# User-Centred Energy Systems

# Social License to Automate

## Emerging Approaches to Demand Side Management

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UsersTCP

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# Acknowledgements

The Technology Collaboration Programme is a multilateral mechanism established by the IEA with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of thousands of experts across government, academia and industry in 55 countries dedicated to advancing common research and the application of specific energy technologies.

The User-Centred Energy Systems Technology Collaboration Programme (Users TCP) is organised under the auspices of the IEA but is functionally and legally autonomous. Views, findings and publications of the Users TCP do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.

This is version 1.0 of the final international report and was released 26 October 2021.

# Abbreviations

AEMC: Australian Energy Market Commission

AEMO: Australian Energy Market Operator

AER: Australian Energy Regulator

aFRR: automatic frequency restoration reserves

AMM: automated market making

API: application programming interface

API: application programming interface

ARENA: Australian Renewable Energy Agency

AUD: Australian dollar

BESS: battery energy storage system

BEV: battery electric vehicle

CHF: Swiss franc

CINELDI: Centre for Intelligent Energy Distribution, Norway

DER: distributed energy resources

DLC: Direct Load Control

DM: demand management

DMIA: Demand Management Innovation Allowance, Australia

DMIS: Demand Management Incentive Scheme, Australia

DNSP: Distribution Network service Provider

DR: demand response

DRED: Demand Response Enabling Device

DSM: demand side management

DSO: Distribution System Operator

EAG: Renewable Energy Expansion Act

EEG: Erneuerbare Energiegemeinschaften, renewable energy communities

EU: European Union

EV:  electric vehicle

FCR: frequency containment reserves

HAN: home area network

HCI: Human-Computer Interaction

HEMS: home energy management system

IAD: Institutional Analysis and Development

ICT: information and communication technology

NDC: Nationally Determined Contribution

NEM: National Electricity Market, Australia

NVE: Norwegian Water Resources and Energy Directorate

P2P: peer-to-peer

PV: Photovoltaic

R&D: Research & Development

RME: Energy Regulatory Authority, Norway

SCC: Self-consumption communities

SEK: Swedish krona

SoC: state of charge

STS: Science and Technology Studies

TNSP: Transmission Network Service Provider

TSO: Transmission System Operator

UNFCCC: United Nations Framework Convention on Climate Change

V2G: Vehicle-to-grid

VPP: Virtual Power Plant

# 1. Introduction

A significant **energy transition** is underway across the participating countries in this project, and indeed beyond. In each country, this transition involves significant challenges associated with the relationship between transmission, distribution, and consumption of energy. Furthermore, electricity usage patterns are becoming less uniform, reflecting both changing societal practices and an increasing share of intermittent energy supplies. New business models are emerging to manage, aggregate and control the bidirectional flows from electric vehicles (EVs), batteries and other distributed energy resources (DER) throughout urban areas and beyond.

**Automation** of these DER is playing an increasingly important role in this transition, and ranges from local automation by the household through the programming of smart appliances and smart home energy management systems (HEMS), to the direct load control (DLC) of appliances and devices such as air conditioners, batteries and EVs by network operators and aggregators.

Across the jurisdictions, **decarbonisation** is a key driver of these changes, though its precise contours are challenged at multiple scales. European policies, including the Clean Energy Package, have emerged as crucial in orienting investment towards electrification. Even in the countries formally outside the European Union (EU), there are important implications to such policies that lead to similar demand management programs being developed.

**Decentralisation** is also an important theme in the development of new automated technologies. In this narrative, control over power systems is wrested from state agencies in control rooms to the hands of sovereign consumers, usually via a mobile device. However, this is not straightforward. High levels of automation, for example, move key judgments about electricity systems to other centres of control; rather than simply 'decentring' power**.**

The role of **digitalisation** is also crucial to high technology decarbonisation and decentralisation of power. Digital technology platforms allow users to produce, consume, store and trade energy services with multiple parties, potentially constructing new forms of value for users, communities and businesses.

These issues in turn raise questions about the **democratisation** of energy, including: how is decision-making distributed, not just between energy users but also between citizens and energy experts and other actors? **What problems are automation technologies addressing and who has control of the DER?**

These are the questions key to understanding the issues of a 'social license to automate' explored in this report.

The case study research:

- addressed the social and technical conditions in which residential energy users are willing to engage with automated management of their electric vehicles, air conditioners, batteries, heat pumps, hot water systems and other loads and distributed energy resources.

- centred on residential settings but findings may be relevant to other energy user groups

- spanned a spectrum of high, medium and low levels of automation, ranging from local programming to remote control by a third party, which inversely require greater user involvement.

Trial and programs analysed in this report addressed:

- Frequency control
- Peak load shaving
- Voltage management
- Bidding into spot, futures and wholesale markets
- Self-consumption of individuals and/or communities

These correspond to the key value streams that industry participants have been seeking to tap in order to develop business models for automated DSM. We conducted original research on these trials by analysing project reporting and other documents, and conducting interviews with the experts involved as well as focus groups and interviews with energy user-participants in the trials. We have also included novel survey analysis of Australian energy user engagement with automation.

## What is a 'social license to automate'?

The 'social license' concept is based on a 'social license to operate', which was developed through experiences in the mining sector. It refers to the extent to which an initiative has the approval or acceptance of communities of stakeholders, and captures a cluster of factors beyond that of formal legal approval which can shape its reception. In the context of energy systems, the concept of a 'social license' appears to sit between the formal and informal rules of conduct for the electricity companies, grid operators and network businesses trialling automation in DSM.[1]

Issues of 'social license' therefore speak directly to the challenges of democratisation that arise from decentralisation. What involvement should users have in automated energy

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[1] Adams, S., Kuch, D., Diamond, L., Fröhlich, P., Henriksen, I. M., Katzeff, C., Ryghaug, M., Yilmaz, S. (2021). Social license to automate: A critical review of emerging approaches to electricity demand management. *Energy Research & Social Science*, 80, 102210

systems? This is a profound question for democracies that warrants a great deal of experimentation and testing - and indeed the projects described in this project could be seen as exemplary **social *and* technical experiments** in their efforts to redistribute agency between users, grid operators, and energy companies.

Energy industry assumptions about the take-up of new automated systems have been repeatedly disrupted by new kinds of user activity, consumer mobilisation, and civic engagement with technologies. Wind farms, unconventional gas exploration and other energy technologies have been challenged through activism that has shown a new need for humility from expert and industry groups. The concept of a social license has most explicitly been taken up in research around extractive industries, especially unconventional gas[2], to address these challenges of wider engagement.

The premise that formal state regulation is no longer sufficient, and that anticipatory engagement with technology users is required, underpins this project. The projects analysed across the six countries in this report developed from the Australian delegate to the UsersTCP's experience with developing large wind farms for an Australian company. Tony Fullelove fronted locals in regional centres to inform them of the benefits to their economy, a cleaner energy system and a route out of dependency on coal, only to be met with skepticism and even hostility. Fearing automated demand response (DR) technologies would meet the same fate, he partnered with Iain MacGill at UNSW and the Energy Efficiency Council through an affiliation with Monash to establish this project.

The Social License to Automate project was born in a modest workshop in Zurich in 2019 bringing Dutch, Swiss, Swedish and Austrian researchers together with Dr Declan Kuch, Dr Sophie Adams and Lynne Gallagher, CEO of Energy Consumers Australia - a government body established to represent the interests of consumers in the energy system.

Over the past year, the concept of a 'social license to automate' has been taken up by Energy Consumers Australia[3], starting a national discussion that reverberated through key

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[2] See Kuch et al. (2013) ACOLA ARC LASP Program Securing Australia's Future Project # 6 Engineering Energy: Unconventional Gas Production: Social License report https://acola.org/wp-content/uploads/2018/08/csrer-atse-social-license-communication-jan13.pdf; Bice, S. and Moffat, K., 2014. Social licence to operate and impact assessment. *Impact Assessment and Project Appraisal*, *32*(4), pp.257-262.
[3] Social Licence for Control of Distributed Energy Resources https://energyconsumersaustralia.com.au/publications/social-licence-for-control-of-distributed-energy-resources (accessed 18 Oct 21)

governing bodies, including the Australian Energy Market Operator and Energy Security Board. It acknowledged the importance of consumer acceptance and identification with the objectives of automated control over distributed energy resources including electric vehicles.

In 2021 many of the members of this collaboration published a major review paper which established the concept of a social license to automate in the prestigious journal *Energy Research and Social Science*. That paper develops a concept of a social license to automate:

> to understand the (mis)alignments between the expectations of actors within the energy system on the one hand, and household practices, sense of control and stake in the energy system, on the other. These domains of energy practices and energy users' engagement with technologies and other actors have largely been considered separately. The concept of an SLA bridges them by making explicit the negotiations between households and energy system planning that are necessary within each.[4]

Table 1 Advantages and disadvantages of the Social License concept

| Advantages | Disadvantages or criticisms |
|---|---|
| • Draws attention to power of community to halt projects with formal approvals<br>• Continuum of 'psychological identification' to 'withdrawal' of support adds useful nuance to accept/or reject binary<br>• Research in mining may have analogies in energy sector, such as dip in approval during construction phase<br>• Provides framework to assess how groups outside government can affect projects | • Ambiguous as to who has power to grant social license<br>• Concept of 'community' too malleable: too much power lies with social scientists to decide legitimate voices<br>• Approach has historically helped projects that lack democratic mandate |

This definition suggests that expert-derived distinctions between public and private benefit require careful empirical grounding through discussion with those involved. The paper argues that a social license requires appreciation of aspects of the user's experience that include **grid sensitivity**[5] - a concept that refers to users' experience of blackouts and other service disruptions - and **flexibility capital**[6] - a concept developed to express the different capacities of energy users to shift when or how they use energy. The relationship between flexibility capital and automation is complicated.

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[4] Adams, S., Kuch, D., Diamond, L., Fröhlich, P., Henriksen, I. M., Katzeff, C., Ryghaug, M., Yilmaz, S. (2021). Social license to automate: A critical review of emerging approaches to electricity demand management. *Energy Research & Social Science*, 80, 102210

[5] Skjølsvold, T.M., Ryghaug, M., and Throndsen, W. 2020.European island imaginaries: Examining the actors, innovations, and renewable energy transitions of 8 islands, Energy Res. Soc. Sci. 65: 101491. https://doi.org/10.1016/j.erss.2020.101491

[6] Powells, G. and Fell, M.J. 2019. Flexibility capital and flexibility justice in smart energy systems, Energy Res. Soc. Sci. 54:56–59. https://doi.org/10.1016/j.erss.2019.03.015
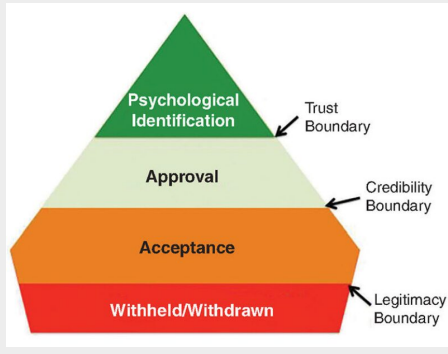
Figure 1: Threshold Conditions for a Social License

Users may grant an aggregator, like a DSO or energy retailer, a social license when they identify with the goals of a program at the highest level. This may be withdrawn if users lose trust or the company acts in ways damaging to its reputation (Figure 1).

The uptake of renewables alone bears no simple relationship to the development and requirements for automated systems across the countries discussed. As Figure 2 below shows, Norway and Austria have a very high share of renewable energy production. However, across all countries, greater need for flexibility to match intermittent renewables, as well as increasing demand from the electrification of heating and transport sectors, have driven new automation projects and programs. Australia is a notable laggard here, although it faces pressing issues associated with high levels of residential rooftop solar PV uptake. The differences across these countries are shaping how automated DSM is being approached as a solution in each.
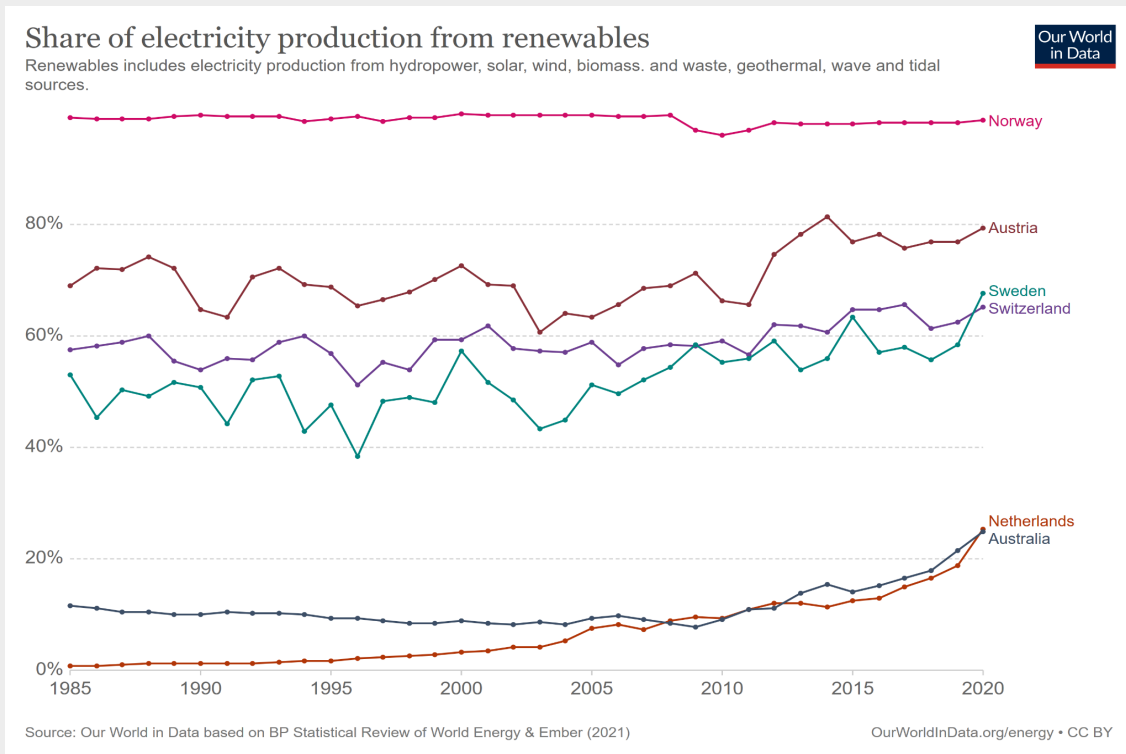


Figure 2: Share of electricity production from renewables

The problems that it addresses are embedded differently in these different contexts, although the common themes and trends of decentralisation and digitalisation are apparent across them.

# Research approach, collaboration and methods

This project has developed a novel approach through a unique international collaboration that seeks to understand issues of trust, engagement and acceptance related to automated DSM. We have developed the concept of a 'social license to automate' at the intersection of different sectors, scales and research approaches.

Table 2 below explains these approaches. The data collected were used in four different analytical workstreams, reflecting the disciplines of the members of the research collaboration. These were:

- **Human-Computer Interaction (HCI) studies**, which systematically examined the level of automation and its impacts on user acceptance according to incentive, feedback, individual and social benefit parameters.

- **Energy sociology**, which was used to explore some of the activities in which energy is used in the home and the ways that energy use that is shaped through such social forces as roles, habits, routines and infrastructures, considering the scope of automation to manage these activities

- **Science and Technology Studies (STS)**, which is a social scientific perspective on technology development. This analysis examined the ways in which automated DSM is made to offer a valuable solution in a variety of contexts, how actors have worked to translate the benefits to energy users and how energy users have accepted or resisted it.

- **Institutional and policy studies**, which was used to explore the institutional settings of automated DSM projects in Australia, Austria, Norway and Switzerland. The analysis maps the institutional settings of planning and implementation of these projects. This mapping comprises (i) which actors are most frequently involved in the initiation and implementation of automated DSM projects, (ii) discussion of how these actors are taking up positions which allows them to undertake certain actions in line with their interests in the project.

| Research Approach | Scale and Subjects | Methods | Research Question Addressed |
|---|---|---|---|
| **Human-Computer Interaction studies** | Micro: user interaction with made technology | User surveys and interviews | How can communications and interfaces be designed to meet the needs of users? |
| **Energy sociology** | Micro: householder and their energy activities make technology | Cultural probe methodology with user interviews | Which energy activities can be time-shifted through automation? |
| **Science and Technology Studies** | Cross-scalar: socio-technical actors (humans + technologies) | User and expert interviews, and critical documentary analysis | What are the solutions offered by automated DSM and to what extent are they do these aligned with users' values and interests? |
| **Institutional and policy studies** | Macro: Citizens and policies contend with rules that are re-made | Policy documentary analysis and analysis of 'institutional settings and rules' in the real-life project cases. Ostrom's Institutional Analysis and Development (IAD) framework | How can common electricity resources be effectively governed? |

Table 2 Workstream approaches

The analysis within each of these workstreams included several, but not all, case studies from the participating countries, according to fit and data availability.

Figure 3 plots the **points of departure** on the X-axis: is automation a 'black box' technology that can be analysed as a real, mobile and transferable technology in the world ('Automation made') or is it still a loose assembly of diverse technical elements, unruly users, mismatched rules that points to gaps between users and energy systems ('Automation in the making')? The Y-axis: refers to a comparative perspective of scale each approach brings to our understanding of a social license to automate.

Formal rules

Institutional
Analysis

Science and
Technology
Studies

Automation
in the
making

Automation
is made

Energy
sociology

Human-
Computer
Interaction
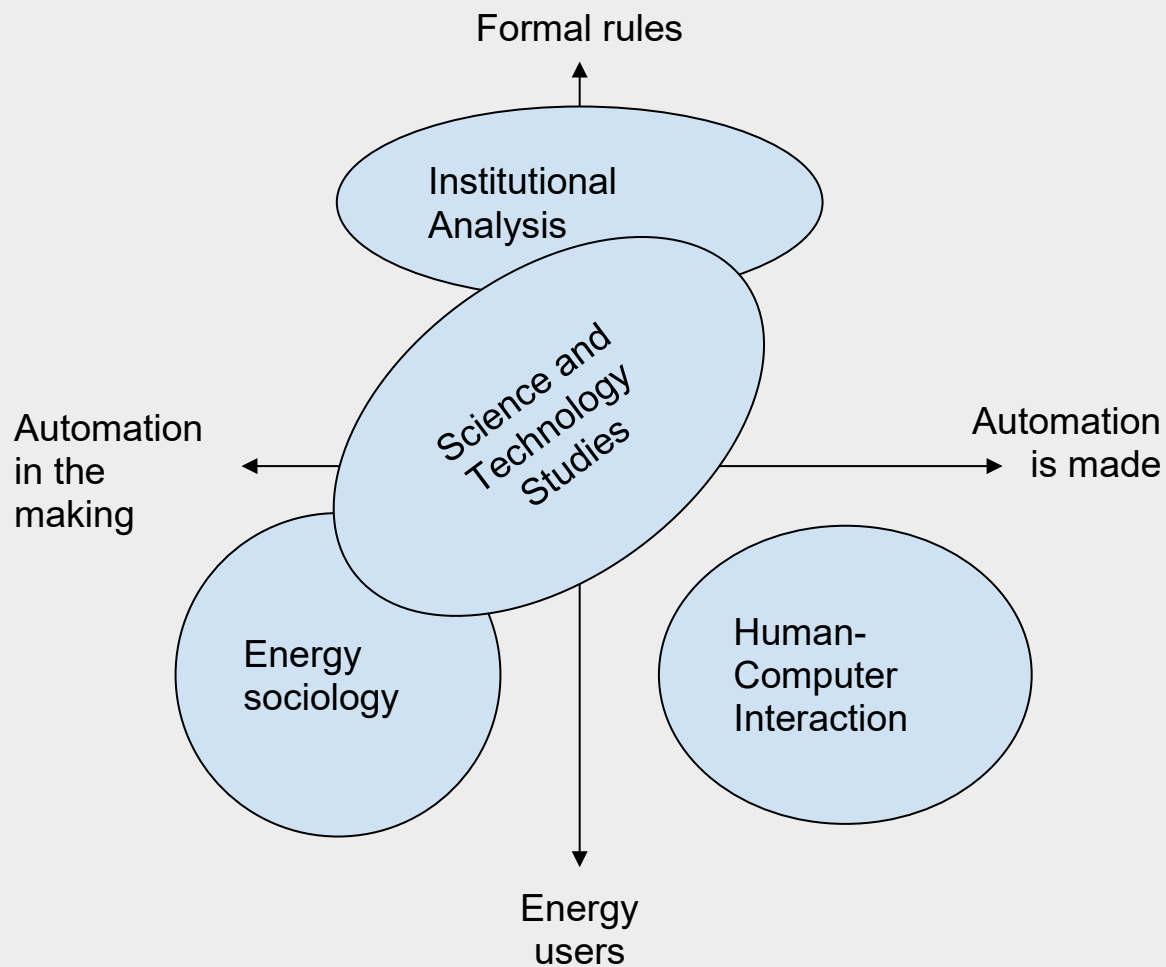
Energy
users

Figure 3: Workstream approaches to automation and scale

The research collaboration involved researchers across six countries who are deeply professionally engaged with energy policy and practice in each of their countries. Each researcher is based at an institution with multiple research projects that overlap with the concerns of this project. This expertise informed the framing and development of this project.

The case studies examined here are not strictly representative of the contexts from which they are drawn, but offer insights into the commonalities and divergences of technologies, energy system reforms and social issues across the participating countries. The case studies came about through collaborations with various research partners, some developed before and some after the commencement of the project.

We collectively developed a template to collect data in each of the case studies, which incorporated aspects of automated DSM that were identified by the research group as having the potential to influence acceptance and engagement. The template was used to gather data on:

- context, aims and framing
- the actors involved and the regulatory context
- technical parameters of automation and impacts on users
- incentives for users
- information provided to users
- user interaction with the automation system
- project outcomes

Part 1 of this report presents profiles of each of the participating countries and the case studies of automated DSM conducted in each. Part 2 presents analysis of these same case studies from different disciplinary perspectives.

# PART 1: COUNTRY PROFILES AND CASE STUDIES

# 2. Australia

- Australia is rapidly transitioning from one of the most coal-intensive energy systems in the world to one powered entirely by renewables through its abundant rooftop solar and wind, a rapidly developing market in Virtual Power Plants (VPPs), and numerous demand-side management trials by retailers, aggregators and network operators.
- How this new electricity system will balance centralised with decentralised controls remains contentious, especially considering the slow uptake of smart meters
- Electricity prices rose sharply ~10 years ago due to increased investment in distribution infrastructure. DNSPs responded to criticism about these price rises by developing several new demand-side approaches, including some of the key trials documented here.
    - Revenue streams for automated control of DER include the Demand Management Innovation Allowance which allows DNSPs to monetise non-network programs, frequency control markets, and bidding on wholesale and spot markets
- Customer and user-centred approaches have emerged throughout the electricity industry in the last 5-7 years
- All demand management trials and VPPs we have analysed have been voluntary and opt-in. Therefore, participant demographics are overwhelmingly skewed to highly technologically literate users, typically middle-aged men
- Those with higher incomes are not necessarily more open to automation of appliances and other DER.

## 2.1 Context for Automated DSM

**Population and housing**

Australia has a growing population, which stands at 25.6 million people in 2021. The Australian government has argued that the 'decoupling' of emissions from the population growth rate of 1.5% has not been a priority, considering that the population growth is 'significantly higher than the OECD average of 0.4 per cent'[7]. Demographic challenges include an ageing population of 'baby boomers'. Australia is highly urbanised, with some 80% of the population living in state capital cities.

Australia has much higher (above 65%) rates of home ownership than most European countries, however this rate is declining, especially among younger people. Furthermore,

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[7] Australia's 2030 Emission Reduction Target
https://www.pmc.gov.au/sites/default/files/publications/Summary%20Report%20Australias%202030%20Emission%20Reduction%20Target.pdf

there are now 12% more homes than the 9 million households, with an increasing number of vacant rental properties, second homes and holiday houses.

**Energy mix**

The main Australian electricity network is the National Electricity Market (NEM) – one of the largest in the world. It was created by competition policy reformers in the late 1990s as the amalgamation of state-based electricity commissions established throughout the twentieth century.[8]  The share of renewables in the NEM has grown rapidly since it was established. The take-up of rooftop solar PV to capitalise on abundant solar resources across most of the country has seen Australian rates of adoption among the highest in the world on a per capita basis. There are now some 14 GW of rooftop solar PV capacity, with a further 8 GW of commercial solar farms across Australia. These rooftop installations constitute the majority of the 14% of Australia's electricity generated outside the electricity sector by businesses and households in 2018–19.
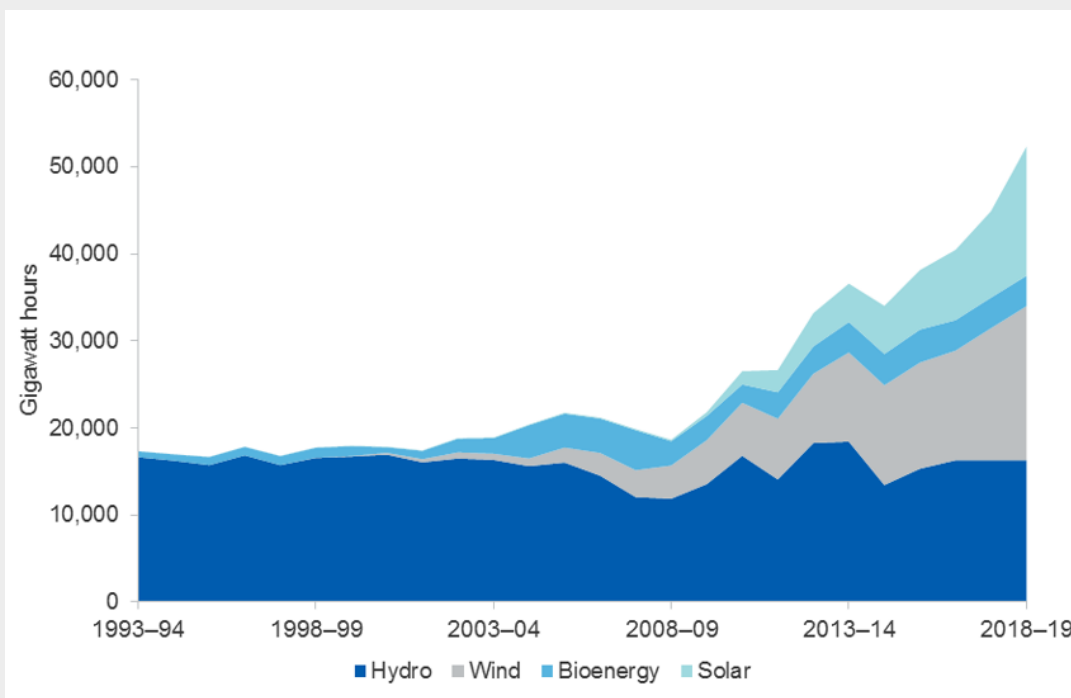


Figure 4:  Renewables generation in Australia GWh source: energy.gov.au

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[8] MacGill (2010) Electricity market design for facilitating the integration of wind energy: Experience and prospects with the Australian National Electricity Market *Energy Policy* https://doi.org/10.1016/j.enpol.2009.07.047
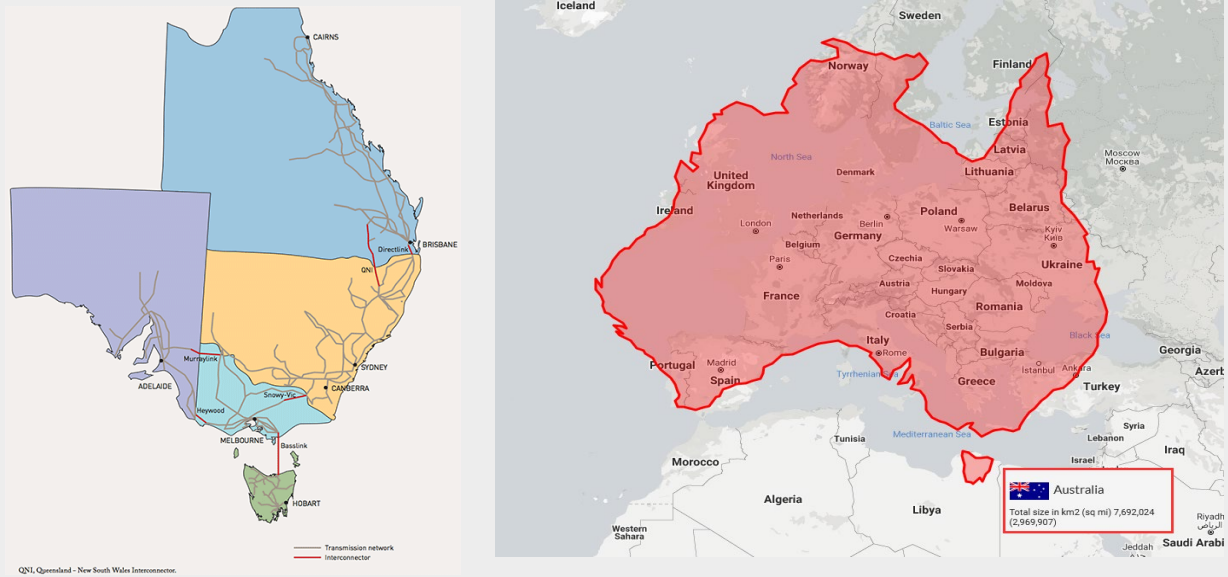
Australia is still largely reliant on fossil fuels for electricity, although this is changing rapidly. Total electricity generation in Australia in 2019 was around 265 TWh. This figure includes all electricity generation, including by power plants and generation by businesses and households for their own use. Fossil fuels contributed 79% of total electricity generation in 2019, including coal (56%), gas (21%) and oil (2%). Renewables contributed 21% of total electricity generation in 2019, specifically hydro (5%), wind (7%), and solar (7%) power. The share of renewable energy generation increased from 19% in 2018.
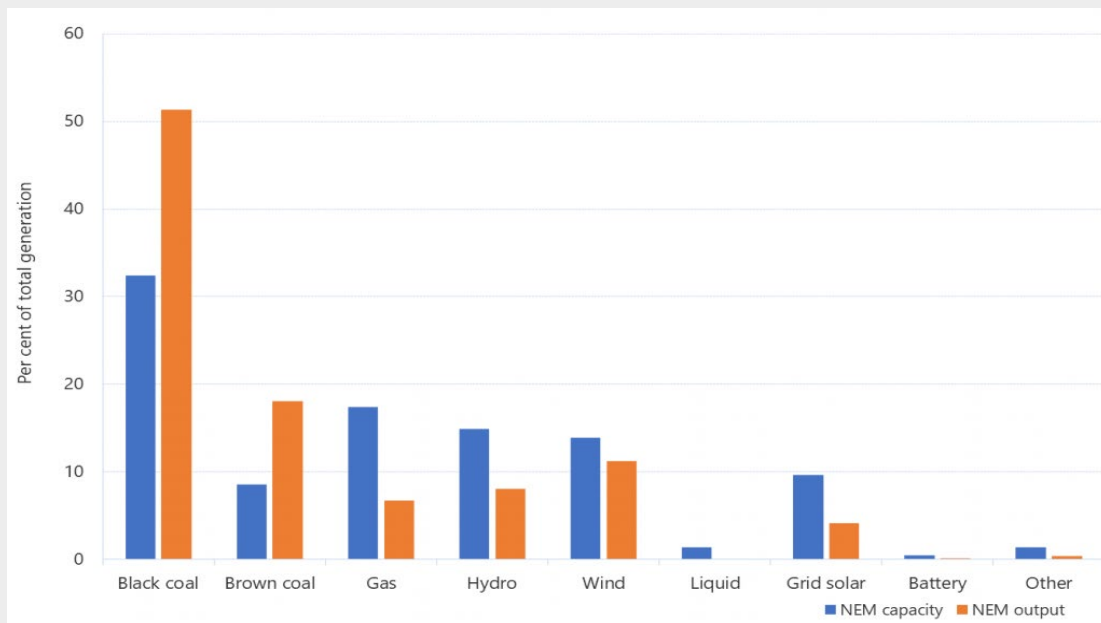


Figure 6: Percentage of capacity that each type of fuel source contributes to overall generation capacity in the NEM and the percentage of output that each type of generation contributes to overall output, for the 2020/21 financial year (source: energy.gov.au)

Falling solar power prices have also placed enormous pressure on wholesale power prices, undermining the business model of coal-fired power station owners. These companies, including the three largest energy companies (the vertically integrated 'gen-tailers' AGL, Energy Australia and Origin) have written down the value of their coal-fired power assets by billions of dollars as part of their transition to renewables-focused businesses.

