still using them but not necessarily to manage energy use (but for lifestyle improvements, as above).

The above results **not only indicated the potential for significant tech waste, they induced feelings of confusion, inadequacy, frustration, and exclusion.** Some younger household participants were initially enthusiastic but later found that the devices only worked with high end smartphones which they could not afford, or that their Internet speed or the cost of sufficient data to download and operate IoT devices excluded them from participating. Even Internet services in newly built apartment buildings were sometimes insufficient for the trial devices to operate reliably. Households are eager for ways to reduce energy bills but failed technology or provider promises can have longer term impacts, reducing household willingness to engage with the next energy offer, opportunity or communication. These negative experiences need to be balanced against potential benefits for those that successfully use these devices to manage energy use.

Younger households may be the target market for IoT but these devices are not always desirable or productive in households with children. The smart home control trial also highlighted how IoT can demand greater reliance on smartphones by more members of the households. For example, smart control of light bulbs can be disabled if some members of the household continue to use manual wall-mounted light switches. *All* household members lighting habits needed to change for a productive outcome, which means that children without a smartphone could be excluded from switching the lights on or off. **Parents were concerned that IoT devices might make their children more reliant on smart phones, or increase household costs by making smart phones 'necessary' for children**. Parents were also concerned that the automation of lighting or other appliances would undermine their efforts to teach children to be energy conscious.

Novel social experiences and interactions from energy use and IoT

As IoT devices become more integrated into people's lives we can expect a range of new social experiences and interactions that are likely to affect energy consumption. Some of these are discussed below.

1. New pet care and entertainment possibilities

Australia has one of the highest rates of pet ownership in the world. With many pets kept indoors or at home during the day, **more people are turning to IoT devices to provide their 'fur babies' with care, comfort and entertainment** (Strengers et al. 2019b). As part of 'humanisation' and 'premunisation' trends in pet care globally, emerging pet care practices with energy implications include:

- Heating or cooling rooms and homes exclusively for pets during the day
- Monitoring pets with livestream security cameras or 'pet-cams', or
- Providing IoT-enabled entertainment devices such as games and screen-based content (Strengers et al. 2016; 2019b).

The trend towards heating and cooling homes during the day for pets could have a significant impact on energy consumption – potentially changing or shifting the current peaks in electricity demand. We recommend paying more attention to these energy consumers, including considering their role in future energy visions and forecasting models (Strengers et al. 2016; 2019b).

2. Additional digital housekeeping and changing gender division of labour

Research on the integration of connected and smart devices into households is finding a corresponding **rise in 'digital housekeeping' – referring to the labour involved in installing, maintaining and operating this technology** (Kennedy et al. 2015, Rode & Poole 2018, Strengers & Nicholls 2018, Strengers et al. 2019a, Tolmie et al. 2007). The amount of digital housekeeping required by IoTs is generally underestimated by the IoT industry, and commonly overlooked by the energy sector. Further, it is not currently tracked in ABS statistics.

Digital housekeeping associated with smart home technologies and IoTs could change the gendered division of labour in the home. Men are more likely to undertake digital housekeeping, often viewing it as a form of leisure or a 'hobby' rather than as housework. However, the considerable amount of time some men spend on digital housekeeping may take them away from other more 'traditional' household chores, which are more likely to fall (back) to women. This trend may become exacerbated as more IoTs enter the home. Alternatively, it could become less pronounced as next-generation IoT devices are simplified, streamlined and become a normal technology in everyday life.

The necessity of digital housekeeping in keeping IoT-enabled devices operating 'smoothly' points back to the risk that those without these skills (or the time to perform them) are unlikely to sustain their engagement with these devices or incorporate them into their lives in any meaningful way.

3. E-changing, working and caring from home

Increased access to high-speed broadband in Australia's regions in resulting in some people making an 'e-change' to rural and regional communities (Glover & Lewis 2019). Like the phenomena of 'sea-changing' or 'tree-changing', e-changing refers to people's relocation into communities that offer lifestyle benefits enabled by enhanced internet connectivity and more affordable housing and living costs.

Greater internet connectivity and access to IoTs is also enabling **more people to work from home and engage in new forms of mobility and collaboration** (Gorman-Murray & Bissell 2018, Gregg 2011).

These emerging work location trends have potential implications for the energy needs of cities and regions, and the changing energy demand profile of households. **More households working from home during the day may reduce the afternoon/ early evening peak in electricity demand**, for example, by providing opportunities for households to consume on-site renewable generation from rooftop solar PVs. This practice may be particularly important and possibly worth incentivising in areas where high solar PV penetration generates excess electricity on mild sunny days. Some electricity networks are already looking at ways to link operation of high energy usage appliances to periods of excess production. Greater capacity and penetration of home battery energy storage will assist daytime 'demand troughs'.