**Key challenges and actors in the energy system**

High solar PV and air conditioning uptake is seeing a rapid shift in the profile of grid supply and demand. As in the other countries analysed, **energy consumption is too high, and too concentrated around particular times of the day, week, and year, especially around hot days.** In combination with more wind and PV power in the grid it can become more challenging to handle security of supply. Beyond these technical issues with energy system management, there are many other key policies, agencies and issues shaping the development of automated DSM in the Australian energy sector. These include:

- **National Energy Objectives:** These objectives govern energy investments but *exclude* environmental and climate considerations. The National Electricity Objective as stated in the National Electricity Law (NEL) is: 'to promote efficient investment in, and efficient operation and use of, electricity services for the long-term interests of consumers of electricity with respect to price, quality, safety and reliability and security of supply of electricity; and the reliability, safety and security of the national electricity system.'[9]

- **Federal policy uncertainty (amidst 'the Climate Wars'):** Automated demand-management technologies are embedded in some 25 years of climate policy debates in Australia.[10]  At the international level, Australia's climate policies are presented amongst Australia's Nationally Determined Contribution.[11] The Contribution lists several energy policy initiatives related to energy productivity.[12] These mainly relate to the gas industry, however several research initiatives related to lowering battery costs such as the Future Batteries CRC are also listed. Many trials and pilot projects analysed in this project were financed by the Australian Renewable Energy Agency (ARENA, established 2012 as part of a federal climate policy package passed by the Labor/Greens government. ARENA has a similar scope to CINELDI in Norway).

- **Networks:** The 22 network businesses in Australia deferred much network expenditure as climate policies of the early 2000s were being shaped. The sharp rise in spending on network infrastructure led to accusations of 'gold plating' in the early 2010s after a rapid rise in energy bills. Early automation trials emerged in the late

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[9] Australian Energy Market Commission, 'National Energy Objectives' https://www.aemc.gov.au/regulation/regulation  (accessed 18 Oct 2021)
[10] See, for example, Wilkenfeld, G., 2007. Cutting greenhouse emissions-what would we do if we really meant it?. *Australian Review of Public Affairs*. http://www.australianreview.net/digest/2007/08/wilkenfeld.html; Kuch, D., 2015. *The rise and fall of carbon emissions trading*. Springer.
[11] Australia's Nationally Determined Contribution https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Australia%20First/Australia%20NDC%20recommunication%20FINAL.PDF (accessed 2 October 2021)
[12] https://www.industry.gov.au/sites/default/files/September%202020/document/first-low-emissions-technology-statement-2020.pdf

2000s, including many financed through the Demand Management Innovation Allowance (DMIA) Scheme.

- **Households:** Many Australian households have enthusiastically taken up rooftop solar PV (~11 GW capacity) driven by:

    - Some very high feed-in tariffs developed by state governments to directly incentivise their uptake.

    - household-level concern about climate change and a lack of action by federal governments.

    - Australia shifting from having some of the lowest retail electricity prices in the OECD to some of the highest between 2003-4 and 2011.

  Air conditioning systems and hot water have been key targets for automated control by DNSPs and retailers. Large electric, gas and instantaneous hot water heating systems are most prevalent in Australia. Around half of electric hot water heaters in most large DNSP jurisdictions use a controlled load. Heat pump systems make up just 3% of the market, but their uptake is increasing.

- **State government agencies:** These are also emerging as key enablers of smart meters and home batteries. For example:

    - The Victorian Government led the national smart meter roll-out and is currently supporting several initiatives through its Renewable Energy Action Plan that centre consumers.[13]

    - The South Australia Government is participating in the Tesla and Energy Locals VPP. Following the 2016 South Australian blackout, South Australian energy policy has accelerated to become a prominent part of the state government, including extensive investments such as the Hornsdale Tesla Battery.

    - The NSW Government is also subsidising home batteries in certain regional areas. Households are encouraged to participate in VPPs through this program 'to improve their return on investment'.[14]

**Digitalisation**

The slow uptake of smart meters and supply-centric structure of energy market and governance in Australia has hampered digitalisation. Authors of the 2017 UTS review of DM argued that Australia is 'lagging behind the USA'.[15] The review covered peak load

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[13] Victoria's Renewable Energy Action Plan https://www.energy.vic.gov.au/renewable-energy/victorias-renewable-energy-action-plan (accessed 3 October 2021)
[14] https://www.energysaver.nsw.gov.au/sites/default/files/2021-08/APPROVED%20Empowering%20Homes_Frequently-asked-questions_Jan%202021.pdf (p.5)
[15] Dunstan, C., Alexander, D., Morris, T., Langham, E., Jazbec, M., 2017, Demand Management

management, distributed generation and energy efficiency. The authors argued that demand management has great potential to reduce energy costs for consumers as well as to enhance reliability. Citing the Australian Energy Market Commission's (AEMC) 2012 Power of Choice review, the authors argue that automated and behavioural DM could defer significant network investments, while delivering potential benefits of between $4 billion and $12 billion in the period from 2013/14 to 2022/23. Since the NEM was established in 1998, there have been several major missed opportunities to apply DM to trim billions of dollars of supply infrastructure costs and energy bills."

Despite these 'missed opportunities', resulting in sunk cost expenditure in transmission and distribution infrastructure, the authors cite emerging trends which highlight the ongoing need for DM in the NEM:

1.    The rapid growth of variable output renewable power generation such as wind and solar, for which flexible DM is likely to be the most cost-effective complement.

2.    The rise in small-scale decentralised generation, such as rooftop solar photovoltaics (PV), which creates both challenges and opportunities for managing energy supply and demand in the local low voltage network.

3.    The rise in low-cost decentralised energy storage, in particular batteries, both in standalone units and in electric vehicles. These provide both a load and a generation resource. If well managed, batteries could deliver lower costs and greater reliability for consumers. But if not well coordinated, including through DM, these new technologies could also impose major costs to consumers and adversely impact supply reliability.

4.    The emergence of smart energy management, including through 'internet of things' technologies, offers very large potential to reduce costs to consumers. Smart remote monitoring and control of appliances and equipment, such as Demand Response Enabling Devices (DRED), are already installed in many air conditioners, pool pumps, water heaters, etc. Tapping this technology, in conjunction with large-scale, intelligent, real-time consumer-responsive software (such as applied by ride sharing services like Uber), could offer large cost savings for consumers and major economic development opportunities.

The precise extent of smart meter coverage in Australia is contested. The Australian Energy Market Commission (AEMC) released a consultation paper in December 2020 to, *inter alia,* 'develop a greater understanding of the current costs of smart meters and associated services…'[16] The paper noted 'the Commission did not have specific expectations relating to

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Incentives Review: Creating a level playing field for network DM in the National Electricity Market (Prepared by the Institute for Sustainable Futures, University of Technology Sydney) https://www.uts.edu.au/sites/default/files/article/downloads/Dunstanetal2017DemandManagementIncentivesReview_0.pdf

[16] AEMC Consultation Paper 'Review of the Regulatory Framework for Metering Services' https://www.aemc.gov.au/sites/default/files/2020-12/EMO0040%20Review%20of%20the%20regulatory%20framework%20for%20metering%20services-%20Consult%20paper%20FINAL%20v2.pdf (accessed 19 Oct 2021)
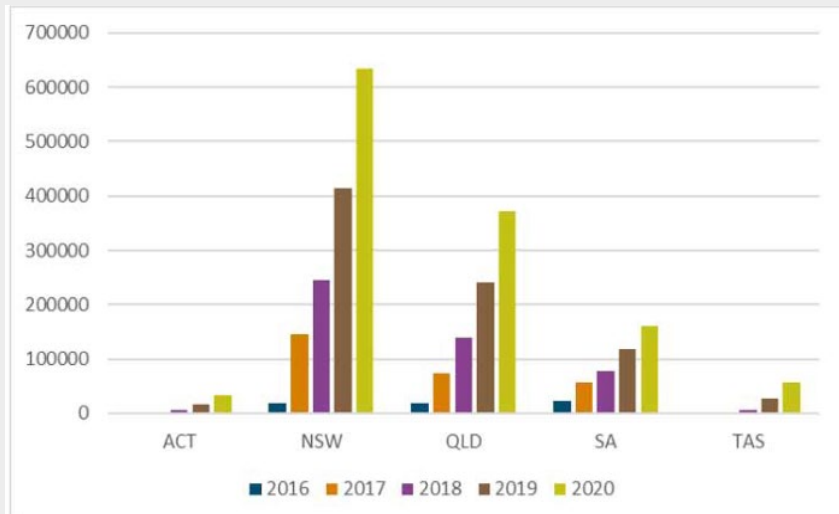
Figure 7: Residential and Small Customer Smart meter coverage by Australian State (source: AEMO)

the speed at which the roll-out of smart meters would be achieved as the framework is designed to enable a consumer-led deployment of smart meters […] The Commission has limited visibility of the current price of meters, incorporating the costs of their installation, maintenance and other ongoing costs associated with services.'

This uncertainty is in large part because of the contentious roll-out of smart meters in Victoria through the early 2000s. Retailers and some government agencies claim that over 2 million devices have been installed in Victoria.[17] A 2018 Sydney Morning Herald article stated that 'The uptake in other states across the NEM has been significantly slower, with almost 400,000 smart meter users in NSW, South Australia, Queensland, and Tasmania installing them as part of a wider solar rooftop panel installation if owners want to sell energy back into the grid. By comparison, Western Australian has more than 47,000 smart meters installed.'[18]

## 2.2 Case studies

The Australian case studies were selected to capture a variety of forms of automated DSM. The analysis was based on reporting from these trials and programs, interviews conducted with people involved in running them, and – in some of these cases – analysis of household participant survey and interview data.

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[17] Smart meters | EnergyAustralia https://www.energyaustralia.com.au/home/bills-and-accounts/understand-your-meter/smart-meters (accessed 2 October 2021)
[18] Latimer, C. (2018) What's so smart about electricity smart meters? smh.com.au

| Project name | Project partners | Dates | Devices automated | Purpose of the project | Scale |
|---|---|---|---|---|---|
| **AGL EV orchestration trial** | JET Charge, Chargefox and FlexCharging and a cohort of distribution network | 2020- | EVs, smart chargers | Explore challenges and opportunities in EV charging orchestration through value pool investigation and emerging technology investigation | 200 participants with smart chargers, 50 participants with V2G, 50 participants with vehicle API integration, 100 control group participants on time-of-use tariffs |
| **UNSW EV charging study with Solar Analytics monitoring** | Solar Analytics | 2021- | NA | Understand EV charging decision-making and assess willingness to participate in a hypothetical managed charging program | 18 participants |
| **RedGrid smart home trial** | Mirvac (property developer) | 2020-2021 | Smart plugs household appliances | Trial smart home software and investigate participant engagement with smart home technology and load shaving/shifting | 20 households |
| **Energy Queensland 'PeakSmart' program** | | 2012- | Air conditioners | Manage peak demand (4-8pm) across Queensland, especially during heat waves | 92,000+ participants |
| **AusGrid 'Coolsaver' trial** | | 2013-2017 | Air conditioners | Test the demand response standard AS4755, and customer take-up and satisfaction | Approximately 140 households in 3 areas over 4 summers |
| **AGL Peak Energy Rewards 'Managed for You' and Sensibo trials** | | 2018- | Air conditioners and EVs | Trial the control of residential loads that typically coincide with peak demand, and test various incentives for participation in various 'spot' event formats | Approximately 60 participants in 'Peak Energy Rewards Managed For You' trial, and 610 in Sensibo trial |

| Ausgrid VPP trial | Providers Reposit, Evergen and ShineHub | 2019- | Home batteries | Explore ways to better integrate DER, make the grid more efficient, and achieve cost savings for participants | 750 participants across 3 providers |
|---|---|---|---|---|---|
| AGL VPP trial | | 2017- | Home and business batteries | Test technical capabilities, conduct value pool assessment, explore participant recruitment, installation and satisfaction | 1000+ customers |
| Solar Analytics VPP study | UNSW, GreenSync, Ausgrid, Essential Energy and Endeavour Energy | 2020 | NA | Investigate user willingness to participate in a hypothetical battery VPP | 47 participants |

## AGL EV ORCHESTRATION TRIAL

*Trial of EV orchestration through smart chargers, vehicle API integration and V2G*

**Trial design and rationale:** This trial is funded by ARENA, with the aim of 'accelerat[ing] the development of EV charging management and orchestration to realise benefits for customers and the electricity supply system whilst ensuring impacts on the electricity grid are minimised'.[19] This is in a context in which electric vehicles are recognised to have the potential to pose significant challenges to the electricity supply system; namely system operators and network companies concerned about charging during peak evening periods especially exacerbating the 'duck curve'. The trial, announced in November 2020, is investigating three forms of EV orchestration: via smart charging, control via vehicle API, and vehicle-to-grid. A fourth group of participants on time-of-use tariffs have been included as a control group to evaluate the effectiveness tariff incentives against charging control. A user experience component of the program is investigating participant perspectives and experiences, and insights from a participant onboarding survey as well as interviews by consulting firm Perspicacious are presented in this report.

**Recruitment and participation:** Marketing of the trial was undertaken through email direct marketing via two car manufacturers, but approximately 70% of all expressions of interest to participate were received from people who had heard about the trial through word of mouth. The rationale for the trial presented to prospective participants on the website is that EV

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[19] https://arena.gov.au/projects/agl-electric-vehicle-orchestration-trial/

charging orchestration 'is an efficient way to power your electric car', and is a means to manage the pressure on the grid that could result from everyone charging at the same time of day, in order 'to ensure we make the most of the resources we already have'.[20] Three key incentives are offered to the participants: 'help save the planet', 'manage your charging: See your charging schedule, preferences, and receive notifications about managed charging events, all in a handy app' and 'more cash in your pocket'. Participants are offered AUD200 bill credit per year to participate in the trial. Information about the trial directed to prospective participants also informed them that they could always opt out of managed charging events. Participants are predominantly male, highly skilled professionals, aged between 45 and 60 years of age. They own a range of EV makes and models, with Nissan Leaf, Hyundai Ioniq, Tesla Models 3 and S, MG ZS among the most represented.

**Results and implications for a social license to automate:** The onboarding survey and interviews revealed that the motivation to join the trial was, for 59%, to 'support programs that help electric vehicles become a better option for Australians'; for 33%, to receive a free or discounted charger; and, for 6%, to receive bill credits. Most participants demonstrated a good understanding of what smart charging involves. Current charging behaviours and preferences among the participants vary, and the two main variables affecting charging behaviours are whether PV exists at the property and whether the customer is on a time-of-use tariff. Interviewees indicated a level of trust of 7.5 out of 10 in the AGL team to deliver a trial experience that meets their positive expectations. 71% of participants said they were 'not at all concerned' about AGL having control over the times their vehicle charges if they have the option to opt out. Among the approximately 26% of participants 'somewhat' or 'extremely' concerned about AGL having control over their charging, the reservations centre on a concern that their car would not be available for use when it is needed, and some people seem to be more concerned about this because their vehicle has only limited range.

## UNSW EV CHARGING STUDY WITH SOLAR ANALYTICS MONITORING

*Study of willingness to participate in a hypothetical managed EV charging program*

**Study design and objective:** This is a study of charging practices and attitudes to managed charging among EV drivers. Solar Analytics monitoring devices were installed in the homes of participants to allow the study team to track and analyse their rooftop solar energy generation and consumption, including for EV charging. 18 participants were also interviewed in the onboarding process and these interview data have formed the basis of this case study.

**Study results:** Participants were asked about why they chose to purchase an EV; how their travel habits have changed since the purchase of their EV; how, where, when and how frequently they charge their EV; and how they view the roles of other actors in supporting the uptake of EVs as well as the outlook for EVs in Australia. A variety of charging routines were evident, even among this cohort of EV drivers who have rooftop PV systems. For some

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[20] https://www.agl.com.au/get-connected/electric-vehicles/smart-charging-trial

participants it was most important to charge with renewable energy and/or with the least-cost energy source. For many participants these options are also weighed against several other considerations, such as travel routines and a preference to maintain their EV at a nominal minimum level of charge. These observations suggests that their willingness to participate in a managed charging program may depend on the extent to which the program can accommodate the priorities of individual EV drivers, as is discussed in Chapter 9. Understanding the User's Household Energy Activities'. Some of the participants directly expressed that they would be very interested to participate in a managed charging program; for most, however, willingness to participate would be conditional on the terms of the program, including compensation, options to opt out, etc.

## REDGRID SMART HOME TRIAL

*A trial of smart plugs in homes and participant engagement in load-shifting/shaving*

**Background**: RedGrid's trial of smart energy management in a housing estate on the outskirts of the city of Melbourne commenced in mid-2020 and concluded in mid-2021, encompassing three seasons and trial phases: winter, spring and summer. Its aim was to test RedGrid's software technology in combination with smart plugs and their potential to 'influence and empower customers to use and share their energy in new, innovative, more sustainable and more community-centric ways'[21]. The trial involved several components in each of its three phases:

- Engagement

- Remote control

- Gamification

- Reward redemption preferences

**Context and framing:** Given the challenges associated with the all-electric approach adopted by the housing estate developer, it is expected that there are significant financial opportunities to find ways to reduce load at the household level. Participants of the trial included owner-occupiers and tenants of detached houses and apartments in a new housing estate. In the trial, smart plugs were connected to existing devices in participants' homes, including heaters, fans, refrigerators, power boards, enabling remote control and the provision of household-level and device-level consumption data to participants.

The trial was presented to prospective participants as a way 'to create economic benefit for people and save the environment at the same time' and a way of 'putting the environment and the economy together' where, for too long, 'they've been pitted against each other'.[22] Emphasis was placed on the possibility to participate 'without you having to do very much at

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[21] RedGrid Tullamore Trial Phase A report, August to October 2020
[22] RedGrid, trial introduction video, 2020, https://redgrid.io/getting-started-archive-2/ (accessed 4 Oct 2021)

all' and 'let[ting] us do the work on the back end'. Participation was incentivised with the offer of a free-of-charge smart home kit.

**Engagement:** Participants were initially recruited initially via Electronic Direct Mail (EDMs) as well as direct phone calls from the housing developer team with follow-up calls by RedGrid, to funnel interested parties to RedGrid recruitment landing webpages. 4 of the 20 target participants committed to the trial. A significant level of contact between the RedGrid team and the participants was then maintained in the form of emails, phone calls, phone messages and information via the app. Phone calls supported a smooth set-up process for most participants, and one of the conclusions drawn from the first phase is that they 'proved a strong way to develop personal relationships with customers and educate them'.[23]

The trial also tested forms of engagement beyond the initial phase. In Phase B, recruitment by neighbour referral was tested but resulted in recruitment in only one case, which was less than expected. Interest in the 'smarts' web app among a small, targeted subset of the participants was high. The return on advertising investment for SolarBooster service recruitment was described by RedGrid as 'strong', with 52 pre-orders. In Phase C, RedGrid tested the open rate for a monthly analytics report that had been improved based on feedback from the previous trial and found that 63% of participants opened the report delivered via email. There was ongoing interest to continue using the 'smarts' web app among the select group of participants that had started using it in Phase B. RedGrid reported interest from participants in the new 'powers' app but not enough downloads yet to draw conclusions.

**Remote control:** In Phase A, RedGrid trialled the control of household appliances to reduce consumption per device by up to 50%. The automation of household loads in the trial permitted participants to veto their remote control, but did not notify them of upcoming control events, to test the extent to which participants noticed their devices being controlled. It was found that the energy consumption of participants' devices could be reduced by 40%. Participant interviews revealed that most participants had not noticed or been affected by the control. Those who did reported impacts on comfort when heaters turned off and one participant had difficulty turning it back on; on participants' work or schooling, when a powerboard disconnected and Wi-Fi connection and unsaved work were lost, or when a laptop had not charged overnight ahead of the school day. This part of the trial was deemed broadly successful, indicating significant potential to turn off devices without impacts on users.

In Phases B and C, a 'smarts' web app was introduced to 3 of the participants which allowed them to set 'smarts', or the parameters of the remote control of selected devices. This part of the trial was successful for only one of the 3 participants in Phase B. One of the other participants applied a control policy to an appliance that was unsuited unless set with the correct parameters and the other disconnected the powerboard that the 'smart' was applied to over the Christmas period, so the data gathered was limited. In Phase C, remote control successfully continued in two participants' homes.

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[23] RedGrid Tullamore Trial Phase A report, August to October 2020

**Gamification:** In Phase A, the gamification component encouraged participants to respond invitations to participate in events by either manually turning on appliances such as washing machines and dishwashers (during solar soaking events) or giving permission for appliances to be turned off remotely (during demand response events). The SMS event invitations provided event rationale, parameters of event and rewards (as pictured in Figure 8).
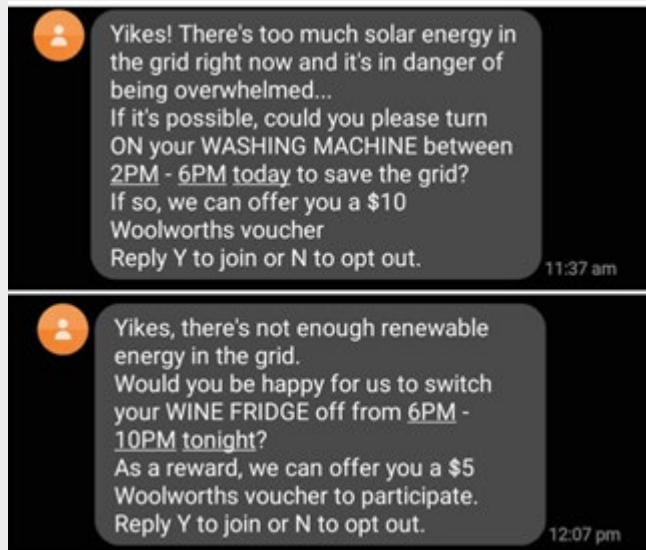


Figure 8: RedGrid Invitations to demand response events (source: Phase A report)

These invitations failed to get significant levels of opt-in participation but in the case of the two participants who accepted the invitation the technology worked, and the targeted energy consumption changes were achieved. Participation depended on availability to respond and, in the case of a solar soaking event, to manually turn on an appliance - which could preclude participants who are not available and ready to do so. One participant also commented that the gamification to reduce consumption could only work if the load was not essential (they needed their powerboard for work).

In Phases B and C, the gamification components were entirely manual. In Phase B participants were encouraged to reduce their energy consumption through a weekly analytics report email that provided the following information (as pictured in Figure 9)

- Individual device analytics

- The total consumption of all RedGrid connected devices

- A daily view of device consumption compared to the previous week

- The % by which a user's total consumption increased or decreased compared to the previous week.[24]

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[24] RedGrid Tullamore Trial Phase B report, November 2020 to January 2021
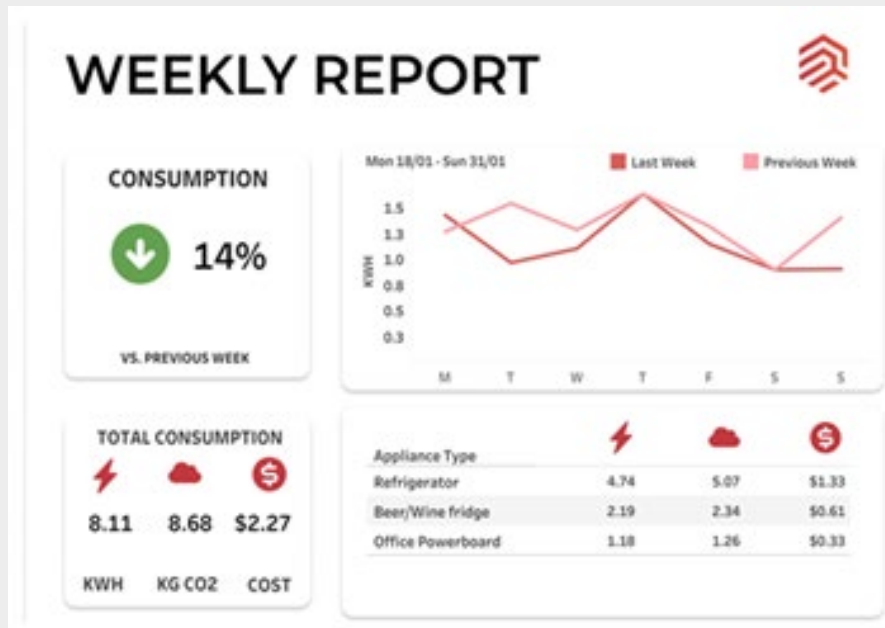
Figure 9: RedGrid Weekly analytics report sent by email to participants in Phase B gamification trial (source: Phase B report)

For the challenge to reduce their energy consumption per device from the previous week, 76% of participants reduced the consumption of the targeted device - although less than half stated in the interview question that they had been motivated to intentionally reduce their consumption. The average decrease in consumption was 68%. Feedback on the weekly analytics report indicated that participants found the information interesting but not particularly useful. Of the three metrics, $, C02 and kWh, cost was considered most useful, and the participants consistently noted that the C02 and kWh metrics were meaningless to them, especially without any point of comparison.

In Phase C, based on this feedback the report was provided only monthly in a different form (Figure 10), and was tested in the engagement component of the trial phase, as mentioned above.

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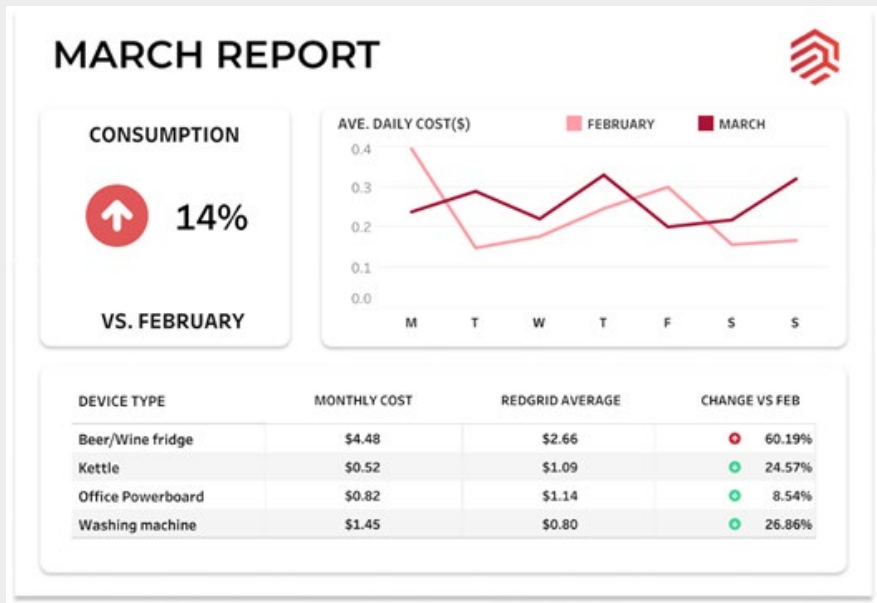


Figure 10: RedGrid monthly analytics report sent by email to participants in Phase C engagement trial (source: Phase C Report)

Phase C trialled invitations to participate in demand response events by turning appliances on (in peak renewable energy periods) and off (in peak non-renewable energy periods) in response to renewables prediction, rewards, and community collaboration incentives. Only 23% of participants shifted their load during tests.[25]

**Incentives:** Phase A tested preferences for reward of voucher, donation, cash or points for smart energy device. Shopping voucher (47%) and contribution to more smart energy devices (35%) were more popular than a donation to an environmental organisation or cash to bank account. Phase B tested whether participants choose to claim rewards immediately or save credit points to use for later smart energy devices. All participants chose reward or accumulation of points rather than cash, and most participants accruing points chose to save them for later. Phase C tested whether participants choose to claim immediate rewards from reward partners or redeem points for cash. 66% of participants redeemed points for rewards.

**Results and implications for a social license to automate:** RedGrid has shown that some households are willing to sign up to remote, invisible control of some household loads. It was demonstrated that 40% of energy use by some household loads can be saved with minimal impact on users, with just a quarter of participants (24%) reporting that they noticed the changes being made. Engagement with manual demand response in the gamification component of the trial was relatively limited. Responses to the web apps and analytics reports suggest that people want to understand their energy consumption, and especially how they can save on their bills and use more renewable energy. The trial results suggest that those solutions that are 'set and forget' – enabling oversight by the user but not requiring active ongoing engagement – may be most appealing to them.

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[25] RedGrid Tullamore Trial Phase C report, February 2021 to June 2021

## ENERGY QUEENSLAND 'PEAKSMART' PROGRAM

*Air conditioning direct load control program*

Energy Queensland's 'PeakSmart' program is Australia's first and largest established, ongoing DLC program, with more than 92,000 household participants and 139,000 connected appliances. Established in 2012, it addresses peak demand by reducing demand of air conditioning units by 25% to 50% – equivalent to placing the unit in 'economy mode' – for 1-2 hours during extreme network demand conditions on several days per year. The units are activated by the DRED technology built into them in accordance with Australian standard AS4755. This is in a context of significantly increasing air conditioning penetration in Australian homes and temperature driven peaks, particularly in residential areas. The rationale for the program presented to participants has been the need to manage peak demand at the local area level (i.e. to avoid local area outages due to fuse overloads).

> "Peak demand is when electricity usage on the network is at its highest, usually between 4pm and 8pm. Every now and then, the network reaches a point of extreme stress, such as during a heat wave, when households and businesses across South East Queensland switch on their air-conditioners at the same time. On these occasions, our innovative PeakSmart technologies are called on to help manage demand. We call this a PeakSmart event."[26]

**Communication and compensation:** A cashback reward is offered for customer participation which can contribute towards a discount on the cost of a new air conditioning unit or air conditioning servicing fee (for retro-fit participation). Participants are not required to do anything, and Energy Queensland expects that participants will not be noticeably impacted by the change to the output of their air conditioning units, which adds to the 'set and forget' nature of this program. While participants are not directly notified of activation events, information is published via the website. Energex/Ergon network call centres as well as industry partners, including installers and air conditioning retailers, are notified directly so that they can respond to any queries from households received during a PeakSmart event. A variety of approaches to recruit participants have been employed over the course of the program. Initially participants were recruited through air conditioner retailers. A disadvantage of this mode was that some customers did not claim their rebate, despite having a DRED installed in their air conditioner, and as such Energex was unable to register the location of the DRED. The second mode of recruitment was through installers who could enrol participants during the installation process, given that installers have considerable influence on householders receptiveness to the proposition. A third approach has been to work with

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[26] https://www.energex.com.au/home/control-your-energy/managing-electricity-demand/peak-demand (accessed 22 Sept 2021)

builders of apartment blocks or housing estates so that participating air conditioning units are sold as part of new-build sales.

**Implications for social license to automate:** This project represents a 'high automation level', as will be discussed in Chapter 8. The User's Interactions with Automation Technologies'. The program is considered successful by Energy Queensland. Quantification of the demand response from the program is reported annually via demand-side participation information to the Australian Energy Market Operator (AEMO). Participant experience surveys are also conducted from time to time, such as after heatwaves during which activation events are held, but are not publicly available. According to Energy Queensland, over one prolonged heatwave, 80% of participants reported that they had not noticed that an event had occurred, and 76% of participants consider the program fair and equitable. In the past the Queensland Household Energy Futures survey results have indicated that 78% of respondents not already in the program would consider joining.

## AUSGRID 'COOLSAVER' TRIAL

*Air conditioning direct load control trial*

**Trial objective:** Ausgrid's 'CoolSaver' trial, which ran from 2013 to 2016, was conducted to test the DR standard AS4755 as a way to offer a flexible air conditioning load control solution to customers. It tested its technical feasibility and costs as well as whether customers would take up the demand response solution and their satisfaction with it. The trial was run over several phases in three local areas of New South Wales: the Central Coast, Lake Macquarie and Maitland.[27]

**Recruitment and onboarding:** Initially 16,141 customers in selected suburbs in the Central Coast and Lake Macquarie areas were targeted through mail-outs, letterbox drops and direct marketing. Interested customers were asked to register with their details about their air conditioning unit, with 1205 (7.5%) registering their interest in the trial program. Of the 1205, only 134 (11%) were found to have an AS4755 eligible air conditioner. Offers were made to 129 of these customers with 112 customers accepting the offer and 109 installations completed successfully.

It was found that, due to the voluntary nature of AS4755, none of the 109 air conditioners were AS4755 compliant 'out of the box' with all requiring site installation of enabling devices. For 16 of the 109 installations, customers had newer models from Panasonic, Samsung and Hitachi where only installation of an AS4755 DRED was required. The DRED operated as a signal receiver allowing remote signals from Ausgrid to the air conditioner. The remaining 93 customers required the installation of the DRED and an additional air conditioner control part from the manufacturer to enable the demand response functions.

At a later stage of the trial, recruitment of participants through purchase of new air conditioning units was trialled in the Maitland area, but resulted in a small number of participant recruitments through these retail partner channels. Higher take-up though was gained in Maitland through retro-fitting customers' existing systems via a local air

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[27] Ausgrid Demand Management CoolSaver Interim Report, February 2017, https://www.ausgrid.com.au/-/media/Documents/Demand-Mgmt/DMIA-research/Ausgrid-CoolSaver-Interim-Report-2017_Final.pdf

conditioning installation company and direct marketing methods. A key learning from this part of trial was that direct mail-out and retro-fit of air conditioning units were more effective than encouraging customers to sign on to the program at the time of purchasing their air conditioning units.

**Communication and compensation:** Participants received advance notification and were able to override the automation in the Central Coast and Maitland areas only. In Lake Macquarie a different type of signal receiver was used where participants were not aware of nor able to opt out of events. Participants were informed that there would be a maximum of 8 automation events per season with events of about 4 hours each typical. The payment structure varied across the phases and geographical areas of the program. Participants received an installation reward upon entry to the program, as well as rewards following each summer. In one phase, participants in the Central Coast, who were given the option to opt out of events, a portion of the total season award was deducted each time they opted out of an event. In a later phase, the rewards offered to participants at the end of each season varied according to the size of their air conditioning unit and were offered only if participants had not opted out of any events.

**Results:** The 2015 participant survey found that in Lake Macquarie, where participants were not notified of the automation event, 90% did not notice a difference in their air conditioning cooling experience on the very hot days. In the Central Coast, on the other hand, where participants received notifications about events, 70% did not notice and a further 25% noticed a slight difference. In the 2016 survey, in Lake Macquarie, 88% of participants didn't notice and 8% noticed a moderate difference; in the Central Coast, 37% didn't notice, 21% noticed a slight difference; 18% noticed a moderate difference and 13% noticed a big difference; in Maitland, 21% didn't notice, 32% noticed a slight difference, 16% noticed a moderate difference and 5% noticed a big difference. Interestingly, participants in the Lake Macquarie area, who did not receive event notifications or have the possibility to opt out of events, did not request either, according to Ausgrid, and had high levels of satisfaction with the program. The participants in the Central Coast and Maitland who did have these possibilities valued them: only 55% of Central Coast and 42% of Maitland participants said that they would participate in a trial that did not offer notifications. Survey results indicated high levels of willingness to continue to participate in subsequent summers.

## AGL PEAK ENERGY REWARDS 'MANAGED FOR YOU' AND SENSIBO TRIALS

*Trials of air conditioning and EV direct load control*

Alongside the large behavioural demand response component of the 'Peak Energy Rewards' program, AGL has conducted two trials of automated DSM.

The Peak Energy Rewards 'Managed for You' trial was launched in 2018 with funding from ARENA, and included the control of air conditioning units and electric vehicles.[28] Prospective air conditioning participants were targeted among AGL's existing customers if they had higher than average energy consumption, high energy use on hot days and were located in the Sydney metropolitan area, and the EV trial participants were recruited from among AGL

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[28] AGL NSW Demand Response ARENA Knowledge sharing report, October 2019,
https://arena.gov.au/assets/2018/09/agl-nsw-demand-response-report-october-2019.pdf

customers on the Electric Car Plan. Participants were paid a sign-up incentive of AUD300 to be enrolled in the program, as well as a AUD30 flat incentive for participation during an activation event. In the air conditioning program, DREDs were installed in 45 houses, which AGL reported proved challenging, with some participants not able or willing to be home during business hours for the installation, and many models requiring supplementary hardware in addition to the DRED. Charging stations were installed in the homes of the EV participants.

Ahead of the 2-hour activation events, air conditioner participants were notified of the event start and end times and offered the option to opt out by email, but were not able to directly override the control at the air conditioning unit – which AGL notes as a shortcoming of the trial.[29] The EV participants were similarly notified and given the option to opt out via the Chargefox app. In addition to the challenges of installing DREDs in air conditioners, AGL found that the responses of the air conditioners to the standard control commands also varied, and were not easily verified from consumption data. It was concluded that remote control of already installed air conditioning units is not viable. The EV control events were more successful, shifting significant load from peak periods with no reported inconvenience to the participants and very high levels of reported satisfaction with the trial.

In 2020, AGL commenced trials of remote control of air conditioning units via the Sensibo smart plug device, valued at AUD159, which was offered free of charge to incentivise participation of AGL customers with eligible split-system units. Initially it has involved events of the format employed in the broader Peak Energy Rewards program, i.e. called one day in advance and 2 hours in duration. Participants need to opt in when contacted about an event. During the event their air conditioner is adjusted by no more than two degrees and participants are able to opt out by adjusting the settings through the Sensibo app. Research with participants has been conducted to explore willingness to participate in 'spot' events, with no advance notice, of varied event duration (5, 10 or 20 minutes) or event frequency (3, 5 or 10 per year); no significant differences in the levels of take-up among the offerings were found. Price testing of Sensibo devices with different levels of discount has also been conducted and found that conversion is very strong at AUD29 and strong at AUD69.

## AUSGRID VPP TRIAL

*A battery Virtual Power Plant trial*

Ausgrid's battery VPP trial commenced in 2019, with an initial partnership with provider Reposit Power and later expansion to include partnerships with providers Evergen and ShineHub. As of September 2021, there was a combined total of approximately 750 battery customers in the trial across the three VPP providers, with a total storage capacity of 7.3 MWh and a discharge power capacity of 3.4MW.

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[29] AGL NSW Demand Response ARENA Knowledge sharing report, October 2019,
https://arena.gov.au/assets/2018/09/agl-nsw-demand-response-report-october-2019.pdf

The VPP was presented to prospective participants as an investigation of means to integrate DER, make the grid more efficient, and achieve cost savings for participants. The people who have signed up may be described as early adopters who are interested in technology – although, interestingly, when asked what level of knowledge they have about VPPs in an onboarding survey of participants who joined the trial with one of the providers in 2020, most responded with either 'moderate amount' (39%) or 'very little' (31%)[30]. Participants were notified of upcoming events, but had no option to opt out of a particular event but have the opportunity to leave the trial at any time. Almost all participants stated in a survey that they found receiving a notification about the event useful (92%), mainly to be kept informed about when they received a credit or to know if the operation of their battery system would change.

When customers of one of the VPP providers were surveyed about how concerned they would be if their battery was discharged down to its minimum level during a dispatch, just over half said they would either not be at all concerned or a little concerned (58%). Out of the remaining 42% who said they were reasonably to very concerned about this, they wanted to know if they still had control over the battery settings or were concerned that they would not have enough stored energy to power their own home's needs'.[31]

## AGL VPP TRIAL

*A battery Virtual Power Plant trial*

AGL's South Australian battery VPP trial commenced in early 2017 with the core objective of 'demonstrat[ing] the role of distributed 'smart' energy storage in enabling higher penetrations of renewables in the grid'[32] through the installation and orchestration of a 5MW VPP capable of dispatching 12MWh of energy stored in up to 1000 residential batteries[33].

The majority of the trial participants could be characterised as tech-savvy 'early adopters'[34]. They also were more wealthy and more educated, with a high rate of home ownership, than the average household in the trial location of Adelaide. To be eligible for participants, participants were required to purchase an energy storage system and give up their existing premium feed-in tariff if they had one. To incentivise participation, a discount of AUD2000-

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[30] Ausgrid VPP Progress report Nov 2020 https://www.ausgrid.com.au/-/media/Documents/Demand-Mgmt/DMIA-research/Ausgrid-Battery-VPP-Progress-Report-November-20.pdf?la=en&hash=CD5DB4BD9905EE50AD63FC8EFB13BC51267569D4 (accessed 2 Oct 2021)

[31] Ausgrid's Virtual Power Plant, Progress Report, November 2020, https://www.ausgrid.com.au/-/media/Documents/Demand-Mgmt/DMIA-research/Ausgrid-Battery-VPP-Progress-Report-November-20.pdf (accessed 2 Oct 2021)

[32] AGL Virtual power plant in South Australia, Stage 1 Milestone Report, 31 July 2017, https://arena.gov.au/assets/2017/02/VPP-SA-Public-Milestone-1-Report-Final-for-issue.pdf (accessed 2 Oct 2021)

[33] AGL Virtual power plant in South Australia, Stage 2 public report, June 2018, https://arena.gov.au/assets/2017/02/virtual-power-plants-in-south-australia-stage-2-public-report.pdf (accessed 2 Oct 2021)

[34] AGL, Virtual power plant in South Australia, Stage 1 Milestone Report, 31 July 2017, https://arena.gov.au/assets/2017/02/VPP-SA-Public-Milestone-1-Report-Final-for-issue.pdf (accessed 2 Oct 2021); interview with AGL

3000 off their battery purchase. There were also some participants who joined with an existing battery, and for them up to AUD280 in bill credits were offered. For participants who brought their own battery to the program, there was an upper limit of 30 automation events per year; for participants who purchased a battery upon entry into the program, there was not a limit. The participants were not notified of activation events – although they were able to view the status of their battery via AGL app – and were not able to veto events.

Participant satisfaction was found to be high: 60% of respondents in a customer satisfaction survey had a positive experience and would promote the VPP. Approximately 25% were neutral, and approximately 15 were negative.


## SOLAR ANALYTICS VPP STUDY

*Study of willingness to participate in a hypothetical Battery Virtual Power Plant*

Solar Analytics conducted a study, in partnership with UNSW, Greensync, and NSW DNSPs Ausgrid, Essential and Endeavour, of willingness to participate in a battery VPP.[35] The participants included Solar Analytics customers with existing solar systems and monitoring, as well as some participants with solar systems but not monitoring, and some with neither. Only a small proportion of all participants have a battery. The VPP was described in the following terms to the participants:

> 'A VPP groups together solar, batteries and other energy resources in multiple households and uses the energy when it is needed most - either selling the energy into the National Electricity Market or supporting grid security and stability, just like a conventional power plant. For example, VPPs could play a role in responding quickly to unexpected disruptions in the electricity system. Your battery would be used as part of the VPP and you would get a share of the value generated from that.'

The participants were then shown different participation and compensation options and discussed the advantages and disadvantages of them. The participation and compensation options gave the participants the option to access greater compensation in return for greater access to their battery – as represented in several factors such as number of activation events per year, the proportion of the battery capacity discharged in VPP events, and whether participants may opt out of specific events. The study therefore explored their views on the trade-off between battery access and compensation.

The study found that most participants were interested to learn more and would consider participating in a VPP, but required more information and their willingness to participate was conditional on transparency and the opportunity to opt out of events, in particular. Given that the energy independence and security were the main reasons for interest in having a battery

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[35] VPP User Research Final Report (2020) https://userstcp.org/wp-content/uploads/2019/10/VPPUserResearch-FinalReport-20201127r.pdf

among the participants, the idea of a VPP required a significant conceptual shift for those who have already invested in solar and are considering a battery to those ends. On the other hand, people who do not yet have solar or batteries appear to be more receptive to the different functions that these DER can serve, such as participation in a VPP. Further, many of the reasons that the participants gave for being interested in participating in a VPP were related to its community, environmental and grid benefits. They tended to appreciate and respond to the challenges of the energy transition to which VPPs are a part of the solution.

## 2.3 Lessons learned

**Key findings from case studies and survey analysis**

- **Successful recruitment depends on a shared understanding of and commitment to addressing problems of the DSM program.** Our findings broadly align with other countries here. Users want to understand not only their own private benefits, but also the wider environmental and common benefits to which their participation will contribute.

- **The case studies in Australia have largely framed automated control as an 'end-of-pipe' solution** to detached households requiring appropriate incentives. This can be contrasted to many European projects set amongst cooperative and shared housing, such as control over hot water and other heating systems. Automation in Australia is framed as delivering efficient and cost-effective energy (per the National Energy Objectives). However, as in other countries, the wider benefits are crucial to user participation and tend to be undersold. The cases presented here could be understood as experiments in creating appropriate frames for public and private benefits through both incentives and communication of the benefits of grid stability, etc.

- As in other countries, trials with high levels of automation (see Chapter 8. The User's Interactions with Automation Technologies') in Australia have overwhelmingly involved early adopter participants who are male, 30-60 years old, highly technically literate and techno-optimistic. This very specific cohort should be understood in the context of the survey analysis which suggests different experiments may be required to gain the trust of less techno-optimistic participants.

**Policy recommendations**

- **For federal regulatory agencies:** AEMO should include measures of trust, reputation and other social metrics in its annual Statement of Opportunities.

- **For DNSPs:** Continue building programs to engender trust with consumers, including, but not limited to deliberative forums that many DSOs regularly undertake to test assumptions about the value of network expenditure.

- **For users:** There are emerging consumer rights issues associated with automated control over batteries and electric vehicles. Our findings suggest accountability for issues caused by third party control over DER may need addressing.

**Future directions**

Trust, social license, and reputation are now explicitly considered in current policy discussions. Recommendations in a variety of settings, including the Energy Security Board, and AEMO reporting make this explicit. Such recommendations are often framed around energy user acceptance in the abstract. However, there is an especially pressing need for **many more diverse participants in automation trials.** Such diversity includes household types, cultural and linguistic backgrounds, genders, housing settings and urban settings. Furthermore, explicit reporting of social dimensions in trial data, rather than simply technical parameters, would better aid in future research. Such reporting should be developed with expert social scientists, but may include gender, age, income bracket, postcode or similar data.

# 3. Austria

- Austria is distinctive in that many automation trials are embedded in more communally owned and run housing ('Erneuerbare Energiegemeinschaften', EEG); however, the social benefits of automated programs tend to be undercommunicated.
- Austria has had a lot of renewable production through hydropower plants, but it is expected that the number of DER such as PV and wind will increase substantially. Especially the amount of needed redispatch for solving grid congestion is growing steadily over the past years and there are efforts from distribution and transmission grid operators to expand the usage of distributed flexibility to solve these problems.
- Historically DSOs have already been using flexibility to solve grid congestion and voltage problems by ripple control; for instance, there are interruptible tariffs for heat pumps available in Austria. Several research projects about demand side management are being carried out at present, including control of DER by DSOs or aggregators by participation at spot and balancing markets. Some aggregators have already achieved a prequalification for participation at balancing markets for some devices, such as boilers. Also, the number of energy communities is increasing over the years and regulatory changes, such as reduced grid tariffs, are being made to enable the emergence of energy communities.
- As can be seen in other countries, the main drivers for increasing need for flexibility are the ongoing energy transition and digitalisation. This leads to a substantially increasing amount of research on this topic.
  - Industries and utilities are more and more involved in flexibility projects. Bigger companies, some also with their own production units, are already participating at balancing markets or are optimising their consumption to day-ahead prices. The aim is to make this more and more practicable for smaller industry units as well in the future. For instance, there are currently efforts in Austria to enable industry to participate in a redispatch procurement process as well, to offer their flexibility for DSOs and TSOs.
  - Although the increase of potentially flexible units such as electric vehicles, heat pumps, boilers or batteries is gaining momentum, a lot of these devices cannot yet be automated, because of the lack of digitalization. The missing incentives and value of household flexibility and the lack of business models is reinforcing this situation. Still, there have been changes in regulatory framework conditions in the past years, which should lead to an increasing use of flexibilities in the upcoming years.
  - Aggregators, DSOs and TSOs are expected to gain importance in the next few years in Austria in terms of flexibility use.
  - User acceptance must be strengthened and the understanding of the users for the need and the rationale of household flexibility for the grid will play an important role

## 3.1 Context for automated DSM

**Population and housing**

Austria has 8.93 million inhabitants as of 2021. In 2019, around 58.5% of the population in Austria lived in cities. The so-called urbanisation rate thus reached a new height, having already risen only slightly but steadily in each of the previous years. In 2019, 45.8 percent of the population lived in detached houses; 7.5 percent in semi-detached houses; and 46.1 percent in apartments. 55.2 percent of the Austrian population owned their homes, and 44.8 percent lived in rental properties.

The state and third sectors are substantial housing providers. These forms of collective ownership enable innovative partnerships such as the Flex+ project examined below. The number of social housing projects differs a lot between federal provinces. Vienna is a pioneer and has the biggest share of council housing, with 31% percent of people living in that type of housing. It started in the time between 1918-1934, where the social democratic labour party was elected repeatedly, and continued from the end of the second World War 1945 until today. The most recent projects are 'Seestadt Aspern' (a combined housing, business precinct north-east of Vienna)[36], 'Northern Railway Station' and 'Sonnwendviertel'[37]. These developments have sought to – or are seeking to – realise the vision of 'smart cities'.

Outside Vienna, there are also many apartments owned through cooperatives. Since a lot of those social housing facilities can be dated back to the 20th century, they are very difficult to automate and it seems that there are limited concerted efforts to achieve this. However, there are already many builders who are trying to set up innovative concepts within the framework of cooperative or council buildings (for instance, there are a lot of innovative projects realised in Seestadt Aspern).

**Energy mix**

The share of renewable energies at the gross final energy consumption is already quite high, when compared to the rest of the European Union. Austria sits in 5th place (after Sweden, Finland, Latvia and Denmark) for highest renewable energy consumption[38]. Gross electricity consumption has the highest share of renewables within the European Union, and Austria sits in third place of renewable energy in transport fuel consumption. The transition to electrified and renewable-powered domestic heating and cooling remains slower than the

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[36] The 5bn Euro 'smart city' precinct is projected to house 25 000 residents https://www.aspern-seestadt.at/en Siemens, a partner in the project, states: "[having Austria run on 100% renewables] will require the optimal interplay of smart buildings, smart users, smart grids, and information and communication technology for data collection and integration across all domains. The development of end-to-end solutions for perfectly coordinated building management will also lead to the optimized and transparent use of energy by all systems in the building. This will in turn make a key contribution to the energy transition."
https://new.siemens.com/global/en/company/topic-areas/smart-infrastructure/smart-cities/aspern-seestadt-future-blueprint.html
[37] https://corp.at/archive/CORP2011_242.pdf
[38] Energie in Österreich 2020 https://www.bmk.gv.at/themen/energie/publikationen/zahlen.html Exports/imports of electricity from Austria are not considered as renewable energy
https://ec.europa.eu/eurostat/documents/2995521/10335438/8-23012020-AP-EN.pdf/292cf2e5-8870-4525-7ad7-188864ba0c29 (accessed 21 Sept 2021)

rest of the EU. Just 34% of homes use heat pumps and similar technologies, compared to Sweden, with 65.4%.



Electricity production by source, Austria
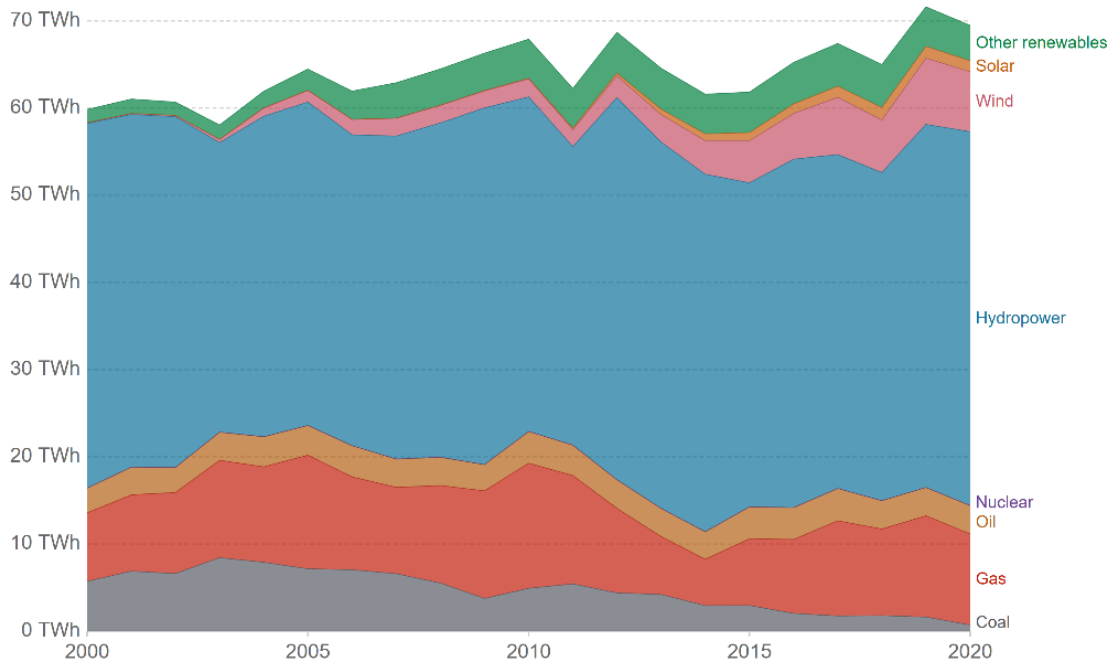
Source: Our World in Data based on BP Statistical Review of World Energy & Ember (2021)
Note: 'Other renewables' includes biomass and waste, geothermal, wave and tidal.
OurWorldInData.org/energy • CC BY



Energy consumption by source, Austria

Primary energy consumption is measured in terawatt-hours (TWh). Here an inefficiency factor (the 'substitution' method) has been applied for fossil fuels, meaning the shares by each energy source give a better approximation of final energy consumption.
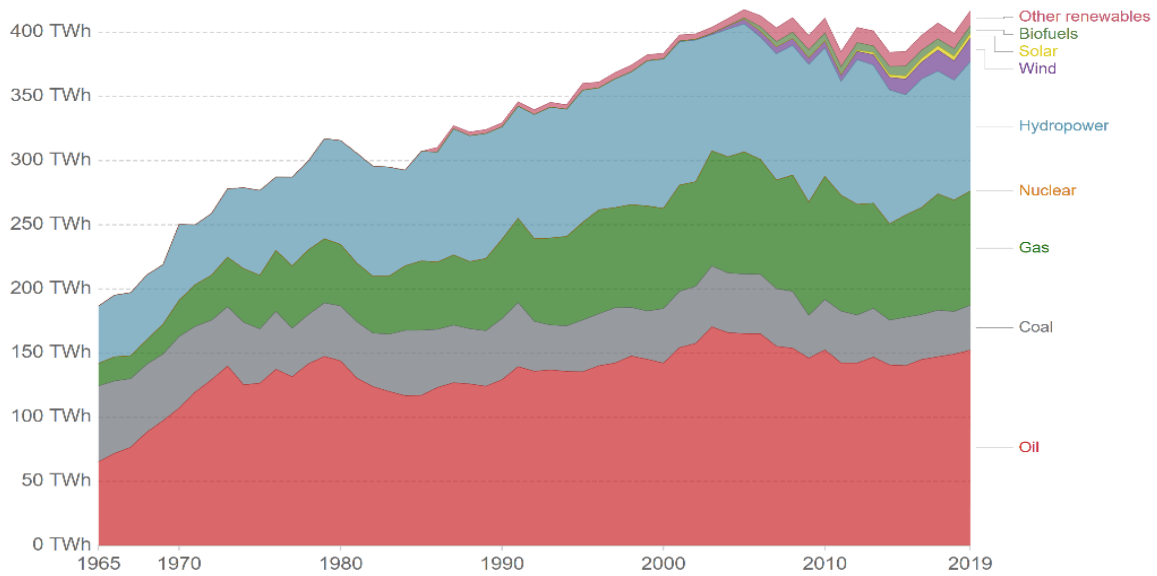
Source: BP Statistical Review of World Energy
Note: 'Other renewables' includes geothermal, biomass and waste energy.
OurWorldInData.org/energy • CC BY

**Challenges in the energy system**

One of the central energy and climate policy goals of the federal government is to convert the country's electricity supply to **100 percent electricity from renewable energy sources (national net balance[39]) by 2030**, and to make Austria carbon-neutral by 2040. The potential associated with hydropower has already been largely realised, however, to reach this target, an increase of 13% of hydropower by 2030 is planned. Significantly more potential lies in projected increased wind farm (167%) and PV power plant (786%) capacity by 2030. This means that the annual electricity generation from renewable energy is to be increased by 27 TWh by 2030 in total, taking into account strict ecological criteria, with 11 TWh to be accounted for by PV, 10 TWh by wind power, 5 TWh by hydropower and 1 TWh by biomass. In addition, investments for existing and future renewable gas generation plants are to be ensured and the share of nationally produced renewable gas in Austrian gas sales is to be increased to 5 TWh by 2030.

Demand-side programs are primarily stimulated through the EU level Clean Energy Package discussed below. The Renewable Energy Expansion Act (EAG)[40] 2021 is intended to create the necessary legal and organisational framework and a stable climate for long-term investments. One aspect is to encourage the formation of renewable energy communities, which indirectly enhances the usage of demand-side management to optimise self-consumption within the community.