Enabling more households to work from home (including with the assistance of IoT devices) can also contribute to smoothing residential electricity loads. For example, people working from home with EVs can charge directly from their own or centralised renewable energy generation during the day, rather than arriving home during the afternoon/evening peak and charging their vehicles after the peak in renewable energy output.

4. Holidaying and 'resorting' at home

The future meaning of home is changing in relation to highly-mobile lifestyles and globalised workplaces, alongside increasing access to digital and emerging technologies in smart homes (Jensen et al. 2018, Strengers et al. 2019a).

For example, **some middle- or high-income households with highly mobile lifestyles and careers are viewing their home as a place to provide entertainment services and other 'luxury' opportunities** previously delivered by out-of-home service providers or only experienced on holidays. This includes equipping homes with entertainment rooms (such as in-home cinemas), resort-style pools and spas, or whole-of property light and sound features such as automated fountains and coloured feature lighting. These experiences are enabled and supported by IoT. While often sporadically or only occasionally used, these services create new forms of energy consumption and entertainment opportunities that are underexplored in existing research.

5. Energy sharing and charging

In recent research with households who are engaging in emerging relationships with the Future Grid, we found **strong interest in peer-to-peer energy trading, similar to AirBnB or other sharing economy platform models** (Strengers et al. 2019c). While opportunities for peer-to-peer trading are currently limited and complex for Australian households, there are indications that this an emerging Australian and international trend for households and businesses with solar PV generation and battery storage. It is likely that a variety of options for platforms to share or trade energy will emerge. This research found that opportunities to share or donate energy to people within a household's network or community who need affordable access to energy is likely to attract significant interest, as households seek to put their 'clean' energy to positive, 'local' use.

6. Mobility/ transport trends

Future transport mobilities are increasingly envisaged as smart, automated, connected, integrated with IoT, and powered by electricity. This introduces possible futures scenarios relating to EV charging in what may be a mixed economy.

Private EV ownership: Currently Australian households' uptake of EVs and charging infrastructures in Australia are growing (Climateworks 2018) but are low in comparison with Northern Europe and the US. In the existing literature, consumer EV adoption is seen as a challenge (Dini 2018:25). Australia has an existing private car ownership culture, whereby 'the majority of consumers currently use their private vehicle for all purposes, whether commuting to work alone or going on holidays with the whole family' (Climateworks 2017) and it is likely that that this will persist in future EV adoption for both practical and personal identity reasons. Existing research elsewhere suggests that in such a scenario, privately owned EVs will be charged at similar times of the day when owners arrive home from work, adding to peak electricity demand, particularly in areas of high ownership (Pajic et al 2018) for air conditioning and other appliances (see above).

Mobility as a Service (MaaS): MaaS refers to future intelligent transport systems, integrating modes of transport to create seamless, effective and sustainable mobility solutions using Artificial Intelligence (AI) and Automated Decision Making (ADM). MaaS has both public and private sector stakeholders and a determining factor regarding how energy demand and supply are managed in future MaaS in Australia will depend on the extent to which these sectors can be motivated to collaborate in the future. It is usually envisaged that MaaS will be provided through virtual platforms that people access through smartphone apps or similar future personal mobile technologies. If householders begin to use MaaS fleet EVs (sometimes envisaged as ADM cars or pods) these are likely to be shared vehicles, charged at public or private charging stations, thus reducing peak demand in households, and opening possibilities for energy trading to be integrated into MaaS systems. However, it is uncertain as to whether car-sharing systems themselves will reduce energy demand in Australia since without appropriate policy intervention they could increase demand for car use above public transport (Climateworks 2017).

Further issues relating to battery charging: A key issue for consumers is what has come to be referred to as 'range anxiety' (Jung et al 2015), which refers to concerns regarding the distance an EV can travel without needing to be recharged. EV battery charging also raises issues relating to a possible public/private sector divide (Bowen et al 2018) and has generated a range of proposed technological solutions related to energy demand and 'topping up' batteries. These generally propose that charging should be flexible. They confront questions relating to consumer and organisational trust through Blockchain-based applications (Pajic et al Gorenflo et al 2018), through the development of transparent centralised charging systems. Another proposal involves responsive decentralised charging applications based on predictive analysis of supply and demand (Radenkovic & Walker 2018). The implications for the grid will thus be contingent on how flexible charging systems are developed. IoT would enable such systems.

The World Economic Forum web site refers to future 'smart-charging' infrastructures and 'preference-learning assistants', and suggests: 'The usefulness of automated information systems in managing the transition to sustainable energy and electrification applies not only to the rise of EVs, but extends to the integration of households that put energy they produce back into the grid' (Ketter

2019). However, we note that as yet these remain technological possibilities in Australia and in depth research would be needed to investigate their suitability for everyday life use.

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