**Automated DSM**

According to a recent survey commissioned by the national government regulator for electricity and natural gas markets E-Control, electricity is perceived as important among the Austrian population. 90% of the participants perceived themselves to be active decision-makers in this context and 83% were familiar with the concept of smart meters, although many do not have a clear picture of the stakeholders involved in the electricity market and their responsibilities. 83% indicated that they would like to understand their consumption better and 64% showed interest in time-based tariffs. An older survey[41] further indicated that there is a notable interest in smart homes (51%) and support in energy management (47%) and further interest in taking on the role of the prosumer (42%). Looking specifically at privacy-related concerns and requirements in the smart grid context, Austrians show a high awareness for privacy relevancy with perceiving a risk that data is used to learn about user habits (60%), concerns regarding having no control over data and a risk of the data being used for break-in purposes (54), the risk of data manipulation (52%), and the risk of data

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[39] Renewable energy generated by terrawatt hours equal total consumption in Austria, allowing some fossil fuel imports at certain times
[40] https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=20011619
[41] Diamond, L., Fröhlich, P., Schrammel, J., Röderer, K., Reisinger, M., & Tscheligi, M. (2016). Smart Grid Anwendungen für EndnutzerInnen: Bestehendes Interesse und Erfolgsfaktoren [Poster]. SmartGridsWeek 2016, Linz, Austria.

selling (51%). For the communication of protected privacy, data-related control options and transparency are particularly important.[42]

DSOs have been involved in an increasing amount of research projects in the last few years. With the Clean Energy Package (§ 32) the regulatory framework has been set for the DSOs, to encourage them use even more distributed flexibility for solving congestion and voltage problems, and to reinforce the DSO-TSO interaction. This interaction will prevent flexibility activations by the TSO from causing congestion on the DSO level. An expert working group at Österreichs Energie ('Kaskadierte Netzführung und Aktive Verteilernetzführung') is targeting this topic with involvement of all required stakeholders. Household flexibility is also considered for the future, but there is still some lack in optimisation and digitalisation tools, the coordinated activation of flexibility requires a lot of effort at the moment which leads to the fact that it might currently not really be monetarily feasible. Self-consumption optimisation or the usage of flexible tariffs, either manually, semi-automated or fully automated, will be easier to implement. Interruptible tariffs can of course lead to a loss of comfort as well as rebound mechanisms on the grid, more complex optimisation algorithms for instance for balancing are tested only in research projects at the moment. The use of small household components for the utilisation for more complex grid applications will still require some years of extensive research.

There are two different systems for the market, one is price-based (for instance, the day-ahead market), where the deviations to the traded schedule are automatically billed afterwards via the imbalance settlement costs. The second one is balancing reserve, where power is reserved for frequency stabilisation. In the case of an activation of the component, the component has to fulfill the power demand/generation and has to give proof that the power has been activated specifically for that balancing call. In the case of not being able to provide the power, there is the threat of fines and market exclusion.

Market participation in balancing markets is possible for producers who can offer a minimum limit of 1MW. For smaller participants or DSM components the participation is possible only if several components are pooled in a way that they can reliably offer the minimum bid sizes together.

The Clean Energy for all Europeans Package[43] states that the consumers are a central part of acquiring the flexibility needed to adapt the electricity grid to variable and distributed renewable electricity generation. It states that a discrimination-free market has to be guaranteed which reflects the real supply and demand. Moreover, DSOs should become more responsible to procure flexibility services in their area to improve efficiency in the operation and expansion of the distribution network.

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[42] Diamond, L., & Fröhlich, P. (2021). Communicating Privacy: User Priorities for Privacy Requirements in Home Energy Applications. IFIP Conference on Human-Computer Interaction, 665–675; Döbelt, S., Jung, M., Busch, M., & Tscheligi, M. (2015). Consumers' privacy concerns and implications for a privacy preserving Smart Grid architecture—Results of an Austrian study. Energy Research & Social Science, 9, 137–145.
[43] European Commisson (2021) Clean Energy for all Europeans package https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en (accessed 24 Sept 2021)

As an incentive for small users to participate, innovative flexible tariffs are required for them. These are only available on the Austrian market to a small extent but are increasingly offered by more influential suppliers as well.

Further marketing opportunities and remuneration models are currently investigated within different research projects. The regulatory context in Austria also strongly focuses on enabling P2P trading within energy communities and research projects are carried out in which DSM is also used in this context. Reduced grid tariffs can already be used for energy produced and consumed within a community. This enables more renewables within the grid, and through the motivation to consume the energy locally, it also bears additional incentives to use flexibility. Another topic of the right usage of flexibility, especially in terms of interaction between the TSO and DSO, is targeted in several research projects. In addition to the question of whether flexibility is better used on markets or for voltage problems, there is also the question how to prevent undesirable physical states of the grid (if everyone is buying when the price is low).

Flex+ and the other Austrian projects introduced below give insights to some typical challenges for the usage of small flexibilities for bidding at markets:

- Planning a demand schedule for small components (in the case of a variable tariff, for instance) is very difficult, because it relies a lot on forecasts and the user's behaviour. If done badly, the electricity bill could be even higher than before the automatisation. This of course is very dependent on the chosen tariff design and does not apply for all remuneration schemes and technical use cases.

- The prequalification process for balancing markets needs certain technical requirements and the evidence of a so-called 'baseline'. The baseline helps the TSO to prove the activation for balancing, detailed measuring data and a baseline concept is required for that.

- Technical requirements for the IT-infrastructure are very high in terms of amounts and level of exchanged data as well as privacy and data security aspects.

**Typical use case for flexibility**

**Energy communities:** In renewable energy communities ('Erneuerbare Energiegemeinschaften', EEG) several members (e.g. households, municipalities or commercial enterprises) join together to share electricity. A PV system is mounted on one of the buildings and the participants can use the self-produced electricity. For the implementation of a renewable energy community the spatial proximity to the electricity production is important. Citizen energy communities ('Bürgerenergiegemeinschaften') are a group of people or households who join together to benefit from joint electricity use. The spatial proximity to the electricity production is not mandatory for this model. Thus, participants can also participate who, for example, come from different federal states. In Austria for instance 'E-Friends' is offering this concept: prosumers do not have to rely on

feed-in tariffs for their PV or only on the current spot market prices, but can also trade their electricity to other participants of E-Friends within the whole of Austria at self-defined prices. Certain flexibility markets, such as EEG direct marketing of PV and minimisation of balancing energy costs, as is in Germany, are not possible in Austria due to the subsidy and market design compared to other markets.

**Local voltage problems:** There are discounted tariffs for interruptible loads (e.g., heat pumps) that are typically switched at fixed times or interrupt power purchases in the event of grid problems. Currently these do not consider current market prices or customer self-interest/comfort limits.

**Day-ahead market oriented prices:** On the other hand, there are time-dependent tariffs with flexible, often monthly prices, which allow consumption to be adjusted to the electricity price and thus create an incentive to reduce load during peak load periods and consume during periods of high production. For example, aWATTar is a pioneer in Austria for flexible tariffs and offers an hourly tariff based on hourly spot prices to customers with smart meters. However, there is no compensation for balancing energy and no marketing on an intraday basis yet. Moreover, suppliers are quite restrictive and there is currently no option to take two different suppliers and for instance a flexible tariff for the flexibility and another tariff for non-flexible loads. Two tariffs and two meters are possible regarding some suppliers.

**Balancing reserve market participation:** During the research project Flex+ a heat pump pool and a boiler pool have been already prequalified for the balancing energy market in Austria. Currently, this has to be done separately for every manufacturer and every kind of device. Within the iWPP-Flex project, the use of heat pump flexibility to the day-ahead electricity market and the tertiary control energy market was evaluated as economically positive for Austria, but only under the condition that the costs for ICT integration are low. The Austrian transmission grid operator APG is working on a flex-hub, where flexibility from household components should be able to be offered at different markets through a common platform.

**Minimisation of imbalance settlement costs:** Further application possibilities are being investigated within the framework of various research projects. The MBS+ exploratory project investigated whether private PV storage systems can contribute to reducing schedule deviations in a balance group. Initial results show that there is potential even without management of privately owned PV home storage by the balance group manager, and despite that, PV storage systems can thus make a relevant contribution to reducing the balancing energy demand of a balance group. In the EcoGrid EU project, a dynamic, innovative 5-minute market was simulated and the extent to which heat pumps and boilers respond dynamically to it was tested. It was shown that highly dynamic price fluctuations are difficult to control - especially if there is a short-term feedback between price and flexibility (e.g. if the transmission system operator specifies dynamic prices for the balancing energy costs of the next minutes). As the results show, ideally - at least in the first development step - the existing markets should be used for the integration of prosumer flexibility.

**Digitalisation**

In 2014, Austria committed to equipping 80% of Austrian electricity customers with smart meters by 2020, and 95% by 2022. In the 2019 'Report on the Implementation of Smart Meters in Austria', the percentage of households with smart meters was 15.4% (or 950,000 out of 6,200,000). The efforts of grid operators to increase this uptake are gaining momentum, however, it is still safe to assume that Austria will not reach the set targets. The latest figures, from E-Control, estimates 28% uptake across households for the year 2019.

The status of the roll-out varies a lot between grid operators. While a few grid operators have already completed the roll-out and more than one-third of grid operators have started a major, nationwide installation of smart meters, the majority of grid operators are not meeting the roll-out targets of 80 percent by the end of 2020 and 95 percent by the end of 2022 imposed in 2017.[44]

Concerning the opt-out option, the legal text formulates the deregistration from the smart meter in a vague manner: 'Within the framework of the specifications for the installation of smart meters determined by the ordinance, the network operator shall take into account the wish of an end-consumer not to receive a smart meter'.[45] If more than 5% households opt out of smart meters, this may emerge as an issue.

## 3.2 Case studies

**FLEX+**

**Participants:** 877 homeowners surveyed, 37 participants of demo, Austria-wide. Mostly living in detached households in rural areas. Knowledgeable prosumers, 30-60 years old, about their own energy use and issues facing the energy system. Relatively high technical affinity, environmental awareness.

**Automation objectives:** Develop technologies to address **frequency/balancing markets and peak demand**. The aim of the project is to participate in spot- and balancing markets by aggregating automated control over household heat pumps, boilers, batteries and e-mobility. The aim is to enhance grid stability by creating more balancing capacities and shift demand to times with high production/low prices. All components are fully automated; apart from setting comfort limits, no active participation/involvement of the prosumer is required. Manual override only occurs through changing setpoints. If the temperature exceeds the comfort limits, there is a fall-back mechanism which overrides the optimised schedule. Otherwise, the comfort limits can be changed at any time during the day.

**Use case context and framing:** At the beginning of the project, there was a survey within Austria (with 877 participants), about potential customers of the DSM concept. Survey participants are in regions with a reliable grid, and most participants are male (88%), aged

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[44] https://kurier.at/wirtschaft/ziele-fuer-smart-meter-rollout-werden-um-jahre-verschoben/401444980
[45] §83 (1) ElWOG 2010

30-60, and have received higher education. Their self-estimation of knowledge about their own household electricity consumption is very high. 32% of respondents know about flexibility prosumer networks; they have high technical affinity and environmental awareness.

For the demonstration, participants were either existing customers (heat pumps/boilers) or employees (batteries/e-mobility) who were willing to participate in research projects. The customers were told that the components would run when grid capacity is available. Green aspects, contribution to the energy system transition and scientific research and saving of costs were mentioned as well, they were told it is not a final product. It was mentioned that some restrictions could evolve within the testing period (e-mobility charging restrictions, lower temperatures water/heating, higher costs for batteries). Some of them had to change their supplier, but otherwise no change in energy practices was required. For recruiting, it turned out to be useful to have physical meetings, such as tenant gatherings (boilers, during a renovation project). Gatherings and person-to-person talks, where the potential prosumers can ask questions about their concerns and details about the project, lead to a high participation rate (22/31). For the heat pump pool, people were addressed with a postal letter, but there was little response. People stated that they did not have time to read it. By phone calls, more people could be convinced (24/170). For the battery and e-mobility pool, workshops were conducted to discuss technical details; the sign-up rate here is unknown.

**Actors involved and relevant regulations:** There are suppliers involved which oversee the trading of the aggregated amounts of energy of the component pools. Each component has its own schedule because of the optimisation, these schedules are aggregated, and the supplier is buying these amounts at the spot-markets or selling amounts at the balancing markets. For participation at balancing markets, the components must be pre-qualified, which means that the components have been able to prove, that they can react within the required amount of time, can follow a profile and that there is backup concept, so that the flexibility can really be provided when needed, otherwise fines must be paid to the TSO. In Austria there is the possibility to offer variable prices as a supplier, which are following the spot markets. Therefore, a smart meter has to be installed at the customer's home. There is even a rule that each supplier has to offer at least one flexible tariff. Between the supplier and the prosumer are the component manufacturers, which pool the information of all components and run the optimisation for generating schedules. The information exchange between the pools and the suppliers is done by an extra platform, which provides APIs to get and send data, and an IT provider is involved in the project for this purpose. Contracts have been established for demonstration participation, but beyond that all participants have the regular contract between customers and supplier.

**Parameters of automation:** The automation within the project is 'full' in that it requires no active user involvement. A schedule for each component is calculated for the next 24 hours, which considers spot- and balancing price forecasts, upper and lower temperature limits, time for leaving the charging stations for e-mobility, charging state of the battery and weather forecasts (PV production for battery self-consumption, irradiation and outside temperature for building model/heat pump). Participants can adapt the temperature during the day, and fall-back mechanisms are implemented if temperature limits are violated. Prosumers will be able to adapt the comfort limits via apps within the future; however, within the demonstration there are no apps available for this purpose. Ideally, the customer should not notice any comfort limitations, but since it is only at the testing phase, such impacts may appear during the demonstration. There are no additional time limits for activation specified (except boilers, which only can be loaded during the nighttime), and there is no advance

notice period for customers, since the whole schedule is calculated at once and considering all necessary aspects.

**Incentives:** There are monetary incentives offered for each component pool, but the participation was also strongly motivated by being part of a new innovative concept for the renewable energy transition. Technically interested prosumers, who accounted for a high proportion of participants, were able to access a lot of information about the 'green' concept and their contribution.

Monetary incentives were:

- Reduced electricity bill (boilers)

- Vouchers and/or reductions on the electricity bill amounting to €50-300

- Batteries and charging stations have flexible tariffs (possible cost reduction)

- €100 to compensate possible financial losses during the demo (batteries)

Other incentives:

- Yearly evaluation of their electricity consumption (prosumers with boilers)

- Possibility to keep installed equipment

The supplier aWATTar offers prices oriented at spot market prices (real-time pricing). The other cost savings during the demonstration are not given to the prosumers; the monetary incentives listed above are offered instead. There are no business cases developed yet.

**Interaction with users:** Apps have been either developed within the project or modified from existing apps. The apps give the possibility to see the planned/run schedule of the component, and customers also receive feedback when the balancing energy has been offered, at which time it has been activated and what the monetary revenues have been. Settings such as comfort limits should be able to be changed within the app and have been set at least once. There is no other active participation of prosumers necessary. All the aspects have been realised within the demo, and the apps have been tested within workshops. They will not be used during the demo. Customers can call the manufacturer if there are any problems during the demo, but so far only single days have been tested, the customers have been notified beforehand. By setting the comfort limits, the customer can indirectly decide how big the impact of flexibility activation will be.

**Data management:** The component status (temperatures, charging state, etc.) is sent to the component manufacturers, which do the pooling and calculation of schedules by optimisation. The type of individual connections is realised differently for each component pool and is unknown. There is a unified rest API connection from component manufacturers to the flex+ platform, which transfers data from and to the supplier. The supplier only has access to the aggregated power demand of each pool, but not on each single component. The activation of balancing power in case of a call is also done via this platform, and direct access to the component is only possible by the component manufacturer. The connection between component manufacturers and their components was already availability prior to the project start.

**Project results:** The demonstrations are running at present. There are still some technical issues, for instance inaccuracy of the models, so that more or less has been heated than needed, and temperature limits, which have been violated. All in all, the concept is working, but forecast deviations can lead to problems. There has been no evaluation of the demos with customers; only the recruitment phase has been evaluated. In-person contact with housing association members and participation of a whole community is far more successful for recruiting than postal letters or e-mails. Technical affinity leads to a higher interest and participation rate. Not only monetary incentives lead to participation, but also sustainability reasons and curiosity about new concepts.

## LEAFS

**Automation objectives:** The aim of LEAFS was the activation of flexibility using direct or indirect control by the local grid operator, or incentives and manual load control. The users benefit from more flexible integration of DER at minimum network reinforcement costs as well as achieving a higher self-consumption levels. The fluctuating generation of decentralised generation units and the intelligent usage of flexible loads switched by the customer itself or by intelligent devices were tested in field trials in order to investigate the optimising potential of low voltage grids. The incentive was a 'Sonnenbonus', or 'sun bonus', during hours in which irradiation is > 600W/m^2.

**Use case context and framing:** There were different demonstration regions where different use cases were tested.

- UC1 Köstendorf: Automation was carried out within the demo region Köstendorf, where PV-BESS combinations of households were automated. The DSO had no direct control of the component; there were just setpoints provided for the CEMS. Customers were not meant to notice anything, and there was no additional social research for this demo case: it was just on a technical level.
- UC2 Heimschuh: In another region a central battery energy storage system was established, and no information about the prosumers was available. Smart meters had to be installed there, and 10-15 customers indicated that they would have been interested in a follow-up project.
- UC3 Eberstalzell: This demo offers a wide range of results: mainly manual DSM was tested there, but also a small trial of automated load switching. If not otherwise indicated, all of the following information comes from the field trial in Eberstalzell.

The demonstration region provides a reliable grid and has already been used as the test area of previous demos. It is a very rural area and the majority of homes are single and double family houses. There is a lot of PV (for years it had the biggest PV share in Austria), around 1000 households, a lot of young families, and a lot of people are also at home during the day. The residents already have knowledge about this topic through prior projects in this region. The contact with participants was established through postal information. 250 households signed up for the program (~1/4 of households); 200 were active; and there was a post-survey with 185 households. The rationale communicated to users was to consume as much of the produced electricity locally, by actively shifting their consumption to the production hours. The rationale in this sense was not deepened to include why, for instance, it should be consumed locally, but there were not any concerns raised by the participants.

For the manual load-shifting, there could be a lot of participants. The automated load switching constituted a small part of the project, but communication was quite poor for this purpose. It was quite far away from the reality of people there, and maybe the technicians did not 'sell' the idea well enough. It was not clear for people what advantage the installation of these new devices should have. Pro, cons and the rationale for it was not communicated clearly enough, and it occupied little time and little priority within the project.

**Actors involved and relevant regulatory issues:** The main stakeholders involved were distribution grid operators which were carrying out the switching of automated loads and the prosumers itself. Before approaching the customers who would participate in the field trial, the matter was discussed and coordinated with the Austrian Data Protection Agency. At this point, different types of data (active power, reactive power, voltage profile, customer data) needed by the project were defined. The agency checked and approved the data acquisition and usage concept. Each customer had to sign an agreement with the DSO stating that the data from the smart meters could be used for the project and that they would allow the use of the data until the end of the project.

**Technical parameters of automation:** PV-BESS, central BESS and boilers could be switched automatically during the demo. PV-BESS and central BESS received a setpoint signal from the DSO; there was no influence on customers. Boilers could be switched automatically during the demo, between the hours in which the 'Sonnenbonus' was active, and this automated activation was limited to a few tries within one month. The customers were not really informed about the activation (ripple control had been there before). Customers noticed the activation of the boilers and called the DSO for more information.

**Incentives:** Customers received €40 (minimum for participation) – €120 savings within the period of testing. In the field trial area of Eberstalzell the so-called 'Sonnenbonus' was tested. If a forecast for the following day showed a high irradiation (>600 W/m²), the customers (around 200 households) had the opportunity to use the locally converted energy from the PV during the timeframe of the 'Sonnenbonus'. During this special time period the customers got a discount of €cent10/kWh on the grid tariff, and their remaining tariff was the same. The aim was to make the bonus so high that people would participate, but not to control the activated amount. For other use cases, there were gifts for the participants prior to the trial and some of them received hardware for free.

**Information provision and data sharing:** Users were provided with an app and there was also the 'Sonnenmonitor' or 'sun monitor', a big screen in the town hall that displayed the achievements within the community and information about the bonus hours for the next day. In addition, an FAQ section provided further information about the aims of the field trial and answered potential questions of the participants. Furthermore, it provided a how-to-use-the-app video. The consumption data is received by the DSO and stored within a centralised cloud. The app was tested for data security.

**User interaction with the automation system:** Each day at 16:00 a push notification was sent to the prosumers, with the hours of the 'Sonnenbonus' of the next day. The required user interaction focuses on the manual activation and shifting of loads. In the app the prosumers could also see their savings for each day. It was also interesting to find out which functionalities of the app most appealed to the households. The highest approval rating was assigned to the analytics part of the app which showed the household's load profile in different granularities, starting from 15 minute values up to yearly values. Energy saving tips and benchmark information were approved by more than 50% of the households, while the serious game that is implemented in the app was not a hit. Interesting additional

feedback included that the weather forecast for the 'Sonnenbonus' was really accurate and widely used, including for other purposes. People did semi-automation by themselves, by using timers or programmable devices (for instance, washing machines). For automated DSM there was no interaction with the user at all and no comfort losses, because the boilers were just charged additionally, and a different usage of PV-BESS does not lead to a loss of comfort.

**Project results:** Technical feasibility of the concept was shown to be promising. The project was the right combination of an engaged and enthusiastic community that was serviced by a public visualisation of energy savings on a digital screen. This was highly visible, and a talking point during visits to the post office on hot summer days. The program tied this social dimension to carefully considered benefits to motivate people. The trial also found that some home-owners came to identify more with the goals of the program, and adjust their energy use accordingly, than people living in apartments (especially renters).

The 'Sonnenbonus' field trial showed several positive effects, most notably the load-shifting effect of about 5% as well as the overall positive feedback from participants about the value of additional information on their electricity consumption patterns. Power quality management was not improved. Solutions creating a win-win situation between the grid operator and the customers will certainly have to be the overall goal of any real-life customer involvement in actual grid operation. It was found that 50% of the households started to be more aware of their electricity consumption and 9% even replaced inefficient household appliances with energy-efficient ones. Moreover, while the majority of the households were satisfied with the available functionalities, some expressed an interest in further functions, for instance, real-time data transmission from the meters in 15 minute intervals. The energy activities changed included:

- 83% shifted their electricity consumption to the 'Sonnenbonus' time slots
- 70% used their washing machine and dryer
- 28% programmed their washing machine and dryer to automatically switch on during 'Sonnenbonus' time slots
- 33% used their dishwasher during 'Sonnenbonus' time slots.

### SCDA

The SCDA Smart City Demo Aspern ran for 36 months from 2014 to 2017 in a single apartment building in Vienna. This flagship project implemented a large-scale optimisation system between buildings, power grids, users and comprehensive ICT solutions that was integrated into testbeds in the development area of Aspern Vienna's Urban Lakeside, consisting of three construction sites (residential building block, student dormitory, kindergarten and school building).

**Context, aims and framing:** The residential site consisted of an apartment building with 213 units of which 111 (52%) were successfully recruited to participate. All participants were new tenants, young to middle aged, many immigrants, large families, and low to middle income. The recruitment process was managed through the housing association as part of the contract conclusion phase. Participants received initial information via a flyer that advertised participation as a way to 'help to get our energy supply ready for the future' and further information was provided during contract completion. Consumers were encouraged to participate in shifting based on price signals which included tariffs with fixed time zones,

critical peak pricing, as well as a fixed tariff for control group purposes. The project also aimed at engaging consumers in general to perceive themselves as active participants in the grid and show interest in their consumption. They were engaged through an initial open house day, regular information events (every 1-3 months), a house party, workshops, interviews, and a yearly survey additionally to the provided through the web portal. Apartments were equipped with smart meters, eco-buttons to centrally control several marked outlets within the unit, programmable thermostats, and $CO_2$ sensors in order to monitor air quality in the apartment. The building was equipped with PV panels, solar thermal energy, a hybrid system, and heat pumps which were all used to optimise self-consumption within the building. A local smart grid regulation was applied.

**Actors involved and relevant regulatory issues**: The stakeholder groups involved were energy suppliers, distributors, component manufacturers, technology providers for detailed implementation planning, two research organisations, and a dedicated partner that handled all direct interaction with the participants. The energy supplier provided tariff price signals and energy feedback, the consumer contact partner organised all consumer interaction events and data gathering, the supplier handled frequency control and the research organisations analysed grid and consumer needs and developed and evaluated solutions. The lead partner was a joint venture between the involved energy provider, distributor, and component manufacturer.

**Technical parameters of automatisation and impact:** Heat and hot water were optimised for self-consumption via an algorithm developed within the project. Users had no insight into these optimisation processes and were given no possibility to veto anything, but no consequences regarding comfort levels were expected. No impact of building energy management on users was expected. Load-shifting with user impact was only attempted by motivating manual shifting or shifting though a programmable thermostat incentivised via variable tariffs.

**Incentives:** Participants were rewarded for participation in the research project via a bonus point system with an initial large incentive and consecutive possibilities to collect points for participation in research activities such as surveys or workshops. There was also a yearly lottery with a larger price for all participating tenants. The bonus points collected could be redeemed at a number of local businesses or selected online shops. Load-shifting according to price signals enabled the consumption of cheaper power, but consumption prices were capped in such a way that, if the power bill would have been greater than one with a fixed tariff due to the variable tariff rates, consumers only had to pay what their bill would have amounted to under a fixed tariff. Critical peaks were announced one day in advance. Implementation of these tariffs was delayed multiple times, resulting in a reduction of participant attention. Achievable savings were, however, minimal. The ratio between highest and average price was double.

**Information provision and data sharing:** Information channels used to communicate with participants beyond social events were a web portal and via email. The web portal contained feedback information regarding energy and water use as well as air quality. Social comparisons reading energy feedback were provided as well. The system further contained status information regarding home energy management features available (eco-button, heating), tariff-related information, basic privacy and security information, and general

information on the research project. There was no information regarding achieved savings (financial or $CO_2$ emissions) available via the interface. System personalisation was available in the form of heating profiles and activation/deactivation of the eco-button. The system did not actively reach out to users except to provide information on critical price peaks (about twice a week). No response within the system was required but participants with the critical peak tariff were encouraged to shift loads outside of peak times. Data access to the consumers was provided in the form of feedback. Data was stored externally and managed by the project leader. Access to data by project partners was limited to information necessary to fulfil their tasks within the project.

**User interaction with the system:** Only a small percentage of users used the portal actively (mostly users who showed a high affinity towards technology) and any existing interest in the interface existing interest decreased noticeably over time. About 31% of the participating households used the eco-button actively. The participants who did use the platform found the feedback interesting (especially if longer time periods were compared), and they liked the remote-control options and the overall design. They did, however, miss reference information to facilitate feedback interpretation and would have liked more home automation options.

**Project results:** Manual energy saving was mainly realised to a degree using the eco-button (used regularly by about 15 households). Load-shifting occurred to a negligible degree and no significant differences between the three tariff groups could be observed as presumably incentives were too small and no disadvantages for users were possible. Overall, the user interface was only of interest for a very limited number of users and this interest declined over time. It was concluded that the information available via the platform (consumption feedback, limited control options) was on its own not sufficiently beneficial to draw broader interest from participants, although the app itself was perceived positively. Using the app did not seem to influence energy consumption noticeably and energy consumption of the participating households was only marginally below standard consumption. Concerns around data protection after the first year were indicated by below 20% of the participants. 64% felt that existing concerns around data protection were unaffected by their participation in the project and 27% indicated that they were now less concerned. Control over data collection, use and access and transparency were rated to be most important. Throughout the trial period, technical issues with the heat system and heat distribution occurred and it was not clear to consumers that this was not related to the research project which led to irritation among participants.

## PEER2PEER IM QUARTIER

Project P2PQ ran for 36 months from 2018 to 2020 in Vienna. It aimed to explore automated PV and storage battery-based energy self-consumption optimisation within a building block including P2P trading between inhabitants of the building block. Trading was implemented via a blockchain approach, and a new tariff model was tested. It was part of a larger project that aimed at the development and exploration of new energy-related products and services using a participatory approach.

**Context, aims and framing:** The regional energy mix was standard but installed PV panels and storage batteries increased the share of available renewable energy. The building

blocks participating in the project were all new and mostly privately owned by upper middle-class members with a distributed age range (although not many very young owners). Presumably there were not many single-occupant households due to relatively large apartment sizes. User recruitment happened out of a pool of users already participating in a parent project whose original recruitment happened during occupants' moving in, with information provided during contract conclusion, via info events, flyers, and a block party organised by the energy provider. The rationale communicated focused on participatory development and testing of new products and services for a more sustainable and consumer-oriented energy system. Participants could collect points that could be exchanged for vouchers for local businesses and received financial benefits due to a lower energy bill because of a special 'peer-to-peer tariff'. Participation in the P2P project was encouraged based on environmental benefits (locally produced, green energy), tailoring to specific needs, and efficient use of the produced energy due to P2P trading. Behaviour change was not specifically expected but an option to increase financial benefits by matching consumption patterns to availability of PV-produced energy. Implemented automation focussed on the optimised use of PV-produced and battery-stored energy, including automated P2P trading under fairness considerations regarding all participating apartment occupants. Transparent feedback regarding produced and stored energy and trading was implemented via a web portal to communicate a sense of fairness. Participants had a variety of channels: a clear main contact available to ask questions of, provide feedback to or discuss potential concerns or issues; interviews studies; and questionnaire studies. No smart meters were installed initially but sensors were used to regularly transmit feedback on energy use and were substituted with actual smart meters in the course of the project.

**Actors involved and relevant regulatory issues**: The actors involved in the project were a local energy supplier who provided the technical infrastructure, offered a specifically designed tariff and was the contract partner of participating users, a research organisation that designed and developed the user interface and conducted user studies, as well as developed the algorithms for optimised building energy consumption and P2P trading, and a technical partner that realised the P2P trading via blockchain programming. A local communications partner from the parent project supported with user contact and communication. There was direct interaction between all partners and along with the communications partner both the provider and the research organisation communicated directly with the consumers. Regarding regulatory aspects please see country-specific information.

**Technical parameters of automatisation and impact:** Automated energy management was only realised on a building level but not within apartments. No automatic load activation was possible but there was automated control of which energy source (PV-produced, battery-stored or from the grid) was used at a specific time for each user when energy was consumed. Manual load-shifting was possible as a response to renewable energy availability and was communicated but not directly encouraged with any dedicated measures. The P2PQ tariff was 4-tiered with PV-produced energy being cheapest, battery-stored next-cheapest, peer-traded energy next, and grid energy the priciest in comparison.

**Incentives:** Participation in the P2PQ project was rewarded with points as part of the parent project which could be exchanged for vouchers for local shops. Otherwise, participation benefits were expressed as reduced energy bills due to cheaper, green energy and a waiving of the base fee. The cheapest tier (PV-produced energy) was about 20% cheaper than grid energy with savings amounting to about €4 per month. The price signals of the 4 tiers (see above) were steady but times of availability varied depending on PV-power produced, stored, and used by other participants in the program. The aim was to provide an advantage for participating users and avoid a disadvantage for the provider. The benefit from the perspective of the provider was to test out how well the set-up worked and how users responded to it.

**Information provision and data sharing:** Project participants were provided with a web portal enabling access to consumption history (general, broken down according to energy source, and in comparison, with the community, and in list instead of graph form), as well as PV production and battery storage availability history, use of battery storage by the user and the community, and the user trading history. Further, a PV production forecast was included with a specific recommendation when to use energy in order the make the most of the PV production (time window during which the most production was expected and expectation kWh). Finally, users were provided the possibility to gain insights into energy flowing into a household for a specific point in time (live view of current situation or past point in time). There was no information on benefits gained available via the website. Consumer data was stored and managed by the participating provider of the blockchain technology and was available to the energy provider for billing purposes. General information on privacy and security measures was available via the website.

**User interaction with the system:** The web portal provided feedback information to enable monitoring and social comparisons and actionable information in the shape of the production forecasting and the time window recommendation for load-shifting but did not actively contact or encourage users to shift their loads which was only possible manually or via user-active automation (e.g. by programming devices). It was possible to choose between optimising for cost effectiveness or environmental protection but selecting one or the other did not in the end change the optimisation since using green energy was also the cheapest option. Participants could access their data via the provided feedback and could look at detailed transaction information as part of the blockchain nature of the system. Participants did, however, use the web portal only to a very limited degree and did not make regular efforts to actively shift loads (since they lacked awareness of beneficial time windows and the incentive to do so would have been very small). When directly confronted with and asked about the interface they expressed positive feelings about the design and usability but perceived its usefulness to be limited.

**Project results:** The automated building energy optimisation was successful and worked well, also for participants, but the blockchain approach was overly complex and expensive for this setting without provided sufficient benefits. User requirements were collected during workshops at the beginning and acceptance was measured via a short questionnaire and a number of interviews throughout the duration of the trial period. Participants were happy with their experience and the possibility to consume greener energy but were only marginally interested in engaging with it and potential financial benefits were not large enough to

manually shift loads to a dedicated degree (although some participants reported some effort in this regard). No trust issues were expressed. The transparency provided through the interface was appreciated and aided in the experienced trust and the feedback was interesting, but otherwise the perceived benefits of the provided interface were limited. Multiple delays in the beginning of the trial are likely to have contributed to users only paying limited attention to their participation in the project.

## 3.3 Lessons learned

**Lessons from the case studies**

Overall it seems that single-family house owners are easier to motivate and successfully engage in DSM projects than people living in apartments in more urban areas. We suspect this is due to a number of reasons including existing communities, a stronger sense of ownership and active decision-making regarding one's residence and a higher return of investments in upgrading, an easier realisation of the role of a prosumer and overall a more direct and higher benefit of self-consumption optimisation.

Motivating urban participants, especially those in apartments and other multi-residential dwellings, may require incremental approaches that confront problems such as principal/agent issues. Such approaches could start with building level optimisation with roof PV and community batteries to function as a basis to raise awareness, energy literacy, benefits perception, community identity and engagement. These sufficiently engaged participants could then be provided with ways to involve themselves more actively and strongly. Further important learnings are that slow and halted introduction phases of DSM programs can really hurt engagement as people stop paying attention overall if there are too many delays and start to ignore information related to their participation. Finally, it should be pointed out that making use of 'moments of change' with people newly moving in / building has a better chance of succeeding than recruiting people outside of such moments.

**Policy recommendations**

- **Make costs more visible:** To combine the needs of the grid with market-related DSM applications, which can cause spikes at times with low prices, grid tariffs will require reform. Although there are reduced grid tariffs as an incentive for local consumption, on the household grid level, there are no costs charged for power. Though power peaks should be prevented as well, which points out the need for power costs at this level as well. Currently, financial benefits for participating users are miniscule, leading to a misalignment between benefits communication, which often focusses on financial benefits, and experienced benefits. This poses a particular challenge in the urban context with participants renting rather than owning and there is a need for new business models that show sufficient incentive for both landlords and tenants to participate
- **Data protection** requirements sometimes are a challenge for the realisation of DSM applications. For instance, there have been some discussions about blockchain

technology, because customers should be able to insist on deleting their data when terminating their contract, but the blockchain technology with the functionality of storing all the data irrevocably counteracts this requirement. Beyond that issue, blockchain technology is foreseen to be used in many fields, because it is tamper-proof and provides high security. In trials, however, blockchain technology has been largely proven to be cumbersome and pricy and has not really impacted user trust. It therefore seems advisable to focus on clear communication of justification and user benefits provision and to allow control over data collection and use where possible, ensuring data-handling related transparency on the way. This is particularly the case in smart home-related projects.

- **Low-income users** are neglected in public and energy sector discussions in Austria, but with rising energy prices, especially with peaks at certain times and the need for flexibility to save costs, this will become a more significant topic in the future.

**Future trial and research needs**

There is future technical research needed in optimisation and control concepts for DSM applications, without restricting the comfort limits of the prosumers. The regulatory framework has already been adapted in the recent past to the recent developments, but there is still some more need to incentivise certain DSM applications.

Regarding user engagement, research should go into how to improve and tailor benefits communication and better align it with the reasons people have for joining. For situations in which manual shifting is worthwhile in its benefit from a grid perspective, new approaches to user integration and incentives should be explored that match the effort required. Further, ways to increase awareness and energy literacy as a base for a more general energy citizenship beyond the technology affine and already interested part of the population should be investigated.

All in all, there is a lot of work underway to push DSM applications forward in Austria.

# 4. The Netherlands

- Energy users in the Netherlands are currently going through a transition that affects the ways they use domestic appliances, heat their buildings, and transport themselves on a daily basis.
- Several mechanisms are making it possible for energy consumers to respond to more price-based signals as well as to participate in bidding in organised markets through aggregating intermediaries. This is particularly advanced in the case of electric vehicle charging, where the ecosystem in the Netherlands is relatively well developed.
- The development and standardisation of EV charging protocols and the commercialisation of smart charging services with EVs have been key to the development of automated demand response in EVs.
- Experts from both industries and utilities recognise the potential benefits of demand response, but often cite scale of EV usage, legislative limitations, and misaligned incentives as barriers.
- Studies across several trials report that a majority of current EV drivers accept automated demand response in EV charging, if presented with clear financial insights, an easy-to-use interface and the ability to override. However, current Dutch EV users tend to be wealthier, better educated and more enthusiastic about technology than the broader vehicle-owning demographic.
- New market players and novel business models are expected to be key determinants of user engagement with automated demand response.

## 4.1 Context for automated DSM

**Population and housing**

The Netherlands is located along the low-lying coastal regions of north-western Europe. It has a population of about 17 million, and is characterised by a high population density, a temperate climate and a high GDP per capita. A little less than half the Dutch population lives in the industrialised Randstad conurbation in the west, which includes the four largest cities and several important European transport hubs.

The average living area per person disaggregated by municipality is shown in (Figure 11) with an average living space of 65 m$^2$ per person. These vary significantly from the urban west to the more sparsely populated eastern regions.
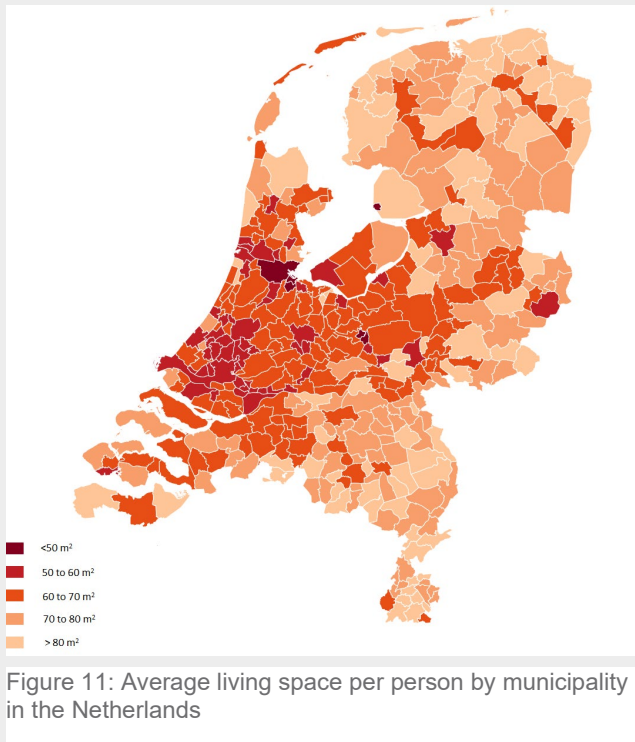
Figure 11: Average living space per person by municipality in the Netherlands

Household sizes tend to be small, with over 95% of them having fewer than 5 members. Around 60% of households have 1 or 2 persons. About 90% of houses were constructed before 2000, with about 60% constructed before 1980. Nearly 70% of the population are owner-occupiers, of which 61% have a mortgage or housing loan while the remaining 9% do not. The Dutch housing stock also has the highest social housing sector in Europe (with Austria second): about 1 in every 3 houses is owned by housing associations and about 84% of all rented housing stock is subject to rent regulation.

**Energy mix**

The energy supply in the Netherlands is primarily dependent on fossil fuels, with oil, coal and natural gas forming about 90% of the total energy supply, as shown in (Figure 12a). When only electricity generation is considered, about 70% of electricity is generated by fossil fuels, primarily natural gas and hard coal.

Transport, industry, buildings (both residential and commercial) and non-energy use[46] are the largest end-consumers of energy, as shown in Figure 12b). A significant part of the end-use of energy is for space heating, where natural gas is predominantly used. The Netherlands is historically a net importer of energy.

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[46] Non-energy use covers the use of other fossil-based products such as coal, white spirit, paraffin waxes, lubricants, bitumen and natural gas. It includes energy products used as raw materials in the different sectors which are not consumed as a fuel or transformed into another fuel. For example, lubricants and bitumen are used for non-energy purposes, while natural gas is a raw material for the petrochemical industry.
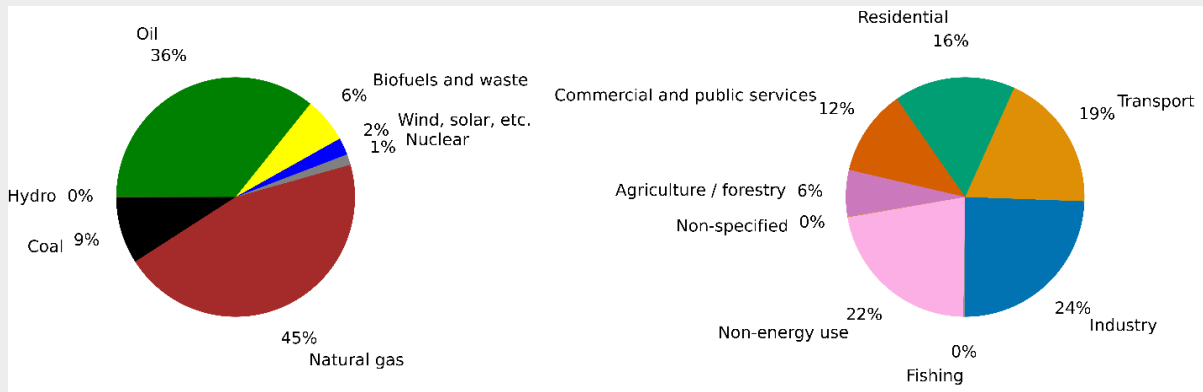
Figure 12: a) Total energy supply by source and b) Total final consumption by sector in the Netherlands

The Dutch electricity grid is very stable, a result of being well connected with the European continent-wide synchronous area. The SAIDI and SAIFI[47] values for the Dutch grid are in the range of 30 minutes and 0.4 per year including exceptional events[48]. With increasing interruptions expected in the future electricity grid, the high expectations of the population for stable and uninterrupted power lead to a potential market for DSM-enabled devices which offer solutions for these anticipated interruptions.

**Challenges in the energy system**

The overarching national climate-related ambition is the reduction of national greenhouse gas emissions by 49% by 2030 relative to 1990 levels, as expressed in the national Climate Agreement by the Dutch government in 2019.[49] This target was subsequently raised at the EU level, with Brussels committing to the reduction of EU-wide emissions by 55% by 2030. Since energy use accounts for about 75% of the EU's emissions, significant decarbonisation is required for energy used in all forms across the sectors of the built environment, mobility, industry, and agriculture. Given the high degree of reliance on fossil fuels for energy in the Netherlands, the fact that the country is a net importer of energy and the limited land resources for alternative energy generation from renewables, there are several challenges for the decarbonisation of the Dutch energy sector.

**Automated DSM**

Several factors in the current Dutch context create suitable conditions for demand side management, with a few of the most important ones listed here:

1. **Smart-meter adoption** is high in the Netherlands with the Dutch DSOs being legally obliged to offer smart meters to their customers. About 6.4 million (76%) of the

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[47] The SAIDI (System Average Interruption Duration Index) and the SAIFI (System Average Interruption Frequency Index) are commonly used metrics to describe system-wide reliability of electricity in power systems.
[48] Council of European Energy Regulators, 2018. CEER Benchmarking Report 6.1 on the Continuity of Electricity and Gas Supply (No. C18- EQS-86– 03). Brussels, Belgium.
[49] Rijksoverheid, 'Climate Agreement'.

approximately 7 million households have a smart meter installed as of 2019[50]. By the end of 2020, all remaining households and small companies were expected to have made offers for transition to smart meters, but this was affected by the COVID-19 crisis. Despite the high levels of smart meter penetration[51]

2. **Electric vehicle adoption** in the Netherlands is progressing at a rapid rate. Already, plug-in electric vehicles (PEVs[52]) comprise around 25% of new vehicle sales. With around 3% of the total passenger vehicle fleet currently composed of PEVs, a high number of PEVs are expected to be plugged into the Dutch electricity grid in the coming decades.

3. **Transition away from natural gas** is an ongoing process in the Netherlands. There was an initial decision to reduce gas extraction from the Groningen gas fields in 2014 and a subsequent decision confirmed that gas extraction would end by 2022. A significant share of newly constructed buildings is expected to be all-electric, leading to increased electricity consumption in households due to the scaled use of electric heat pumps[53]. By 2050, the ambition is for the residential built environment to be completely free of natural gas.

The Netherlands is a frontrunner in the field of electric mobility: it has the fourth highest national share of EVs in the passenger fleet in the world. For this reason, the focus of DSM in this report is on EV charging.

**Acceptance of DSM in electric vehicles**

The use of DSM in EV charging is relatively new and a few studies in recent years have investigated the user acceptance of demand side management, with a focus on Electric Vehicle (EV) charging in the Netherlands. Table 2 shows an overview of these studies.

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[50] Netherlands Enterprise Agency (RVO), 2020. Monitoringrapportage 2019 Convenant - Gebouwde Omgeving (No. RVO-105-2020/BR-DUZA). Utrecht, the Netherlands.
[51] Wiebes, E., 2020. Kamerbrief over Marktbarometer Slimme Meter 2019 and Netherlands Enterprise Agency (RVO), 2020. Monitoringrapportage 2019 Convenant - Gebouwde Omgeving (No. RVO-105-2020/BR-DUZA). Utrecht, the Netherlands.
[52] PEVs include Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs), but not Fuel Cell Electric Vehicles (FCEVs).
[53] Hammingh, P., Menkveld, M., Daniëls, B., Koutstaal, P., Schure, K., Hekkenberg, M., 2020. Klimaat- en Energieverkenning 2020. Netherlands Environmental Assessment Agency (Planbureau voor de Leefomgeving), The Hague, the Netherlands.

Table 3: Dutch surveys of willingness to automate

| | Title | Type of study | Participants | Reference |
|---|---|---|---|---|
| 1 | Charging behaviour of Dutch EV drivers: A study into the charging behaviour of Dutch EV drivers and factors that influence this behaviour | Interviews | 16 | Spoelstra, J.C. (2014), Thesis, Utrecht University, Utrecht, the Netherlands. |
| 2 | Are building users prepared for energy flexible buildings?—A large-scale survey in the Netherlands | Survey | 735 | Li, R., Dane, G., Finck, C. and Zeiler, W. (2017), *Applied Energy,* 203, 623–634. |
| 3 | Increased Participation in V2G through contract elements: Examining the preferences of Dutch EV users regarding V2G contracts using a stated choice experiment | Stated choice experiment | 96 | Zonneveld, J. (2019), Thesis, TU Delft, Delft, the Netherlands. |
| 4 | Acceptance, adoption and nudging of smart charging: Influencing adoption of smart charging solutions through nudging | Nudging experiment | 50 | Noort, D.J. van (2019), Thesis, Utrecht University, Utrecht, the Netherlands. |
| 5 | Dutch electric vehicle drivers' acceptance of vehicle-to-grid at long-term parking | Interviews | 20 | van Heuveln, K. (2020) , Thesis, Delft University of Technology, Delft, the Netherlands. |

| 6 | Factors influencing consumer acceptance of vehicle-to-grid by electric vehicle drivers in the Netherlands | | | van Heuveln, K., Ghotge, R., Annema, J. A., van Bergen, E., van Wee, B., & Pesch, U. (2021), *Travel Behaviour and Society*, *24*, p. 34–45. |
|---|---|---|---|---|
| 7 | Exploring electric vehicles owner's preferences and experiences with controlled charging: a mixed-method case study in the Netherlands | Survey + interviews | 89 surveyed and 20 interviewed | Gardien, L., Refa, N., Tamis, M. (2020), presented at the Electric Vehicle Symposium 33, Portland, OR, USA. |
| 8 | Charge management of electric vehicles at home: Testing smart charging with a home energy management system | | | van Bokhoven, P., Gardien, L., Klapwijk, P., Refa, N., Berende, M., van Zante, A., Heinen, J. W., & Kats, R. (2020), Elaad NL. |
| 9 | Dutch electric vehicle drivers' preferences regarding vehicle-to-grid contracts: Examining the willingness to participate in vehicle-to-grid contracts by conducting a context-dependent stated choice experiment taking into account the EV recharging speed | Stated choice experiment | 148 | Meijssen, A. (2019), Thesis, Delft University of Technology, Delft, the Netherlands. |
| 10 | Are electric vehicle drivers willing to participate in vehicle-to-grid contracts? A context-dependent stated choice experiment | | | Huang, B., Meijssen, A.G., Annema, J.A. and Lukszo, Z. (2021), *Energy Policy*, *156*, p.112410. |

## 4.2 Case study

**POWERPARKING**

The project, Powerparking, is taken as a Dutch case study. It was led by the Province of Flevoland, which also co-financed it together with the European Funds for Regional Development. It aimed to develop solar carports for the charging of electric vehicles at semi-public parking locations, including the Municipality of Dronten, and a business park, MAC3park. The project partners included the knowledge partner, the Delft University of Technology, the energy supplier , Eneco, the chargepoint manufacturer, Alfen, and the municipality and business park on whose terrain the projects were to be developed. As part of the project, a test vehicle-to-grid set-up was built at the Green Village, at the Delft University of Technology, for demonstration and user acceptance studies.

**Use case context and framing:** The test set-up at the Green Village (see Figure 13) included a solar carport with a 3.68 kWp solar array, two electric vehicle charge points and a project vehicle, a 30 kWh Nissan LEAF. One of the charge points was a conventional AC 1 phase 7.4 kW charge point while the other was a V2G compatible 10 kW DC charge point. When the LEAF was plugged in to the V2G charge point, its battery was used for solar self-consumption and peak shaving of the power exchanged with the grid. This ensured that the constraints at the grid connection were not exceeded. Participants in the study, mainly university employees, were given the chance to use the LEAF for a week and charge at their workplace. After this they were interviewed on their experience of the technology. The outcomes from these interviews were compared with those of EV drivers with no experience of V2G charging.



Figure 13: Dutch EV charging station at the Green Village

**Actors involved and relevant regulations**

The envisioned system enables more vehicles to be charged at a location with limited grid capacity without the need for an upgrade in distribution level infrastructure. The parking lot operator or real estate manager responsible for provision of charging facilities at semi-public locations like employment centres, public buildings and transport hubs avoid the costs by deferring this capacity upgrade. This role was played by the researchers in the test, who adjusted the settings on the charge point. The user of the EV experienced demand-side control. Various other actors were involved, including energy providers, mobility service providers, DSOs and so on, as described in Figure 14 below.
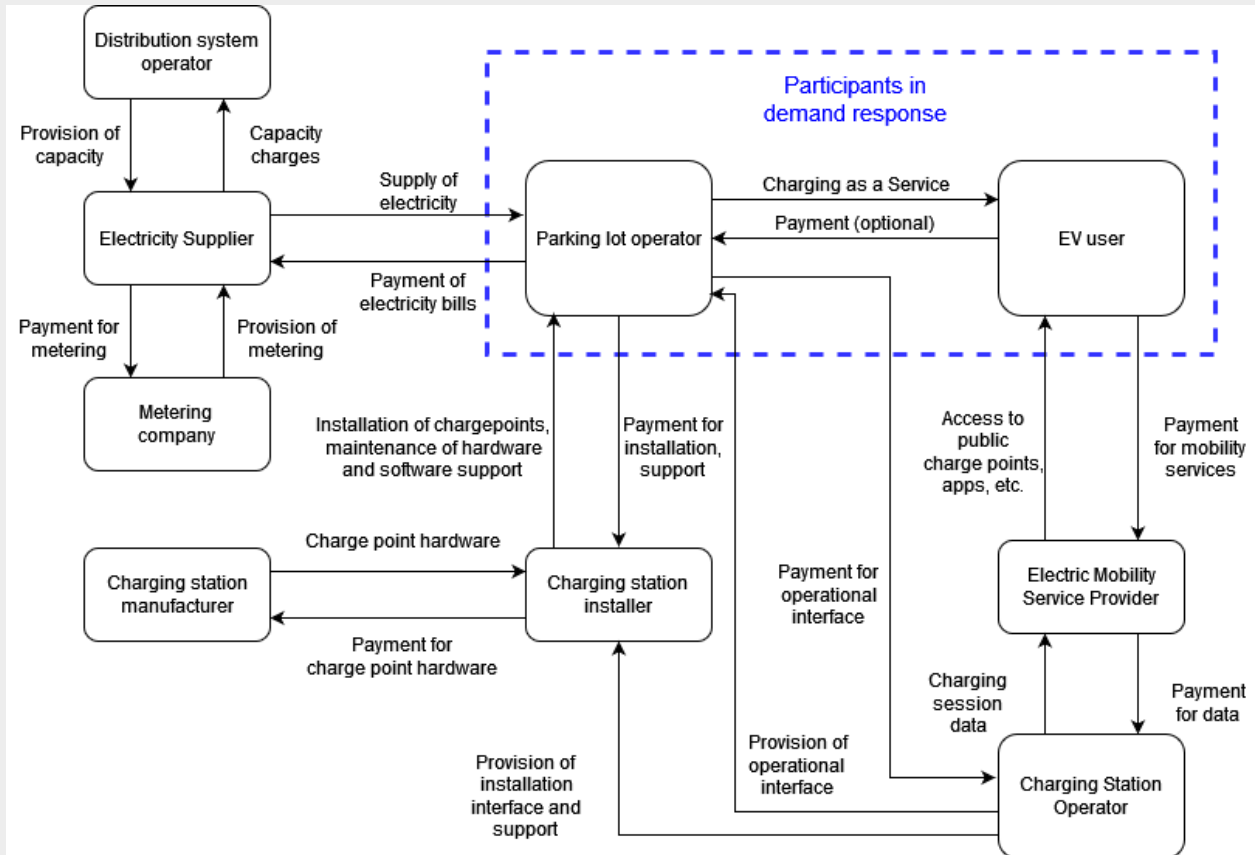
Figure 14: Actors involved in EV charging DSM in the Powerparking test set-up

**Technical parameters of automation:** The system is 'fully automated', in the sense that users are neither involved with decision-making nor are they informed of decisions involved in the charging profile of the vehicle after plug-in. A power threshold is set at the grid connection point. Based on the state of charge (SoC) of the plugged-in vehicle, the available solar energy and the power demand of other vehicles, the system operates within the set threshold. This had the effect of shaving off demand peaks and increasing the self-consumption of energy within the system. The user of the system was informed about the SoC of the vehicle only on the point of return.

**Incentives:** The participants of the system were not given any incentives to participate in the study. However, they received access to an EV for the duration of a week, including free charging. This incentivised many of the participants to join the study, and was frequently mentioned during interviews.

**Information provision and data sharing:** Only a basic description of the operation of the system was provided to the participants before taking part in the study. They were required to sign an informed consent form, based on which their anonymised data could be collected. Metered data from the system was stored in a cloud-based repository for research and analysis, maintained by the University.

**User interaction:** The participants initially had contact with the researchers over email. The researchers provided a face-to-face explanation of the operation of the system to each participant individually. After signing the informed consent form, they were then given the keys to the EV, which were to be returned at a later date.

The participants typically integrated the EV into their daily commuting patterns, taking the EV home at night, and charging at the University during working hours. Their interface of interaction with the equipment was primarily with the vehicle and with the charge point at the points of plug-in and plug-out.

**Project results:** On the basis of interviews conducted before users had experienced the system, the factors found to be most important for fostering acceptance were financial compensation, transparent communication and reliable control of the system by the user. On the other hand, the factors found to have a negative effect on acceptance were range anxiety, the need for additional planning and battery degradation. Preliminary results from the users who used the system indicate that it was easier to use than expected, and the location of the set-up at their workplace fit their lifestyle patterns.

Several participants described anxiety about not knowing the state of charge of the vehicle over the plug-in time and at the point of plug-out.  During interviews, the participants were often found to frame charging of EVs in V2G mode as 'social' or 'cooperative' charging, seen as beneficial to the environment and maintenance of shared infrastructure.

## 4.3 Lessons learned

**Findings from the research**

EV drivers in the Netherlands tend to be male, middle-aged, wealthy, highly educated, likely to have their own parking space and sensitive to favourable tax incentives. They are also likely to be enthusiastic and informed about technology, to be motivated by environmental causes – characteristics seen across a variety of studies. A large fraction of electric vehicles are either privately owned or leased through companies.

Several studies show that a majority of current EV drivers accept DSM and are willing to continue. There are several technical characteristics which are favoured – clear, easy to use and informative displays (either on the charge point or through an app interface), and the ability to override demand response in case of emergencies. Accessibility of fast charging locally and compensation also lead to higher acceptance. The main concerns are with adequacy of remuneration and range anxiety, with battery degradation a significant additional issue among V2G charge point users.

**Readiness for automated DSM**

DSM through unidirectional charging is currently commercially available for Dutch EV drivers, depending on the vehicle brand and model, through services like Jedlix, the

NewMotion and LeasePlan Energy. The DSM functionalities of vehicles are offered as opt-in services for individual EV users in exchange for energy savings. These savings are estimated to be up to €200 annually for individual vehicle drivers but can vary significantly depending on vehicle charging patterns. The opt-in rate for commercial DSM services by EV drivers in the Netherlands remains uncertain due to its commercial sensitivity. However, the results from several pilot projects indicates a high degree of readiness among the current Dutch EV-driving demographic.

With bidirectional DSM, the technology is pre-commercial in terms of vehicle hardware, chargepoint hardware and standardisation. Few vehicles and charge points are V2G compatible, business cases are immature and less is known by users about the range of compensation, battery degradation and the impacts on vehicle resale value and warranty. At the time of writing, the first results from V2G pilot tests are being collected, and as such the readiness for DSM is several years behind that for unidirectional charging.

Generalising to the broader population who do not drive EVs, surveys show that there is relatively low public awareness about smart devices. In a large scale (n=785) survey among Dutch adults who were responsible for paying electricity bills, about 90% of them had either not heard of smart grids or had heard a little but did not understand the concept.[54]

At the policy level, recent EU-level legislation has been passed, which has high relevance to demand response. These directives cover consumer access and participation, market facilitation, new roles and redefined responsibilities for existing actors. They are currently being interpreted for the Dutch context, as in the other member states. Since there is limited empirical evidence of large-scale electricity sectors which enable and utilise DR, there is continuous innovation in the search for a repeatable template.

**Outlook for DSM with EVs**

With increasing EV adoption, the Dutch EV-driving demographic is expected to shift away from early adopters toward the mainstream: a mainstream that is better represented by the current passenger vehicle-driving demographic. These new drivers are expected to be less wealthy, less highly educated, less enthusiastic about new technology and have lower access to private parking. Economic motivators and convenience may be more important than status and environmental concerns, leading to different factors influencing acceptance of demand response.

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[54] Li, R., Dane, G., Finck, C. and Zeiler, W., 2017. Are building users prepared for energy flexible buildings? A large-scale survey in the Netherlands. *Applied Energy*, 203, pp.623-634.

# 5. Norway

- Norway's early and comprehensive **smart meter adoption** has sparked new market players and novel automation business models into being. Norway is also a leading jurisdiction in the development of smart electric vehicle chargers that take advantage of low electricity prices.
- **Framing:** Automated DSM is a part of the sustainability target because of increasing electrification, changes in generation and consumption patterns in Norway. DSM technology makes it possible to increase the utilisation of the existing grid and reduce/postpone investments and system reinforcements.
- **Goals**: Automated systems are envisioned to improve grid security and system voltage stability in distribution networks and to avoid costly grid upgrades. Another central goal is to ease the integration of distributed renewable energy, mainly in the form of wind energy and, to a lesser extent and on a smaller scale, solar PV. The automation is considered useful in shaving/shifting peak loads, especially in conjunction with EV charging.
- **Context**: The Norwegian Water Resources and Energy Directorate (NVE) decided that all Norwegian homes should have a smart meter installed before 2019. In 2022 a power tariff for households will be introduced that the utilities hope will make Norwegians more aware of electricity consumption and give them incentives to shift their consumption off peak hours.
- **Discourse about energy users amongst the industry and utilities:** The solutions aimed at energy users at household level are centred around users as rational agents sensitive to economic incentives (*homo economicus*) and somewhat technically competent or active (and who want to automate consumption, produce energy that can provide flexibility to the power system).
- **Major limitations of evidence analysed in the profile:** Two of the trials were opt-in, which attracted users that read emails from the grid companies or answered the phone. Participants were for the most part middle-aged males.

## 5.1 Context for automated DSM

**Population and housing**

Norway has a population of about 5.4 million people, in an area of 323,802 km$^2$. Apart from the mainland, the country also consists of the island of Jan Mayen and the archipelago of Svalbard, the inclusion of which makes the total area of the country 385,252 km$^2$. The country is sparsely populated with large mountainous areas with permafrost all year in the highest areas. Norway claims the world's second longest coastline, after Canada, stretching 28,953 kilometers from 57° north at its most southern point to 71° north (thus crossing the

polar circle at 66°). Because of the country's northern location and its length, it experiences a variety in climate and daylight conditions. However, due to the Gulf Stream running along the Norwegian coast it has a much warmer climate compared to similar places so far north.

82% of Norwegian inhabitants live in urban settlements.[55] The most common forms of dwellings are single houses and detached houses, although the dwelling type increasing the most is the multi-dwelling building.[56] In Norway electricity has historically been relatively cheap and abundant, resulting in what some have called a comfort-oriented energy culture amongst Norwegian citizens.[57]

## Energy mix and culture

The Norwegian energy system is unique, insofar as ~97% electricity production comes from hydroelectric power. The remaining share of 3-5% consists mainly of thermal and wind energy. With its large, state-owned oil and gas sector, the country is an important supplier of oil and gas to global markets, and almost all the petroleum produced on the Norwegian shelf is exported. This status as a large energy exporter, much like Australia, stands in stark contrast to the energy importing nations analysed here.

Total electricity production in 2020[58] was 154,2 TWh. Most of this came from hydroelectric power (10 TWh came from wind and 0,14 TWh from solar)[59]. Currently, Norway has 1682 hydro-electric power stations. Hydropower has provided substantial income and secured the foundation for the development of the welfare state in the immediate post-war period[60]. It has also made it common to use mostly direct electric heating in homes, putting Norway ahead of both Kuwait and Bahrain, and second only to Iceland, in electricity use per capita.

The Norwegian Water Resources and Energy Directorate (NVE) was developed in 1921 to ensure that the country's hydropower would be developed as environmentally friendly and socially beneficial as possible. NVE is now a directorate under the Department of Oil and Energy of Norway.

## Challenges in the energy system

The main strategy for reaching climate goals in Norway is related to electrification of the transport sector. There are various challenges related to this strategy.[61] From a grid perspective, **energy consumption is too high, and too concentrated around particular**

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[55] Population and land area in urban settlements, Statistics Norway
https://www.ssb.no/en/befolkning/folketall/statistikk/tettsteders-befolkning-og-areal (accessed 4 Oct 2021)
[56] Dwellings, Statistics Norway https://www.ssb.no/en/bygg-bolig-og-eiendom/bolig-og-boforhold/statistikk/boliger (accessed 4 Oct 2021)
[57] Aune, M, Godbolt Å L , Sørensen K H, Ryghaug M, Karlstrøm H and Næss R (2016) "Concerned consumption. Global warming changing household domestication of energy." *Energy Policy* 98: 290-297.
[58] NVE 2020 Annual Report https://www.nve.no/media/11962/versjon-per-29-april-a-rsrapport-2020-for-nve.pdf (accessed 4 Oct 2021)
[59] Solar power, NVE https://www.nve.no/energi/energisystem/solkraft/ (accessed 4 Oct 2021)
[60] Rygg, B. J., Ryghaug, M., & Yttri, G. (2021). Is local always best? Social acceptance of small hydropower projects in Norway. *International Journal of Sustainable Energy Planning and Management*, 31, 161-174.
[61] See for example Egging, R., & Tomasgard, A. (2018). Norway's role in the European energy transition. Energy Strategy Reviews, 20, 99-101. doi:https://doi.org/10.1016/j.esr.2018.02.004

**times of the day, week, and year.** In combination with more wind and PV power in the grid, it can become more challenging to handle security of supply and electricity.

Norway was the first country to submit an updated NDC to the UNFCCC. This document stated a goal to **reduce national greenhouse gas emissions by 50-55% by 2030** relative to 1990 levels.[62] Given the already high share of renewable energy consumption in Norway, the country's main strategy for reducing GHG emission is through electrification of the transport sector. Norwegian homes are also mostly heated by direct electricity from renewable sources, thus decarbonisation of transport, industrial, agriculture, land-use, land-use change and forestry, and waste sectors is covered by the NDC.

Norwegian official policy states that **all new cars sold in 2025 and beyond should be emissions-free**. In 2021 Norway had 340 000 EVs[63] and about 2 823 000 conventional cars. The market share for battery electric vehicles (BEV) has grown extremely quickly compared to other countries. In 2020 54.3% of new cars sold were BEV[64]. In August 2021 71.9% of all new cars sold in Norway were BEVs[65].

**Maritime transport, shipping and ferries are also targeted for electrification** with either battery or hybrid solutions. Today Norway has 34 electric car-ferries. By the end of 2021 the number is expected to have grown to about 60[66]. The electrification of ferries has led to increased investment in the electrification of ports[67]. Also, aviation authorities have a goal to electrify all Norwegian domestic flights by 2040 and there are programs to transition short-distance flights in a more sustainable direction.

Grid infrastructure is ageing in several places and the increased electrification makes it necessary to build more networks. The networks companies compete in operating the networks as socio-economically beneficially as possible, and it may not always be the most cost-efficient solution to expand the grid. Flexibility through automation has thus been cast as a contribution to postponing or avoiding altogether new network investments[68]

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[62] Norwegian Climate Policy, Government of Norway https://www.regjeringen.no/no/tema/klima-og-miljo/innsiktsartikler-klima-miljo/klimaendringer-og-norsk-klimapolitikk/id2636812/ (accessed 4 Oct 2021)
[63] Parking, Statistics Norway https://www.ssb.no/transport-og-reiseliv/landtransport/statistikk/bilparken
[64] Norwegian EV Market, Norwegian EV Association https://elbil.no/english/norwegian-ev-market/
[65] https://elbil.no/nybilsalget-i-august-historisk-elbilrekord/ (accessed 4 Oct 2021)
[66] Øystese KÅ (2021) Grønnskipsfart. nærmere 60 elektriske bilferger innen 2021. Available at: https://energiogklima.no/nyhet/gronn-skipsfart/gronnskipsfart-naermere-60-elektriske-bilferger-innen-2021/ (accessed 4 Oct 2021)
[67] Bjerkan KY and Seter H (2019) Reviewing tools and technologies for sustainable ports: Does research enable decision making in ports? *Transportation Research Part D: Transport and Environment* 72: 243-260
[68] Ødegården L and Bhantana S (2018) Status og prognoser for kraftsystemet, Report

**Automated DSM**

- Norway has a competitive retail market with some 100 providers, 17 DSOs, and Stattnet – a monopoly transmission operator.
- The initial rationale for smart metering in Norway some 15 years ago was to help solve bottleneck transmission issues between regional markets.
- Increasing connectivity to continental Europe has imported price volatility (including carbon market quota effects on energy prices).
- There is now vigorous public debate about the price and regulatory effects of this increased connectivity and the role for automation.

Historically, Norwegian energy policies have traditionally been geared toward cost-effective use and production of energy. This has been challenging for the implementation of new renewable energy technologies, because in the liberalised Norwegian electricity market the governance of renewable energy has largely been left in the hands of the market.[69] A long period of relatively low electricity prices slowed down investment in renewables. To mitigate this, Norway introduced electricity certificates in a joint market with Sweden, thereby creating a new class of incentives for investment in renewable energy generation.[70] The building of new transmission cables with neighbouring countries, most recently transmission cables to Germany and UK are further integrating Norway's hydropower balance with the European power system. The initial rationale for smart metering in Norway was to help solve bottleneck issues between regional markets. More recently, the increased transmission capacity to the surrounding energy markets raised new concerns about the need for more flexible and active electricity management in Norway.[71] Increasing connectivity to the continent has imported continental price volatility and $CO_2$ quota effects on energy prices to Norway, and these developments may demand fast development and implementation of demand response and flexibility solutions to mitigate large price increases for end users.

The energy sector in Norway is governed by the *Energy Act, No. 50 of 1990*. It ensures that generation, conversion, transmission, distribution and use of energy are conducted in a socio-economically rational manner that takes into consideration all private and public interests and parties.[72] Statnett, which is a designated TSO, owns most of the transmission grid. Statnett is responsible for coordinating the operation of the power supply system, dealing with congestion, and facilitating international power trade. About 6% of the transmission grid is owned by regional DSOs, but Statnett rents these parts. All Norwegian energy is traded through Nord Pool, which markets itself as 'Europe's leading power market

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[69] Skjølsvold, T. M., Ryghaug, M., & Throndsen, W. (2020). European island imaginaries: Examining the actors, innovations, and renewable energy transitions of 8 islands. Energy Research & Social Science, 65, 101491.
[70] Skjølsvold, T. M., Ryghaug, M., & Dugstad, J. (2013). Building on Norway's energy goldmine: Policies for expertise, export, and market efficiencies. In Renewable Energy Governance (pp. 337-349): Springer.
[71] Ballo, I. F. (2015). Imagining energy futures: Sociotechnical imaginaries of the future Smart Grid in Norway. Energy Research & Social Science, 9, 9-20.
[72] The Norwegian Energy Regulatory Authority is the national regulator for the Norwegian electricity and downstream gas market, NVE *https://www.nve.no/norwegian-energy-regulatory-authority/* (accessed 2 Oct 2021)

and offers trading, clearing, settlement and associated service in both day-ahead and intraday markets across nine European Countries'.[73]

The Norwegian energy market is composed of power producers, DSOs and utilities. The network company has a monopoly on building and operating the infrastructure in its local area and is overseen by the Energy Regulatory Authority (RME) within NVE. The utilities' roles are to be the link between the energy market and the consumers. In Norway one can choose between about 100 different power companies. In the energy grid the power companies are profit maximising, and their role is to bill the customers based on the network tariff and the energy consumed (variable prices).

**Digitalisation**

**As of 2021, 97% of Norwegian electricity customers have a smart meter,** making its smart meter roll-out one of the earliest and fastest in the world. A coalition of industry and grid utility groups successfully pushed for their adoption.[74] In 2007 NVE intended to develop a smart meter regulation to facilitate the smart meter roll-out.[75]

The NVE and the DSOs in Norway have been responsible for the smart meter investment (AMS). The costs are covered by the grid tariffs. NVE has also mandated Statnett, the TSO, to develop a new IT solution for information exchange between actors in the power market, the Elhub. Elhub commenced operation in February 2019. It facilitates the exchange of smart metering values and customer information needed for settlement and billing of electricity consumers and supplier switching in the retail market (Figure 15).

The Norwegian electricity bill is split up into several parts. One is for the use of electricity (utilities) and one is for the use of the grid (DSO). DSOs are now testing how time-of-use tariffs could motivate users to engage in load-shifting. This is now being put into various pilot projects, where two of them involve how smart home equipment can lower the bill under these new kinds of tariffs. Because the electricity is green and not too expensive, incentives to do load-shifting are low, but this may change in January 2022 when power tariffs are implemented.

To increase Norwegian renewable energy deployment, the Norwegian government funded several large R&D centres for environmentally friendly technologies, including Centre for Intelligent Energy Distribution (CINELDI)[76]. Another way that Norway has been facilitating smart grid development is through research programs (ENERGIX) that provides funding for pilot studies for industry, university, and research institutes. Today there are about 30 pilot and demonstration projects that advance smart grids with flexible consumption.[77] The high

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[73] https://www.nordpoolgroup.com/ (accessed 2 Oct 2021)

[74] Ingeborgrud L and Ryghaug M (2019) The role of practical, cognitive and symbolic factors in the successful implementation of battery electric vehicles in Norway. *Transportation Research Part A: Policy and Practice* 130: 507-516.

[75] Ingeborgrud L and Ryghaug M (2019) The role of practical, cognitive and symbolic factors in the successful implementation of battery electric vehicles in Norway. *Transportation Research Part A: Policy and Practice* 130: 507-516.

[76] SINTEF and NTNU are the main research partners, with grid operators, technology providers, public authorities and international R&D institutes and universities as partners.

[77] Skjølsvold, T. M., Ryghaug, M., & Throndsen, W. (2020). European island imaginaries: Examining the actors, innovations, and renewable energy transitions of 8 islands. *Energy Research & Social Science*, 65, 101491.

level of smart grid pilots and demonstration activities in Norway were triggered by the regulation and implementation of smart metering.



**Elhub has streamlined data processing and market communications related to electricity consumption in Norway.**

Elhub was put into operation by Statnett in February 2019, after a thorough process of requirements specification, where Statnett worked closely with power grid companies and electricity providers in the Norwegian electricity market. The establishment of Elhub, along with the rollout of smart meters, facilitates the automation and digitalization of value chains related to the exchange of meter data, changes in suppliers, sharing of customer information, and financial settlements.

Figure 15: Norway's Elhub Metering (source: https://elhub.no/)

The AMS meter is required by regulation to have a HAN (home area network) port as a standardised interface, while it is up to the market to provide which (smart home) technologies the customer uses for exploiting smart metering capabilities. Norwegian energy users can choose between at least 23 different suppliers of different ports that constitute the interface between the smart meter and the users. The user can also log on to the state owned Elhub without installing an interface, simply by logging on to a web browser to see their time-of-use data. Because of privacy issues the HAN port must be opened for use remotely by the DSO upon request from the costumers. In Norway there is an increasing number of users who want the DSO to open their HAN port to access their own electricity data, and at least 24 000 meters had been opened by June 2021.

**Smart technology for EV owners**

The large deployment of EVs in Norway has spurred the need for new regulations and laws. Changes to the Norwegian Buildings Act have ensured that provision of charging is not hampered in building blocks and condominiums. The act now states that the board of a shared garage in housing cooperatives and co-owned buildings cannot refuse the installation of EV chargers or refuse to allow a resident to charge their EV. In this case this leads to an implementation of different sorts of smart charging infrastructure to handle the increasing demand and the limitation of grid capacity. It has been suggested that EV charging infrastructure should be standard in new building projects, regulated by the building requirements specification (TEK 17).

**Socio-technical imaginaries of passive and active users in Norway and beyond**

The concept of socio-technical imaginaries as well as what has been described as 'imagined lay persons' highlights that assumptions made on behalf of users by designers of technology and policy alike are important to understand socio-technical change and emergent technologies. The typical socio-technical imaginary of the energy user views them as rational and someone who can easily be flexible in their energy use and who may adjust their consumption patterns and actions if they are just given the right information or price signals.[78] Social science studies have critiqued this, demonstrating that such depictions of users are to an extent flawed and that there is a greater need to understand how this coincides with everyday practices of users.[79]

Some imaginaries of how the interaction between the grid and the user's role are presented by CINELDI in Norway. They have issued four main scenarios for the electrical distribution network of the future in 2030-2040. These are 1) automated network, 2) flexible and intelligent network, 3) the grid as a back-up, and 4) business as usual. These scenarios are built around two dimensions. First, the customer dimension, where the network of the future is a consequence of the network customers' needs for networks and network services, which in turn is given by devices, facilities, production, energy storage, control, etc., and what behaviour the network customers of the future have. Secondly, there is the network dimension; namely, the extent to which the network companies use new technology, new work processes and other innovations.
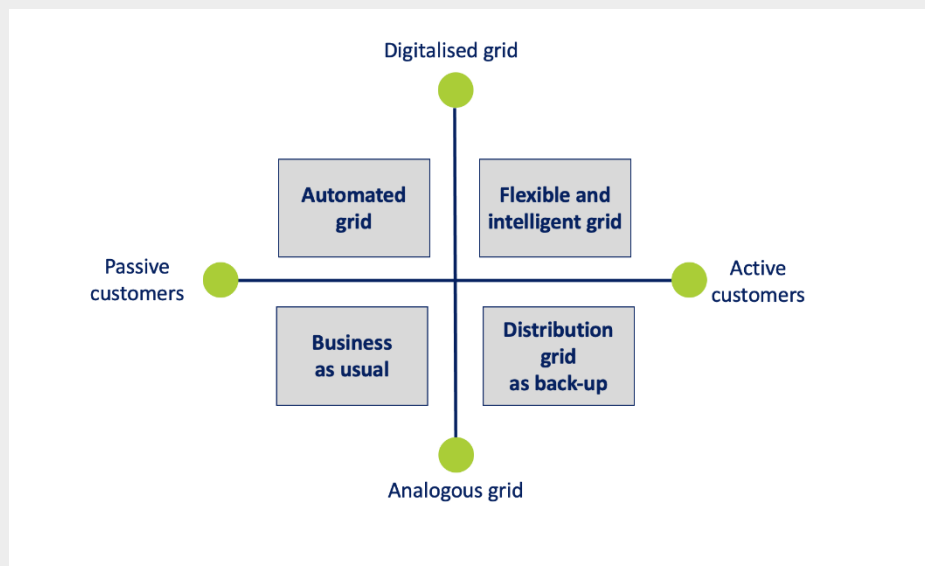


Regarding the social license to automate, we see that these scenarios focusing on the automation of the grid are about **passive users** that means that they produce and consume electricity independently of external signals such as price signals. The automation is more about automation in the grid, maintenance in the network and self-healing grids. Automation

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[78] Fjellså, I. F., Ryghaug, M., & Skjølsvold, T. M. (2021). Flexibility poverty: 'locked-in' flexibility practices and electricity use among students. *Energy Sources, Part B: Economics, Planning, and Policy,* 1-18.

[79] See especially Adams, S., Kuch, D., Diamond, L., Fröhlich, P., Henriksen, I. M., Katzeff, C., ... & Yilmaz, S. (2021). Social license to automate: A critical review of emerging approaches to electricity demand management. *Energy Research & Social Science*, 80, 102210; Ballo, I. F. (2015). Imagining energy futures: Sociotechnical imaginaries of the future Smart Grid in Norway. *Energy Research & Social Science*, 9, 9-20.

is not something that the users engage with. The users with an active role are a part of the flexible and intelligent network. Here, the network has been digitalised to a degree that also considers that the customers have become active and that this can be utilised in network planning and network operation[80]. In the CINELDI center DSM is framed in this scenario where the need for a market for aggregators is important, there are batteries in all homes, and the DSOs are engaged in DLC toward end-user use of energy (2020).

Through two pilots we find that the socio-technical imaginaries were still framed around an imaginary of a flexible energy users motivated by saving money on the electricity bill, but in addition to this we saw an articulation that flexibility of electric use was also about fire safety, equality and fairness, and the possibility to support the community by avoiding grid expansion as well as to save money on smart home equipment.

**Users' trust in the energy sector**

The Norwegian energy system is governed by the above-mentioned trinity under the TSO of DSOs, producers, and utilities. However, in a study, over 40% of Norwegians did not know the difference between the grid operator and the electricity utility in 2014.[81] Another survey showed that about 72% of house owners said that it did not matter what they did regarding energy saving, because the DSO always would find a way to invoice the respective amount.[82] Over 100 electricity utilities compete for customers, resulting in a steady flow of scam deals and secret price policies meeting households. This makes it hard for people to navigate. **In 2020 electricity utilities topped the complaints lists of the Norwegian consumer agency,** and a greater number of inquiries to the consumer agency was about the electricity utility. The RME and the Norwegian consumer agency sent a consultation proposal to the Ministry of Petroleum and Energy and the Ministry of Children and Family Affairs[83] in June 2021 to make regulatory changes to the electricity utility business to meet the challenges that consumers are facing in this market. They state:

> *The price of a service or item is fundamental to a contractual relationship. It is necessary for the consumer to have understandable price information to trust the market, can ensure that they are invoiced in accordance with the agreement, can assess whether the agreement they have chosen is best for their needs, can assess changes in terms and can compare their agreement with other agreements.[84]*

In other words, the need for making the billing of customers more transparent is a part of building trust in the energy market. Today the system may be too complicated for most, and from 1 January 2021 DSOs are also adjusting grid payments. That means that most

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[80] Sæle. H (2020) Flexibility potential at Norwegian households-customer evaluations and system benefits. Paper presented at the 2020 17th International Conference on the European Energy Market (EEM).
[81] https://www.nettavisen.no/artikkel/norske-stromkunder-taper-penger-pa-full-forvirring/s/12-95-5173925 (accessed 2 Oct 2021)
[82] https://kommunikasjon.ntb.no/pressemelding/tynnslitt-tillit-til-nettselskapene?publisherId=15012796&releaseId=17867554 (accessed 2 Oct 2021)
[83] https://www.nve.no/media/12507/forslag-til-endringer-i-forskrift-og-mulige-tiltak-for-et-effektivt-sluttbrukermarked.pdf (accessed 2 Oct 2021)
[84] https://www.nve.no/media/12507/forslag-til-endringer-i-forskrift-og-mulige-tiltak-for-et-effektivt-sluttbrukermarked.pdf (accessed 2 Oct 2021)

Norwegians have two energy bills: one for the electricity they use and one for the grid use. The need to make billing transparent and understandable for energy users is considerable.

**Acceptance of automated DSM**

A survey of ~1000 Norwegians over 25 years of age conducted in 2017 and 2020 found more than half of respondents were willing to accept automated control of heat pump hot water systems and other appliances.[85] Some 56-63% would be willing to accept remote load control and 63-64% would contribute with manual response if it would save them €200 / year. The study showed that 32.8% (in 2017) and 17.2% (in 2020) were willing to reduce electricity consumption in peak loads periods and to allow remote load control if their comfort was not affected. However, some 7 in 10 respondents reported they did not have the possibility for automated control over their electricity consumption.[86] This suggests a gap between practical capability and willingness to automate household loads that case study analysis can shed light on.

## 5.2 Case studies

To understand how a license to automate can appear, we ask the question of how people opt in to automation of electricity consumption, and we follow one pilot through the recruitment phase (Flekshome). In addition to this we also re-analyse two cases of smart EV charging, because in Norway, we can understand EV charging as a part of the 'late majority' and laggard user demographics of EV owners under the classical innovation model.

| Project name | Project partners | Dates | Appliances Automated | Purpose of the automation in the project |
|---|---|---|---|---|
| INVADE | LYSE Smart Innovation Norge | 2017-2019 | Smart home EV charging | Charging off-peak hours when price is low |
| ECHOES | Zaptec NTE | 2016-2019 | Smart charging in shared garages | Billing the EV owners, making (smart) charging available for all EV owners |
| Flekshome | Futurehome Zaptec LEDE | 2019-2022 | Smart meter, smart hub, floor heaters, hating pump, hot boiler | Direct load control for fleet/neighbourhood management |

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[85] Sæle, 'Flexibility potential at Norwegian households - customer evaluations and system benefits,'2020 17th International Conference on the European Energy Market (EEM), 2020, pp. 1-5, https://doi.org/10.1109/EEM49802.2020.9221911
[86] Ibid

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## INVADE: SMART CHARGING IN DETACHED HOUSES

EV charging increases the peaks and overall load in the local distribution network. Automated DSM is therefore developed to avoid or defer network expansion. Automated control in the INVADE smart charging program sees charging paused during the most expensive hours of the day based on the Nordpool hourly rate. This pause is triggered through communication from the smart meter and smart charger through the HAN port. This direct load control is being implemented to all the chargers from the company, and the pilot customers were offered to keep the charging device after the project; a smart device and service bundle that is now a retail offering to all customers. The pilot had 18 users, 12 of whom were interviewed, and 8 of whom also corresponded with the researchers via email.

The research presented in this report is part of an EU funded Horizon 2020 project which trialled an algorithm to improve charging speed. The pilot study of smart charging in single houses began in 2019 and followed up questions about 'smart' charging in 2021.

**Findings:** In 2019 the argument for signing up for the smart chargers was that it is faster and fire-safe. The early adopter interviewees reported that the smart charging technology was interesting and fun to learn about. The chargers made it possible to save money but prevented charging when electricity cost the most. This was a problem for some respondents, but overall, they reported the benefits worth it. The study participants reported that the flexibility of when to start charging can be connected to comfort.

## ECHOES: CHARGING INFRASTRUCTURE IN SHARED GARAGES

In Norway, ~75% of the households are owner-occupied. The most common type of home is the single unit dwelling, followed by semi-detached houses, row houses and apartment flats.[87] The combination of such a dwelling structure with strict planning regulations for on-street parking means many Norwegians use private, off-street parking in common garages.

EV users expect to park and charge their EVs at home at any time, which means that shared charging solutions are required to manage grid pressures. Smart changing with load control provides more equitable access to charging. Automated DSM systems are being developed to handle many EVs at the same time. The automation provides equality and fairness to EV owners. Where the automation provides fair charging for all the available capacity in the local grid. The automation is also connected to the billing system because petrol car owners do not want to pay for the electricity that EV owners use. In this case they never mention giving up control, but electricians, the automation device propends and the housing boards frame automation as a system to get equality, fair use of electricity and fire safety among the inhabitants. EV charging can be unpredictable in how long it takes to charge. This means EV owners are accustomed to variations in charging speed and allows for charging expectations to be met whilst also allowing for automated management. The desire to have the option to opt out of automated control is very strong. The most common question raised by

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[87] Revold, M. K., et al. (2018). Bolig og boforhold- for befolknigen og utsatte grupper. S. Norway. Kongsvinger, Statistics Norway. **3:** 116.

interviewees was about the possibility to overrule the automation system in case of emergency.

**Findings:** The management boards of the condominium in Norway are one important, and under-appreciated, actor for the automation of charging in shared garages. They have emerged from a democratic tradition in which the boards are elected as representatives by apartment owners. This is typically not a paid job, but a voluntary role. Achieving successful integration of smart charging in the use of EVs required a range of different strategies. The material and social elements around urban residential communities figured in important ways, such as how local charging infrastructure were developed, and which users were involved in which decisions. The mobilisation of external experts and local electricians, who stated that EV charging is something everyone should have access to, also influenced the EV transition in Norway.

### FLEKSHOME: DLC OF SLOW LOADS IN PRIVATE HOMES

The Norwegian smart home pilot features smart hubs that can control slow loads like electric devices such as floor heaters, heating pumps and hot boilers. The household participants receive the smart home equipment for free, as well as access to the future home app in which they can customise their own set-ups and add other smart house equipment. The app has the possibility to allow the user to gather all smart home requirements that are using Z-wave and Zigbee, including smart locks, to heating, lighting, fire detectors and security. In this pilot the *Futurehome* hub and app are used as a interface to the devices that are set up to be controlled remotely, where the users receive a notification when the DLC is supposed to happen and they can decide to opt out if it does not suit them. The user can also choose, if they wish, to use the app to optimise their own electricity consumption.

The pilot aimed to automate the power consumption of the users by fleet management in a specific geographic area. They aim to recruit 200 households; households with smart hubs controlling floor heaters, heat pumps and hot boilers are the most common. The home users get the smart home equipment for free by joining in on the pilot. The grid companies that are the project leaders have sold it to the users as an automation project.

The original research reported in this project includes: 5 in-depth interviews of pilot participants, 1 group interview of 3 installing electrician, 1 in-depth interview smart home deliverer, 1 in customer service. The trial has been delayed. As of September 2021, the system was up and running for initial testing at only a few homes.

## 5.3 Lessons learned

**Findings from the case studies**

- EV charging is 'low hanging fruit' when it comes to automation. However, there is a need for the user and the DSO to collaborate and better align their goals. There are different acts and regulations in Norway that facilitate EV charging. There are also initiatives striving to include EV charging as a part of the Norwegian Building Acts and Regulations (TEK-17).
- Those working on the customer service side, as well as electricians, have a lot of **tacit knowledge that the DSO could use in establishing trust for automation.**
- It is mostly **men** signing up for pilot studies. This means that the recruitment strategies need to be made more inclusive, including to get women on board.

- It may be possible to implement smart charging and secure large volumes of flexible EV charging without the need for the user's active participation or behaviour change beyond opting in to it.
- Smart energy solutions like infrastructure investment for EV charging in private spaces must rely on local anchoring such as a system that provides equal access to charging for everyone living there.
- Smart charging enables practical and material means of engaging with grid flexibility, and can impact user motivation to become a prosumer.

**Policy recommendations**

- Radical changes in tariff schemes, like a transition from cumulative energy bills to power tariffs, cause a need for users to employ new strategies and tools in order to be 'compliant'; i.e. to avoid being punished by the prices. It is up to the market to deploy these solutions, but development is slow and reliance on user competence is extremely high.
- Public and fast chargers should have the same simplicity to ensure user-friendliness as a petrol station.
- Smart meter connection to HAN may be a part of the automation of the household level. Our early adopters highlighted that the HAN port in the Norwegian meters had too little electricity capacity and the smart meters needed multiple HAN ports.

**Future trial and research needs**

- Ensure a multiplicity of user roles (and their associated perspectives, interests and requirements) are included in the early design and realisation of solutions.
- More research on why people do not opt in.
- More research on who the technology is including and excluding.

# 6. Sweden

- Sweden's energy supplies are dominated by a mix of hydro and nuclear power, like Austria and Switzerland. Wind energy and DER, such as solar PV and battery systems are rapidly increasing in uptake; whilst the share of electricity used for heat pumps and electric vehicles are expected to increase substantially. These changes have increased the need for demand flexibility from schemes such as automated DSM to match intermittent renewable supply with highly increasing demand from the electrification of heating and transport sectors.

- **Goals:** automated DSM is integral to the Swedish energy plan, which includes substantial energy efficiency goals to meet the objective of 100% renewable electricity production by 2040.

- **Context:** peak load management, distribution capacity constraints and the increasing need for flexibility as part of the energy transition and digitalisation are the major drivers that fastened the automated DSM/DR trials with different actors and business models. Substantial subsidies for zero emissions vehicles are also rapidly driving their uptake. Sweden was an early adopter of first-generation smart meters.

- **Policy discourse:** a history of centralised generation (nuclear and hydro) means that many view flexibility as a transition pathway to carbon neutrality, rather than a pressing need.

- **Limitations of evidence presented:** The case study includes findings from the roll-out of second wave of meters, which is still underway at the time of reporting.

## 6.1 Background

The main source for compiling the information in this chapter is the Swedish Energy Agency, which is responsible for collecting official energy statistics in Sweden.

**Population**

The population of Sweden is 10,395,160. Most people live in the three major cities Stockholm (975,551), Göteborg (583,056) and Malmö (347,949).

The total area of the country is 528,447 km$^2$, making it the fifth largest country in Europe and roughly the same size as California.[88]

Sweden has the 6th highest per capita consumption of electricity in the world[89]. This is partly due to cold winters and continuous economic growth. Other reasons are political decisions made during the 1970s. Electric radiators were installed in Swedish homes, creating a demand for nuclear power implementation. Also, the international oil crisis encouraged electric heaters in the early 1980s. The national Swedish trend of increased electricity usage for heating and warm water lasted until 1990 and then decreased, partly due to frequent installations of more energy-efficient solutions such as heat pumps.[90] To this day, heating (including hot water) represents more than half of the energy used in Swedish homes and buildings. In small residential houses, the most common energy source for heat is electricity, while district heating is the most frequently used source in apartment blocks.

**Energy mix**

Hydropower and nuclear power dominate the power production mix in Sweden, with around 40% each. Wind power and combined heat and power produce around 10 percent each. The production from solar energy is still small - about 0.2%, but it is increasing. Each winter Sweden will have a few very cold days, during which the energy system is especially strained and power from coal power plants may need to be used. Sweden also imports nuclear power, biofuels, oil and natural gas.

The heat market produces 100 TWh yearly. Sweden's well-developed district heating systems enable the country to utilise energy resources, such as waste heat from industry and energy from the recycling of waste. Combined heat and power ensures the best possible use of these resources. In district heating, only 6% of fuels come from fossil resources; the rest is made up of renewable energy (42%) or in different ways recovered heat.[91]

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[88] https://sweden.se/life/society/key-facts-about-sweden
[89] https://www.energiforetagen.se/in-english/
[90] See Wallsten, A., 2017. *Assembling the smart grid: On the mobilization of imaginaries, users and materialities in a Swedish demonstration project* (Doctoral dissertation, Linköping University Electronic Press)
[91] https://www.energiforetagen.se/in-english/
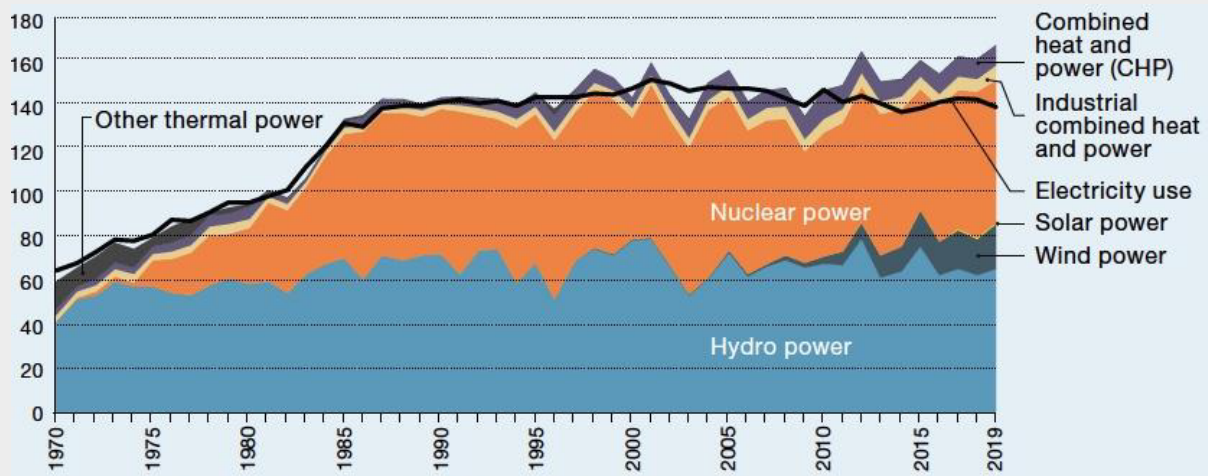
Figure 16: Sweden's electricity use (TWh) and generation by type of power 1970-2019 (source; Swedish Energy Agency and Statistics Sweden)

The amount of energy supplied to the Swedish energy system has been about the same since the mid-1980s, between 550 to 600 TWh per year. In 2019 the total energy supply in Sweden amounted to 548 TWh.

During the last 40 years there has been a 300% increase in the supply of biofuels. Conversely, the supply of crude oil and petroleum products has decreased by more than 50%. This is largely explained by residential buildings rarely using oil for heating today. Also, the supply of wind power has increased in the last decade. Although wind power still accounts for only a small part of the total energy supply, it is beginning to play an important role for the electrical system. More and more solar PV cells are being installed in Sweden. Between 2019 and 2020, the number of grid-connected solar PV systems increased by 50%. By the end of 2020, the total number of systems in Sweden amounted to almost 65,819 with a total installed power of 1,090 MW. The use of petrol and diesel in Sweden has decreased by 75% over the past fifteen years.

The electricity system in Sweden has historically been built on large scale, centralised production (hydropower and nuclear power) with an electricity flow from producer to consumer.

Because of a greater use of wind and solar power, decentralised and variable generation within the electricity system has increased. This imposes new demands on flexibility due to the need for a balance between generation and consumption in the electricity system. The electricity grid also requires improvements as consumers can now produce electricity, forcing flows in both directions. Energy prices for household customers were relatively stable during the second half of the 1990s and then increased significantly during the first decade of the 2000s. Increasing fuel prices and energy taxes are the main reasons for the increasing prices.

**Challenges in the Swedish energy system**

Swedish energy policies aim to promote ecological sustainability, competitiveness, and security of supply. Sweden's climate goals include being net carbon zero by 2045[92], while its energy policies are strongly influenced by EU regulations. The main strategy for reaching climate goals in Sweden is related to electrification of industrial and transport sectors. As other countries are experiencing, there are various challenges related to this strategy. From a grid perspective, **energy consumption is too high, and too concentrated around particular times of the day, week, and year.** In combination with more wind and PV power in the grid it can become more challenging to handle security of supply and electricity.

Swedish energy politics are to a large extent governed by the same basic pillars which direct the EU collaboration. The policy aims to combine security of supply, competitiveness, and ecological sustainability. The energy policy is directed towards creating conditions for efficient and sustainable energy use and a cost-effective Swedish energy supply with a low negative impact on health, environment and the climate, and facilitate the transition to an ecologically sustainable society. The Swedish parliament has decided on these goals because of the energy agreement:

- The goal in 2040 is 100% renewable electricity production. This is a goal, not a stop date that bans nuclear power, nor does it mean a closure of nuclear power with political decisions.
- By 2030, Sweden will have 50% more efficient energy use compared with 2005. The goal is expressed in terms of supplied energy in relation to gross domestic product (GDP).

**Capacity of the electric grid**

Like other European jurisdictions, electricity use in the industrial sector is assumed to increase, which is largely driven by the need to phase out fossil fuels to achieve climate goals. Increased digitalisation means increased electricity use in data centres.[93] The transport sector is also expected to increase electricity use, which means a more efficient sector. As this development progresses, it becomes important to ensure a sustainable production of batteries.

The increased demand for electricity and the increased share of intermittent (variable) power will pose new challenges in the new electricity system. Therefore, it is important to create conditions to meet the demand for electricity in a cost-effective and sustainable way and with high acceptance in society. The electric grid is being expanded. In some areas it is strained due to insufficient capacity. This insufficiency is due to factors such as an increased population, and the electrification of the transportation sector.

There is increased pressure on the Swedish electricity market. One reason that is highlighted is that the production of electricity takes place in the north, and that the transmission possibilities to southern Sweden are too small, at the same time as it is where

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[92] https://unfccc.int/news/sweden-plans-to-be-carbon-neutral-by-2045
[93] Scenarier över Sveriges energisystem 2020". ER 2021:6. Energimyndigheten 2021

the demand for electricity is greatest. But there are also other difficulties, such as how electricity should be sufficient when industry is electrified and how electricity supply should be secured when an increasing proportion of electricity is produced with solar and wind power that cannot be planned. Many believe that part of meeting the challenges in the electricity market is to take advantage of Swedish households' ability to adapt their consumption. Automated DSM for households in Sweden has only been tested to a small extent and there are no conclusive results yet regarding how the issue of trust is perceived. Risks identified in connection with automated DSM in Sweden are that the energy meter could be hacked; platforms managing flexibility on a system level could be hacked; services for smart homes stand in the way of electricity companies making load forecasts; and intentional or unintentional manipulation of the market.[94]

**Key moments that have shaped regulatory decision-making in recent years**

Agenda 2030 established in 2015 as well as the Swedish environmental goals[95], which are annually being reviewed, shape regulatory decision-making in Swedish society.  Subsidies for installing PVs have driven the uptake of private solar production in Sweden. The increase in PV systems has been rapid in recent years. At the end of 2018, there were 25,486 grid-connected plants in Sweden, which is an increase of 10,200 plants since 2017. Consequently, the installed capacity has also increased, from 231 MW in 2017 to 411 MW in 2018. In percentage terms, this is an increase of 67% of plants and 78% of installed capacity in one year.[96] Previously it was possible to receive subsidies for private investment in PV, which has been a driver for households' investments.

The recent tax reduction for the purchase of new EVs has driven the electrification of the transport sector. On 1 July 2018, the five-year vehicle tax relief for cars previously called 'green cars' was removed, and the 'reward for super green cars' was replaced by a bonus for low emission vehicles ('klimatbonusbilar'). For zero emission vehicles the maximum bonus is SEK 70,000.[97]

The Swedish Energy Markets Inspectorate (a governmental agency) has formulated new requirements for functions of electricity meters in Sweden. These new requirements will be applied from 2025.

**Smart meter roll-out and coverage**

**Sweden rolled out smart meters as one of the first countries in Europe to do so,** with the first regulation adopted in 2003. This led to a roll-out of the first generation of smart meters in 2009.[98] In 2014 the governmental inquiry and an action plan for smart grids was published, called 'Plan for power!'.[99] The work with the inquiry started in 2012 when the Swedish Government decided to appoint a Coordination Council and National Knowledge

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[94] https://energiforsk.se/media/29481/digitalisering-for-efterfrageflexibilitet-energiforskrapport-2021-737.pdf
[95] https://www.sverigesmiljomal.se/
[96] http://www.energimyndigheten.se/fornybart/solenergi/solceller/
[97] https://www.transportstyrelsen.se/bonusmalus
[98] Huang, Y., Grahn, E., Wallnerström, C. J., Jaakonantti, L., & Johansson, T. (2018). Smart meters in Sweden-lessons learned and new regulations. *Current and Future Challenges to Energy Security*, 180.
[99] https://www.regeringen.se/rattsliga-dokument/statens-offentliga-utredningar/2014/12/sou-201484/

Platform for Smart Grids. The work of the Coordination Council covered smart grid solutions all along the value chain, from the connection of power stations to new energy user services, such as smart solutions for the home. The coverage of the first smart meters in Sweden is now complete. In 2020 DSO Ellevio carried out the roll-out of the second generation of smart meters in Sweden. These had improved functionality, higher resolution of data and improved possibilities for third parties to connect. In June 2021 the Swedish government decided that all meters would be replaced with the second generation. All households will, in this way, have a meter with hourly measurement of electricity. The new meters will also allow households to view their own consumption.

Major pilot projects for residential areas where the first generation of smart meters were implemented include Stockholm Royal Seaport (Stockholm), Hylie (Malmö) and Smart Grid Gotland (Gotland).

There seems to be a lack of a common definition of smart meters in Swedish policy documents. However, there are common and recurring themes in the description of smart meters. This quote from the Swedish Energy Market Inspectorate, published in a scientific conference paper, captures how smart meters are usually described in Sweden:

> *The electricity meter is the bridge that communicates the supply side and the demand side. Meters provide consumption data to the demand side that in combination with price signals can be used to activate the flexibility of loads. At the same time meters provide information from the demand side to DSOs and to the electricity market. The development of smart meters will enable the integration of more renewable production and empower the demand side. It also increases the possibilities to evaluate DSOs' investments and to evaluate the impact of flexible load. However, with development of data analysis techniques and different needs in the meter market, there are different levels of smartness of smart meters available on the market. For example, some smart meters can offer real-time consumption data and dynamic tariffs to customers. From a regulatory point of view, it is important to continuously and carefully adapt the regulation to accommodate these challenges whilst fostering fair competition for digital solutions.[100]*

Although the automation of flexibility for households has not been implemented, there are a few pilot projects addressing this, e.g. the EU project CoordiNet[101].

## 6.2 Case study

**ELLEVIO**

The purpose of the research project is to study the introduction of the second generation of smart electricity meters and smart grid technology in housing through behavioural scientific methods, focusing on differences in households. The project aims to create knowledge

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[100] Huang, Y., Grahn, E., Wallnerström, C. J., Jaakonantti, L., & Johansson, T. (2018). Smart meters in Sweden-lessons learned and new regulations. *Current and Future Challenges to Energy Security*, 180.
[101] https://coordinet-project.eu/pilots/sweden

about how technology for smart grids should be designed and implemented to fit into people's everyday lives.

As private households frequently are referred to as an untapped resource for demand flexibility, the project will examine how demand flexibility and associated technology are integrated in peoples' homes. The purpose is to study the introduction of smart electricity meters and smart grid technology in households. This is done through a behavioural science methodology, focusing on how different types of households are affected by the technology. The empirical core is a case study of Ellevio's (a leading DSO) roll-out of 4000 new smart meters in the pilot area of Älvsjö in Stockholm. A mobile app (by Ellevio in collaboration with the technology provider Bright) is made available to households in order for them to view their electricity use.  Interviews and observations are made of different types of households living in their own small houses. The results of the project are intended to be used by researchers, the energy sector, service developers and authorities to introduce smart grids in private households.

The project also studies stakeholders' views of the role of households in the smart grid and how this corresponds with everyday practices and the lives in the home. Research questions regarding households are, for example:

- What are the implications of the heterogeneity of households for the use of smart energy technology?

- What is the role of technology in the home for households to participate in DSM?

- What are the values for households in balancing their use of electricity?

To study stakeholders' views of households' roles the research project has interviewed people representing the pilot implementation project, the service developer and the Swedish Energy Markets Inspectorate. Policy documents focusing smart grid development and DSM in Sweden have also been studied.

The smart meters have been installed by Ellevio and One Nordic. Sagemcom manufactured the meters and Telia provided the infrastructure. An app created by Bright was made available to households in May 2021. Other technical components have been installed by households themselves, including home automation.

## 6.3 Lessons learned

The analysis from the Ellevio case is still ongoing, however preliminary results from the study are available. These are divided into two basic categories:1) results from a review of policy documents regarding stakeholders' expectations of households in the smart grid, and 2) results from interviews and observations of 16 households, living in small houses where Ellevio's second generation of smart meters have been installed.

The literature review includes 32 documents published in Sweden 2013-2021. A majority are published within or are linked to a parliamentary inquiry on smart grids in Sweden (Swedish

Smart Grid). To guide our analysis of the literature we used the framework 'What's the Problem Represented to Be?' (WPR), formulated by Bacchi[102].  Through this, imaginaries emerge highlighting households as part of a solution to a socio-technical problem. Aligning with prior research, our results show that solutions including households frame them as an untapped potential waiting to be utilised yet willing to be informed about everyday energy use. They are assumed to be flexible with heating, although it is unclear whether comfort will be impacted. Households' loads are also envisioned as something to be controlled voluntarily, by automation or by handing over the control to an external actor, preferably motivated by price signals. Working backwards we derive problem formulations including serious gaps and silences for stakeholders and policy-makers of smart grid development to address. Although the concept of trust was mentioned, it was not attributed a major role. The same holds for sustainability: even though environmental sustainability is often mentioned as a major motive for smart grids, it is rarely highlighted as a motive that could motivate people to participate in the energy system. On the other hand, the emphasis on maintaining comfort for households is a recurring theme, which implies striving to maintain the same high indoor temperature as people have become used to. This, of course, has implications for the sustainability of the smart grid.

Preliminary results from the case study reveal that there is a heterogeneity of households regarding the homes they create and how these relate to knowledge, energy use, environmental awareness, smart technology, phase of life, and the routines of everyday life. Although the participants of the study were recruited from the same neighbourhood, differences between their homes were striking.

**Further research** will involve constructing home personas, i.e. personas on the level of the home instead of the individual level. So far, we have identified four home personas: 1) the aged and 'good enough' home; 2) the conserving and sustainable home; 3) the optimised experimental workshop; and 4) the sober average Swede home. In communicating details of these home personas to designers, service developers and other smart grid stakeholders we intend to establish a common ground for the inclusion of heterogeneity in further development of the smart grid. Future research involves the design of methods for the involvement of different types of homes and households in smart grid development.

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[102] Bacchi, C. (2009). *Analysing policy*. Pearson Higher Education AU

# 7. Switzerland

- As part of the Swiss energy transition, the number of installations of DER, such as solar PV and battery systems, as well as other low carbon technologies such as heat pumps and electric vehicles, are expected to increase substantially. These changes have increased the need for demand flexibility from schemes such as automated DSM to match intermittent renewables with highly increasing demand from the electrification of heating and transport sectors.

- **Framing:** Demand flexibility via automated DSM schemes and programs is at the heart of the success of unlocking DER for sustainable energy transition in urban systems.

- **Goals:** The benefits of the automated system include avoiding load congestion, coping with over-generation and network losses due to high penetration of PV and shaving increased peak demands and stress on the grid expected due to electrification of heating and transport.

- **Context:** The increasing need for flexibility as part of the energy transition and digitalisation are the major drivers that fastened the automated DSM/DR trials with different actors and business models.

- **Discourse:** Many from both industries and utilities are aware the flexibility does not have a value now, but there is no transition pathway to carbon neutrality without demand flexibility. Digitalisation, through e.g. smart meters, has not been fully achieved. There is a lack of business models in decentralised systems on how to govern flexibility.

- **Major limitations of evidence analysed in the profile:** Major limitations include i) lack of digitalisation (6% owning smart meters), and high costs installations of energy management systems; ii) lack of value of flexibility, or if there is the quantification of values of flexibility in different markets; iii) lack of optimisation tools; and iv) lack of business models in utility companies.

## 7.1 Context for automated DSM

**Population and housing**

Switzerland, officially the Swiss Confederation, is a landlocked country situated at the confluence of western, central, and southern Europe. It is a federal republic composed of 26 cantons, with federal authorities based in Bern. The population of Switzerland is 8.5 million

concentrated mostly on the plateau, where the largest cities and economic centres are located, among them Zürich, Geneva, and Basel. There are 4.6 million private households in Switzerland comprised of 1.1 million single-family houses and 3.5 million multi-dwelling apartments and condominiums. 57.4% are occupied by tenants or sub-tenants; 2.9% are owned by cooperative members; 11.7% are owned by condominium/apartment owners; 24.6% are owned by house owners; and 3.3% are comprised of employee accommodation.

**Energy mix**

According to the Swiss Federal Office of Energy, petroleum and other fuels are the main sources of energy in Switzerland (50.6%), followed by electricity (25%), gas (13.5%) and wood (4.4%). Electricity is mainly generated by hydropower (59.9%), nuclear power (33.5%) and conventional thermal power plants (2.3%, non-renewable) and renewables sources of wind (0.2%) and solar power (3%).

The shares of the transport and household sectors in TFE demand remained approximately at 37% and 28%, respectively. Swiss service and industry sector accounted for 17% and 18% of the final energy consumption. For electricity, the largest sector consuming electricity was in 2019 was households (33.4%), followed by industry (30.2%) and the services sector (26.8%). The transport sector and agricultural sectors consumed 8% and 1.6% of the total electricity consumption.  The electricity consumption of households was used mostly for heating space and hot water production (35.1%). Processes (which includes the use of refrigerators/freezers, washing machines and dishwashers) constitute 22.4% of the household's electricity consumption; air conditioning and ventilation constitute 6.8%. In 2019, there were 327114 heat pumps in Switzerland, with a power consumption of 1,233 MW. The fleet of electric vehicles was 28 719 in 2019, which constituted only 0.6% of the total fleet of passenger vehicles in Switzerland.

**Challenges in the energy system**

Following the nuclear disaster of 11 March 2011 in Fukushima, Japan, the Swiss Federal Council instructed the Federal Department of the Environment, Transport, Energy and Communications (DETEC) to examine the energy strategy and update long-term planning and strategy documents. These documents, especially the *Energy Outlook 2035,* have been regularly revised since the 1970s. After several debates and revisions, a new Energy Act was adopted by Swiss voters with 58.2% of the vote in a referendum in 2017.  Based on new scientific findings published by the Intergovernmental Panel on Climate Change, the Federal Council at its meeting on 28 August 2020 decided to set an even more ambitious target: Switzerland plans to reduce its net carbon emissions to zero by 2050, thus meeting the internationally agreed target of limiting global warming to a maximum of 1.5°C when compared with the pre-industrial era.

The Energy Perspectives 2050+ (EP 2050+) analyses how to develop an energy system that is compatible with the long-term climate goal of net-zero greenhouse gas emissions by 2050 and, at the same time, ensures a secure energy supply. Several variants of this scenario are considered (Figure 17). They differ in their combination of technologies and the speed of the renewable energy transition in the electricity sector.
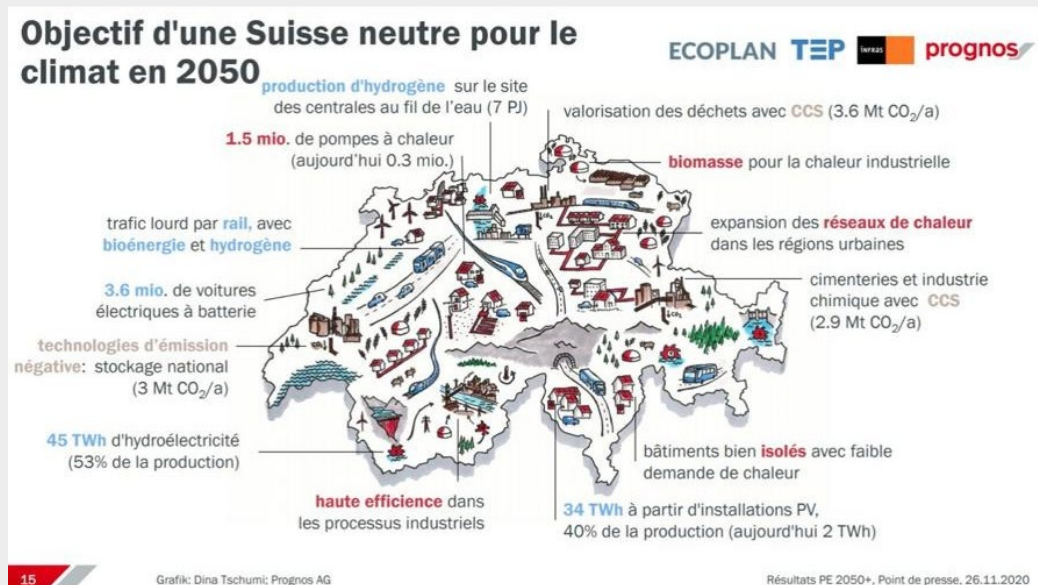


Figure 17: Swiss scenarios to reach zero GHG emission 2050

According to the new Energy Act, Switzerland aims to introduce energy efficiency to reduce final energy demand per capita by 43% and 54%, with renewable energy technologies (excluding hydropower) contributing 14 to 25% and 42% of electricity generation by 2035 and 2050, respectively. The large-scale deployment of rooftop PV is foreseen in the following years. Also, 1.5 million heat pumps are envisaged to be installed (now 0.3 million) and 3.6 million EVs (now only in thousands) will be in the usage to the grid by 2050.

The small-scale production of renewables such as rooftop PV and low carbon technologies such as heat pumps, EVs are distributed throughout urban areas where people live, commute and work. Inevitably, these forces are reshaping the urban energy systems towards more user-centred systems. Far more consent and engagement of energy users will be needed than ever before. This includes gaining planning permission for new distributed assets, automation of devices such as heat pumps and EVs, and trust in the responsible collection and use of energy data.

The self-consumption communities (ZEV/RCP)[103], in which people (e.g. households, municipalities, or commercial enterprises) join to share electricity, are increasing. Typically a PV system is installed on one of the buildings and the participants within spatial proximity

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[103] The new rules for implementing groupings for self-consumption in force since 1 January 2018 (loi sur l'énergie art. 16-18).  RCP stands for 'Regroupement dans le Cadre de la Consommation Propre (RCP) and ZEV stands for ZEV (Zusammenschluss zum Eigenverbrauch).

can use the self-produced electricity. The community is wired through a single coupling point.

It is evident that people are increasingly playing more active roles than mere consumers, becoming prosumers by investing in PVs and storage capacities (batteries, hot water tanks) therefore producing, storing, and trading energy services with multiple parties via emerging digital technology platforms. **This highlights a change in paradigm as the transition from centralised fossil energy to decentralised renewable energy systems.** Such decentralisation introduces new challenges for the operation and governance of urban energy systems. A rescaling of operating and governing activities, and an increase in both the number of actors, technology, and in socio-technical complexity of the overall system are foreseen.

In this context, as expected**, the greatest challenges are associated with the management of the distribution network.** This is due to the increasing stochasticity and bi-directional electricity flow raised from intermittent renewable resources such as PV installations on rooftops. While hydropower may still balance renewable generation at the high-voltage grid level (centralised level), imbalances between renewable supply and demand together with other related problems remain to be solved at the distribution level. Therefore, **a better coordination of flexibility resources (energy use) between buildings to match local production is increasingly required at building, district, and city scales to balance supply and demand within the electricity distribution networks.**

This contrasts with the traditional centralised system involving only the energy company-user relationship. New business models, arrangement and organisations are increasingly needed to broaden the scope of interventions to target a wider repertoire of technologies, possible investments and actors in districts and cities while aligning the interests of different actors with applicable technologies and infrastructure as a whole energy system.

**Automated DSM**

Considering the intermittent nature of the renewable technologies, demand flexibility (the capacity to adapt consumption patterns) realised through DSM is at the heart of the success of unlocking the potential of DER to avoid imbalances in distribution grid networks of districts and cities. It is vital to the operation of the distribution networks to tackle the above-mentioned challenges. Specifically, obtaining decarbonisation benefits depends on temporal alignment of heat pumps and EV charging with stochastic renewable generation to avoid the operation of fossil fuelled plants at peak times. Utility controlled DSM schemes (i.e. DLC) are becoming increasingly attractive to ensure a fast-acting and reliable system responsiveness in decarbonised and decentralised energy systems.

**Key points:**

- *Swissgrid*, a monopoly company established through liberalisation reforms in 2005, plays the role of Transmission System Operator (TSOs). Its role is to keep the demand and supply physically in balance after the market close (i.e. gate close) in the transmission grid with its balancing markets (e.g.: balancing services, voltage control, redispatch). The three roles, DSO, electricity supplier and producer can be present at the utility level, but they are completely unbundled inside. The overall benefit is in the foreground even though unbundling should be always respected.

- **Direct load control via ripple control systems**: Several DSOs carrying automated DSM practices for approximately 50 years with authority to use their ripple control on demand side resources. All the electric water heaters and the heat pumps were already switched off during constant and pre-configured time intervals (boilers mostly daytime, heat pumps only during midday time) via the ripple control signal of the DSO. Currently these do not consider current market prices or customer self-interest/comfort limits. The current revision of the energy law foresees an obligation to ask the owners of the assets that should be controlled (e.g. the respective customers) for consent and remunerate them adequately for participating in ripple control.

- **The extent of smart meter adoption coverage is low.** The Swiss Federal Office of Energy (SFOE, 2015) reported the share of Swiss households equipped with smart meters at 2% in 2015. According to the latest statistics from the Swiss Household Energy Demand Survey (SHEDS)[1] this share is roughly 10% in 2018. The Swiss government has nevertheless planned a general roll-out with a law stating that the proportion of smart meter-equipped consumers from all sectors (residential, service and industry) must reach 80% by 2027.[1]

- Pilot studies that focus on residential sector mainly prosumers and energy communities (in Swiss terms RCP/ZEV) are emerging to explore potential approaches for future grid challenges in the distribution grids.

- Third parties, thanks to the digitalisation (smart meters and new platforms) and new regulations, are emerging as 'Aggregators' of flexibility to participate in balancing markets, for example, by taking the role of ancillary service providers.
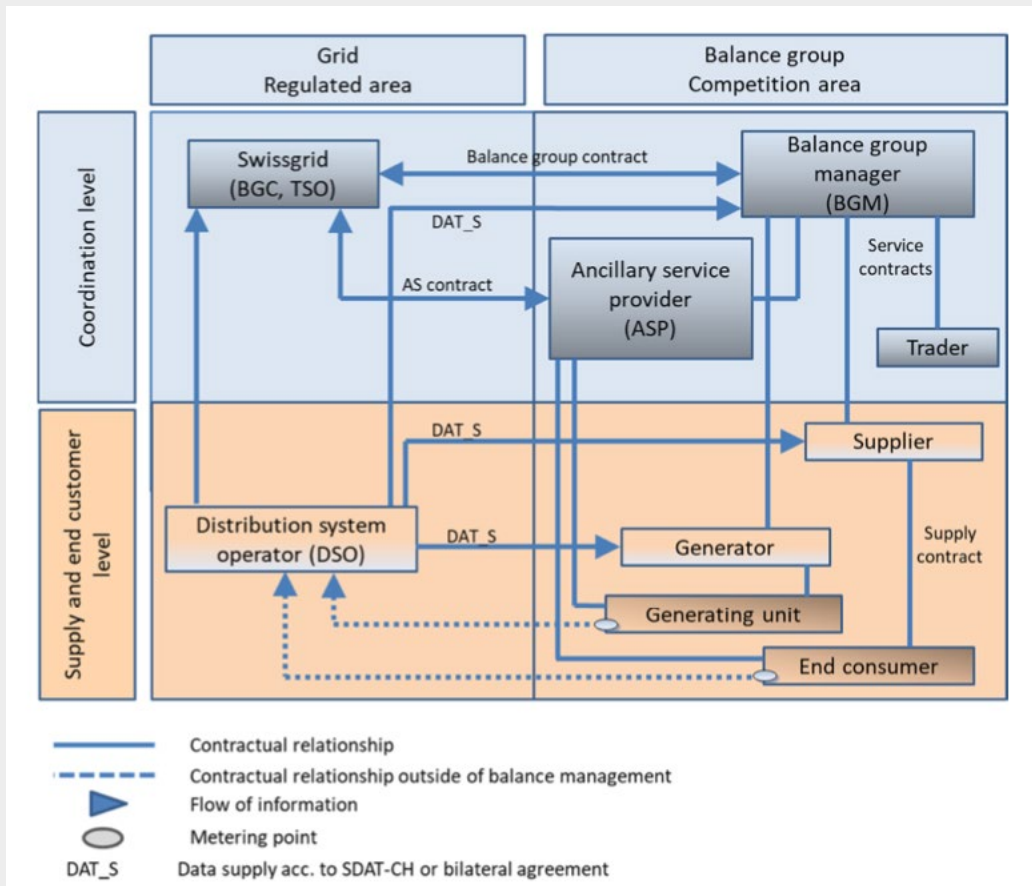
Figure 18: Key roles in Switzerland's electricity sector (source: https://www.strom.ch/)

**Acceptance of automated DSM**

There are several surveys that have measured the acceptance rate of automated DSM in Swiss residential sector (please see Annex for the full list and description). Figure 19 shows the acceptance rate measured by different survey conducted in Switzerland for several appliances. Pilot projects however show lower numbers. It varied between 28% to 50% which were mostly the automation of heating systems.
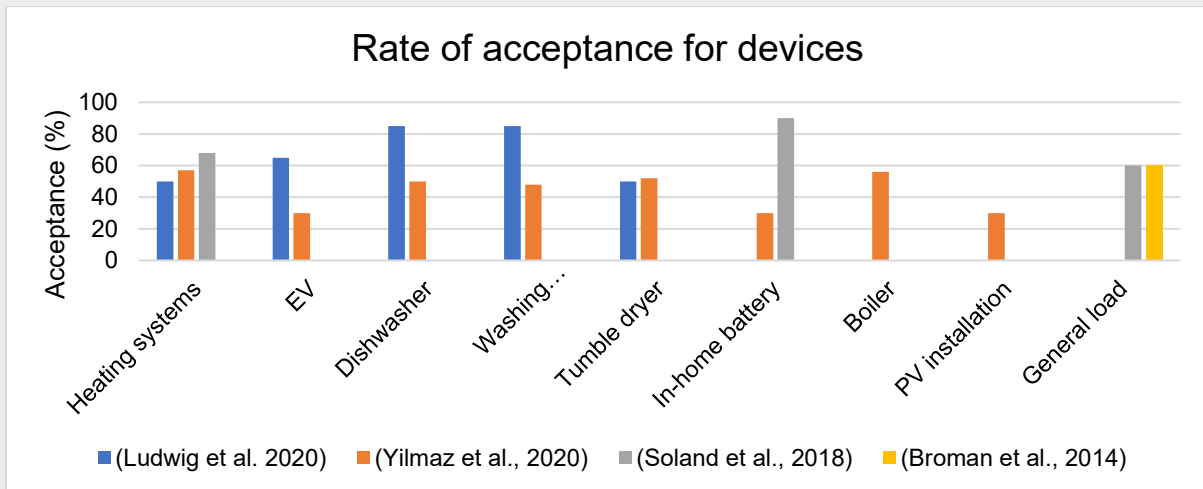
Figure 19: Automation acceptance rate measured by different survey conducted in Switzerland

In terms of privacy concerns and trust, there is little evidence that this is a major concern. One survey in Switzerland found that there has a broad consensus between end-users regarding the fact that data should be protected from other parties and that providing data to the utility should a deliberate choice from the end-users rather than mandatory.[104] Some end-users expressed, regarding data security, that they are ready to trust the energy providers if they are public actors (since those are owned by municipalities). Also, participants suggested that utilities should listen to the consumer's needs regarding privacy and autonomy as well as communicate transparently. The study of Corinne Moser[105] also observed that people are not so aware about risks of data security, but it recommends that utilities should not, under any circumstances, try to hide those risks and should instead inform people about them.

## 7.2 Case studies

This section presents the pilot projects implemented and currently being implemented in Switzerland performing automated DSM by third parties (e.g. utility companies). Table 4 presents the summary of documented experience from Switzerland regarding the automated DSM collected via surveys (experimental research) and pilot projects implemented in Switzerland.

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[104] Soland, Martin, Stefan Loosli, Julia Koch, et Oliver Christ. 2018. 'Acceptance among Residential Electricity Consumers Regarding Scenarios of a Transformed Energy System in Switzerland—a Focus Group Study' *Energy Efficiency* 11(7): 1673-88. https://doi.org/10.1007/s12053-017-9548-x
[105] Moser, Corinne. 2017 'The Role of Perceived Control over Appliances in the Acceptance of Electricity Load-Shifting Programmes'. *Energy Efficiency* 10(5): 1115-27. https://doi.org/10.1007/s12053-017-9508-5

Table 4: List of Pilot Projects in Switzerland

| | Project name | Project partners | Date | Appliances Automated | Purpose of the automation in the pilot project | Size/scale |
|---|---|---|---|---|---|---|
| 1 | Decentralised flexibility | Groupe E, University of Geneva | 2020-2022 | electric boilers, heat pumps, EVs | To decrease the network costs and congestion by automating the devices | 45 heat pumps and electric boilers in single family houses and multifamily flats |
| 2 | Innovative self-consumption optimization for multi-family area development with local electricity exchange | Setz Architektur AG<br><br>FHNW (Fachhochschule Nordwestschweiz), RTB Möriken-Wildegg | 2017-2022 | heat pumps, EVs, washing machine and dishwasher | To increase the part of local PV consumption by automating heat pumps by storing thermal energy in the buildings and automating the household appliances as well as the EV charging stations and reduce energy costs | 35 multifamily flats in 4 buildings (4 heat pumps, one EV charging station, 70 mixtures of washing machines and dishwashers) |
| 3 | Quartierstrom | ETHz, EW Walenstadt | 2017-2020 | Decentralised community battery | Maximise the self-consumption of the community by automating the community battery to decrease exports and imports and keep the PV production consumed in the community | 37 households (28 of them prosumer with rooftop PV), 8 battery (one decentralised shared by 4) and 7 other private in-home batteries (not automated) |
| 4 | GoFlex | ESR (Energie de Sion-Région), HES-SO Valais | 2016-2020 | Heat pumps, electric boilers, electric heaters, EVs | To provide (buy/sell) flexibility to the built local flexibility market for the DSO to reduce the corrective costs (day-ahead and intra-day market), and shave peak loads to avoid congestion. | 195 single family households<br><br>6 EV charging station |

**Table 2 continued. List of pilot projects in Switzerland**

| | Project name | Project partners | Date | Appliances Automated | Purpose of the automation in the pilot project | Size/scale |
|---|---|---|---|---|---|---|
| 5 | Luggagia Innovation Community | Supsi (*Scuola universitaria professionale della Svizzera italiana*), AEM (Azienda Elettrica Di Massagno) , Hivepower, Municipality of Capriasca | 2018-2022 | Electric boilers, decentralised community battery | To maximise the self-consumption of the community by decreasing evening peak, increasing afternoon consumption aligned with the PV electricity production and storing the difference with the district scale battery by charge and discharge | 17 single family households (3 of them were prosumer with rooftop PV), 1 kindergarten with a rooftop PV installation |
| 6 | Warm-up | Ewz (Elektrizitätswerk Der Stadt Zürich), Misurio AG | 2016-2018 | Heat pumps, electric boilers | To provide and optimize flexibility holistically for cost minimization at day-ahead & intraday market, minimization of network charges and congestion as well as for renewables in the future and increasing the energy efficiency and the self-consumption of the buildings themselves. | 4 zone (15 buildings with 22 hot waters fed by 9 heat pumps) |

| 7 | Tiko-BeSmart | Tiko | 2014-commercial | How water boiler, heat pumps, electric heaters, night storage heaters | To provide provide ancillary services to the TSO (Transmission System Operator) such as frequency containment reserves (FCR) and automatic frequency restoration reserves (aFRR). | 6,000 devices (50% heat pumps) in single family houses. |
| 8 | OKEE | Novatlantis gmbh, PSI (Paul Scherrer Institut), ADEV Energiegenossenschaft, ZHAW (Zürcher Hochschule für Angewandte Wissenschaften), Stiftung Habitat, Smart Energy Control GmbH | 2019-2021 | EV sharing | To reduce grid charges (by lowering monthly peaks), and secondly use residual flexibility to generate additional revenues, by selling balancing energy | 2 smart charging stations with 2 EVs for sharing with V2G capability |

## DECENTRALISED FLEXIBILITY

This project is a collaboration between the University of Geneva and Groupe E, the regional DSO of Fribourg et Neuchâtel. The project started in 2020, will end in 2022, funded by the Innosuisse (Swiss Innovation Agency). It aims to develop and demonstrate the feasibility of DLC programs as a service to harvest demand flexibility incorporating an interdisciplinary approach. The novel approach integrates solutions by thorough surveys among the real residential customers of the DSO, and then a trial allowing the identification of the automation programs that maximise not only customer acceptance and satisfaction but also flexibility within the distribution networks. The purpose of the automation of electric boilers (used for hot water), heat pumps and EVs is to decrease the network costs and congestion by automating the devices in certain times of the day.


Figure 20: Aerial View of Decentralised Flexibility project site

First, a survey among 556 households, from the DSO's customer database, was conducted to understand the acceptance and preferences of the households for the DLC of heat pumps and EVs and integrating the socio-technical factors in consumer preferences and engagement such as perceptions, motivations to develop programs tailored to increase the adoption of such DLC programs. According to the results of the survey in terms of preference for the design of a DLC program, several services as a DLC program were offered to the customers of the DSO. In the survey, the rationale for automation to be communicated to users was also tested before recruiting households. The rationale which resonated the most, 'deploying DLC programs to better manage situations of high network demand and lowering the network usage rates' was then communicated with households to recruit them via letters and emails for the pilot project.

The DSO Groupe E controls automated flexibility activation alone and owns the smart meters and remote switching devices to control the heat pumps, electric boilers in the pilot project of 45 households (EVs will commence later in 2021). The DSO switches the electric boiler for at least 6 hours per day, all year round, but may vary switching on times depending on network needs. For heat pumps, the DSO can curtail the heat pump for a maximum of 2 hours per day depending on the network situation. They receive a reduction of CHF3 cts/kWh for each device for the first 2,000 kWh consumed. The users can see the intervention history in the customer portal.

## INNOVATIVE SELF-CONSUMPTION OPTIMIZATION FOR MULTI-FAMILY AREA DEVELOPMENT WITH LOCAL ELECTRICITY EXCHANGE

This project is a collaboration between Setz Architektur AG, Fachhochschule Nordwestschweiz (FHNW) and RTB Möriken-Wildegg, piloted in Möriken-Wildegg (Aarau). The project started in 2020, will end in 2022 and is funded by the Swiss Federal Office of Energy. A new green quarter is being built with four buildings including four heat pumps and several PV installations totalling 160 kWp. The project's aim is to have a system that manages the heating consumption of these buildings, but also 70 appliances and EV charging with real-time price electrification to maximise the PV self-consumption and minimise electricity bills. The project also has the purpose of being an innovation example in the region with the first realisation of 'real-time pricing' for solar power in a local real-world environment.



Figure 21: Aerial view of 4 apartment buildings, site of Innvoative Self-Consumption project (source: Setz Architektur AG)

End users are new inhabitants in the four buildings (pictured above) who had to accept specifically the full-automation systems for the heat pumps. The rationale for automation was communicated as 'the automation allows the increase of the self-consumption of the buildings, consuming the PV production'. During the project, a visualisation in the buildings and an application on the smartphone also motivated the users to consume local PV power by encouraging them to activate the automation mode of their dishwasher and washing machines, and EV charging. The purpose of the automation is to increase the part of local consumption by storing thermal energy in the buildings and run the appliances as well as the EV charging stations with as much solar power as possible, also leading to reduction in the

energy costs. Four smart energy system controllers drive the four buildings (appliances and heat pumps) and one is used for the parking (EVs). In total, there are 66 smart meters which are calibrated to save a value every 15 minutes; those will stay in the building as they seem to be included in the building project. Additionally, 70 actuators were installed to switch the household devices as well as a KNX connection to measure and influence the room temperatures. The local DSO is the contractor who owns the PV installation including the smart energy system, and the appliances such as heat pumps, household appliances, EV charging stations etc. belong to the building owners and households.

The DSO (RTB Möriken-Wildegg) controls the automated flexibility activation in contracting the self-consumption community (ZEV/RCP)[106], and Smart Energy Engineering GMbH is the technology provider for the optimisation of the automation. The DSO has the access to power demand of the households and communicates with the energy management systems provided by Smart Energy Engineering GMbH, which have the data of room, hot water, and boiler temperature as well as the PV production and charging of the cars. Owners of the apartments (which also includes the PV installation) have a servitude administration contract within the frame of the law for a self-consumption community[2] with the DSO, which has the rules for the automation system, in addition to their classical renting contracts. Real-time pricing is used for managing the load-shifting rather than fixed frequencies and durations; the system uses the peak hours and off-peak hours of the DSO; and PV local production price (according to the law of self-consumption which is lower than the standard costs provided by the DSO), is same for all users in the buildings.

Heat pumps are fully automated by the DSO (changing the temperatures communicating with the sensors according to the real-time prices). EV users must indicate the distance and the departure time when they plug in their EVs, then the automation systems calculate the charging power and the use of PV electricity generation if it is possible, encouraging users to charge their EVs during daytime when the PV production is high. Moreover, washing machines and dishwashers are semi-automated and are activated automatically when there is an overproduction of PV but should be manually loaded by the users, who set a pre-request for the day. The users can indicate what time the laundry and dishwasher should be finished by, and these appliances are never interrupted when they are on. An advance period is never communicated to the households.

Real-time pricing is used to influence load-shifting, and the system uses peak hours and off-peak hours of the DSO and PV local production price. Depending on the electricity mix of the self-consumption community a price is determined on a 15-minute basis, which are also visualised in real-time for the users. The peak hours tariff is equal to 21.12 Rp/kWh, the off-peak hours tariff is equal to 17.89 Rp/kWh and the solar tariff is equal to 16.81 Rp/kWh. So the ratio between the highest price and the price of PV corresponds to 0.796 and the ratio between the off-peak hours and the solar tariff corresponds to 0.939. The revenue of the whole system that uses the real-time pricing corresponds to a saving of 7.8% on the bill for end-users. The revenue allowed by the automation is shared equitably between inhabitants

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[106] The new rules for implementing groupings for self-consumption in force since 1.1.2018 (loi sur l'énergie art. 16-18). RCP stands for regroupement dans le cadre de la consommation propre (RCP) and ZEV stands for ZEV (Zusammenschluss zum Eigenverbrauch)

(considering heating surface), nevertheless the electricity consumption for appliances and EVs (including washing machines and dishwashers that can be switched into an automated mode) is calculated independently for each apartment.

In terms of information provision and data sharing and user interaction with the automation system, there is an interface in every apartment which can be seen on a smartphone also. The real-time price of the electricity, the electricity consumption, the actual consumption of EVs, the room temperature, the solar percentage of the electricity consumed for every apartment are indicated on the interface. The historical value of the consumption and self-consumption can also be seen for every apartment. The values of consumption and production directly of the whole self-consumption community are also shared as well as the history of its self-consumption, consumption, and PV exports.

## QUARTIERSTROM

This project is a collaboration between Energy Lab ETH-z and EW Walenstadt, the regional DSO. The project started in 2018, ended in 2020, and was funded by the Swiss Federal Office of Energy. It was piloted in Walenstadt, in the canton of St. Gallen. The QuartierStrom project's aim was to investigate the feasibility of a real-world P2P energy market from different perspectives: the technical feasibility, market design, acceptance and behaviour of households participating in the market, privacy aspects, regulatory hurdles and potential business models.

The users were 37 households, including one retirement home, with 470 MWh yearly consumption (28 of them were prosumer with rooftop PV and an approximate yearly generation of 250 MWh), 8 batteries (one decentralised shared by 4) and 7 other private in-home batteries (not automated). They were recruited by receiving a letter announcing the project from the local utility, EW Walenstadt, and also inviting them to an information event with the utility. The purpose of automating the community battery of 28kWh was to decrease exports and imports and keep the PV production consumed in the community and help to maximise the self-consumption of the community. This purpose was communicated as the rationale of the automation to the users, and several benefits are mentioned such as financial benefits (i.e. they will receive lower electricity bills) as well as the promotion of fair, green, and local communities as the project is all about optimising the exchange of clean PV electricity generation between the neighbours in the community. Smart meters were installed in every user's house to enable the data collection of energy consumption and production on a 15-minute basis as well as the charge/discharge of the community battery. For the control of the community battery the API of the energy system management was used through the cloud.

The blockchain system (installed conjointly with a ETHZ lab and EW Walenstadt) functioned in a decentralised way through the public grid infrastructure, giving a schedule for the battery to charge/discharge and verify if the battery owner has agreed to control the battery or not. The technology provider for the blockchain was the ETHz laboratory 'Bits to Energy Lab'. Users of the community were linked via blockchain and a trading platform from which they established a contract between themselves. It was a market rule that was led between every user with an auction mechanism or with a mechanism of automatically calculated price.

Grids operators may not use information of the electricity grid for other areas of activity. Self-consumption is governed by private law internally and the self-consumption community is then treated as an end user in itself (the DSO must buy its PV exports and furnish its electricity demand). An agreement should be made between the consumers but also between the community and the grid operator. Quartierstrom used the public grid infrastructure and a trading platform which is very different from a traditional self-consumption community in Switzerland (normally the private micro-grid by law).

The community battery shared by 4 households was fully automated, which was charged when there were exports from the community and discharged when there were imports to the community. Therefore, there was no fixed duration, frequency, or specific time window in which the automation was scheduled. There were no direct incentives offered for the consumers or prosumers to join the P2P energy market; however, households indirectly saved money on their electricity bills with the possibility to buy cheaper electricity and to sell at a better price their PV overproduction. In the scale of the P2P energy market, the incentives to shift corresponds to real-time pricing (with a 15-minute resolution). There was also a system of auction for electricity produced within the community, so the electricity was cheaper when there was the maximum production in the community and the minimal consumption. In the scale of the P2P energy market, the highest price corresponds to CHF20.75 cts/kWh from the utility and the minimal price for the tariff corresponds to 4 cts/kWh. Sellers asked for 7.37 cts/kWh and buyers were willing to pay 18.9 cts/kWh. As there is a system of auction which divides by two the price of the seller and the buyer it results in an average price of 9.79 cts/kWh. Consequently, the ratio to consume the electricity from the P2P energy market instead of the electricity from the grid is 2.11. Consumers pay the grid tariff plus the trading price, which is equal to 0 for a household, to 5.79 cts/kWh for the community and to 13.03 cts/kWh from the utility.

In terms of information provision and data sharing and user interaction with the automation system, emails were sent on the first day of each month to every user with a monthly summary report. There was an online application to fix the price of the willingness to sell and buy to and from the community and to see the load curve of households with the provenance and destination of their consumption/production and the percentage of self-consumption and self-sufficiency. Users also sent some requests of a technical nature regarding the web application (related to the firewall, web browser of the users). Interviews were conducted at the end of the project, to collect users' perceptions of the project. No feedback was gathered during the project.

## GOFLEX

This project, entitled GoFlex (Generalized Operational FLEXibiltiy for Integrating Reneables in the distribution Grid), is a collaboration between utility company ESR (Energie de Sion-Région) and HES-SO Valais. The project started in 2016 and will end in the beginning of 2021. It has been piloted in the City of Sion (Valais) and is funded by the European Union's Horizon 2020 research and innovation program. The project aims to propose a bottom-up system that allows users (both residential consumers and prosumers) to activate flexibility (buy and sell), and by this to provide an optimisation of the balance for the DSO to reduce

corrective costs (intra-day) and reduce peak loads on the distribution grid, thus reducing the need of upgrading the infrastructure in area where decentralised PV is growing.

The users selected for the automation are residential customers who have heat pumps labelled as smart grid ready, hot water electric boilers, electrical heating system, existing ripple control and access to the optical fibre. One third of them also has a PV system installed on their rooftops, making them a prosumer. 195 households are recruited via three rounds of letters and a campaign on social networks for the DLC of their heating systems (heat pumps, electric boilers and electric resistance heating). The rationale for automation was communicated as 'to integrate renewables but also to better understand households' own electricity consumption, reduce it and earn money by this way'. The value proposition of the project is also communicated as contributing to the energy transition with zero costs of installation for the automation. DLC: Room temperature sensor, water temperature sensor (for domestic hot water), smart meter (Landis+Gyr E450) and sub system (with relay) in the heating system to perform the DLC are installed for free to these households and these installations belong to the DSO. 10 residential consumers installed a HEMS with temperature sensors in the room and domestic how water voluntarily to follow a dynamic pricing system. Similarly, 10 industrial partners which includes retailers with no food storage and offices with air conditioning also voluntarily installed a factory energy management system (FEMS) that follows a dynamic pricing system. These entities are not part of the DLC (full automation). Finally, and a CEMS (charging energy management system) to automate the EV charging and a CDEMS (charging discharging energy management system) to provide V2G are installed in two EV charging stations.

Figure 22 demonstrates The DSO department of the utility ESR does the activation of flexibility via the DLC through a global server, and through a smart solution system which offers a VPP where all energy management systems (HEMS, FEMS, CEMS) communicate available flexibility to a Flex Offer Agent (FOA, which is an algorithm as part of the VPP) and provide the individual bottom-up flexibility to a centralised flexibility manager (FMAN). This FMAN aggregates the FOA's flexibility and places the offer on a flexibility market (FMAR), and these offers are traded by the DSO on this market. The DSO expresses the required flexibility as a buy-offer in this trading platform of the FMAR. The required flexibility of the DSO is calculated according to its operational needs on Service Platform, grid data in a separate unit called DOMS (Distribution Observability and Management System). Once this flexibility is activated (either buy or sell), the FMAN notifies the energy management systems via the FOA to optimise their load.
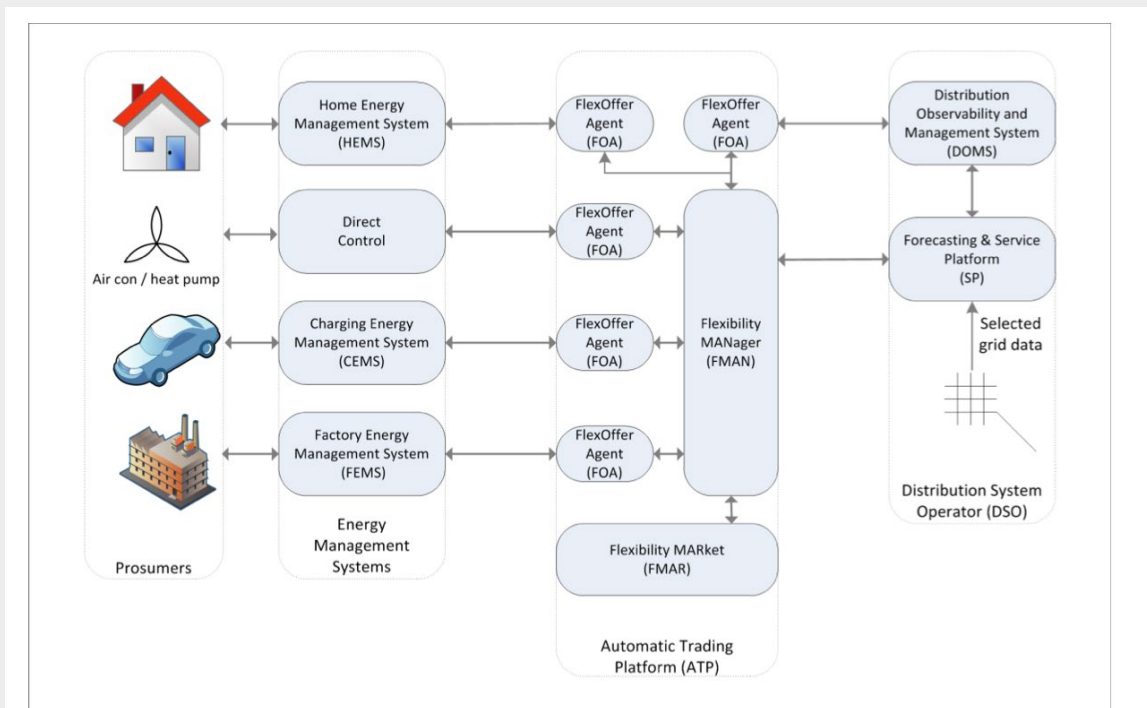
Figure 22: GOFLEX System Components (Source: HES-SO Valais)

There are several actors that have different roles, performing different tasks in the pilot project. ESR (Energie de Sion-Region) is the DSO but also, like many other energy utility companies in Switzerland, serves as the energy supplier as well (though unbundled inside). HES-SO Valais, as the research partner and integrator, supports ESR during the demonstration phase and coordinates the pilot experiments. The GoFlex system developed as a VPP acts as a flexibility aggregator and comprises an automatic trading platform managed by a techno-economic algorithm/optimization that communicates with the DSO's global server for DLC and energy management systems at homes and EV charging station. This system of GoFlex can also be seen as a local market operator as the FMAR manages local balancing market for energy flexibility for the DSO. The technology providers are comprised of INEA, a provider and installer of the component FEMS to the factories as well as HEMS in the household for them to follow the dynamic pricing tariffs; AAU, adeveloper of the CasaApp smart plug-in for the washing machines; ETREL, a provider of the CEMS (charging energy management system; ROBOTINA a provider of the component of V2G which is called charging discharging energy management system (CDEMS). The market rules of the GoFlex system are based on the Harmonized Electricity Market model in Europe (ENTSO-E, 2009, ENTSO-2015), and its adaptation by Mirabel project. The optimisation algorithm does a techno-economic analysis to enable local balancing market for energy flexibility. There is no fixed frequency or duration for the activation of the flexibility. On the other hand, by law the DSO is eligible to interrupt the load to manage grid overload (i.e. for security reasons).

There is no direct incentive to participate, but the installation of smart components for both DLC and HEMS is free. The algorithm does a techno-economic analysis in order to enable local balancing market for energy flexibilities following the day-ahead and intra-day market

(i.e. dynamic pricing) as well as other grid issues which later lead to lower electricity costs for the households.

In terms of information provision and data sharing and user interaction with the automation system, a web interface is provided for the users in the DLC program. It provides information on the electricity consumption, PV electricity production, thermal consumption, room temperature and hot water consumption and use of the flexibility. The users can see their own historical flexibility provided, however it does not communicate the benefits gained such as money saved or reduced $CO_2$ emissions. They also do not receive any early notice for the DLC that they will have an intervention. All this data is stored in a private cloud of the DSO.

## LUGGAGIA INNOVATION COMMUNITY (LIC)

This project, entitled LIC (Luggagia Innovation Community), is a collaboration between SUPSI, the regional DSO Azienda elettrica di Massagno (AEM), HivePower, Optimatik and Municipality of Capriasca. The project started in 2019 and will end in 2023. It has been piloted in the municipality of Capriasca, in the village of Lugaggia, and is funded by the Swiss Federal Office of Energy. The LIC project aims to test and verify the capability for self-consumption communities (SCC) to integrate renewable energies by leveraging two novel technical solutions: i) a centralised energy management platform, which uses the existing smart meter infrastructure for sensing and actuation and ii) a decentralised control approach secured by blockchain technology and requiring the installation of computing and controlling units connected to the smart meters. Further aims include a) assessing blockchain as a decentralised billing management method introduced by the utility; b) comparing centralised vs decentralised load management methods from the DSO's point of view (grid costs), energy consumption and economic point of view; c) assessing the local flexibility potential and the different ways in which it could be exploited from a technical point of view; and d) evaluating the degree of knowledge or acceptance among the community stakeholders to be willing to participate in these new self-consumption communities (a living lab to test users' acceptance will be set up).

In compliance with the new Swiss energy law[107], a self-consumption community was implemented to optimise and automate the use of local solar energy between the users in a district of Lugaggia. The community is in the north-east suburbs of Lugaggia region and consists of 18 single-family houses and a kindergarten. Most of the building stock is typical two-storey family houses constructed between 2010 and 2015, hosting approximately 75 residents and covering a total area of 18 000 m$^2$. Most of the dwellings cover their energy needs by utilising electricity as a source with a total annual consumption of approximately 270 000 kWh. The Lugaggia Innovation Community distribution network is served by a 250 kVA substation located a short distance from the neighbourhood. The district counts 4 PV installations on the roof of the local nursery (30 kWp) and on the roofs of 3 dwellings (with a

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[107] The new rules for implementing groupings for self-consumption in force since 1.1.2018 (loi sur l'énergie art. 16-18). RCP stands for regroupement dans le cadre de la consommation propre (RCP) and ZEV stands for ZEV (Zusammenschluss zum Eigenverbrauch)

total installed power of 32.5 kWp). An electric storage (a decentralised battery) unit of 50 kWh owned by the DSO is also installed in the neighbourhood to increase the penetration level of the PV systems and shift demand out of the peak hours. Several the residential buildings have installed heat pumps and electric boilers (with a total power of 26 kW) to cover heating and domestic hot water needs. The community is wired to connect the kindergarten to the households through a single coupling point. The community battery is installed in the Lugaggia kindergarten, and the decentralised monitoring and control equipment is installed and operational at the household main cabinets. The specific households to engage were identified based on the characteristics of the local distribution network and the presence of a sufficient number of PV systems. The eighteen households of the Lugaggia Innovation Community are in fact all connected to a single grid substation, which also connects the local kindergarten, which also hosts a PV system.
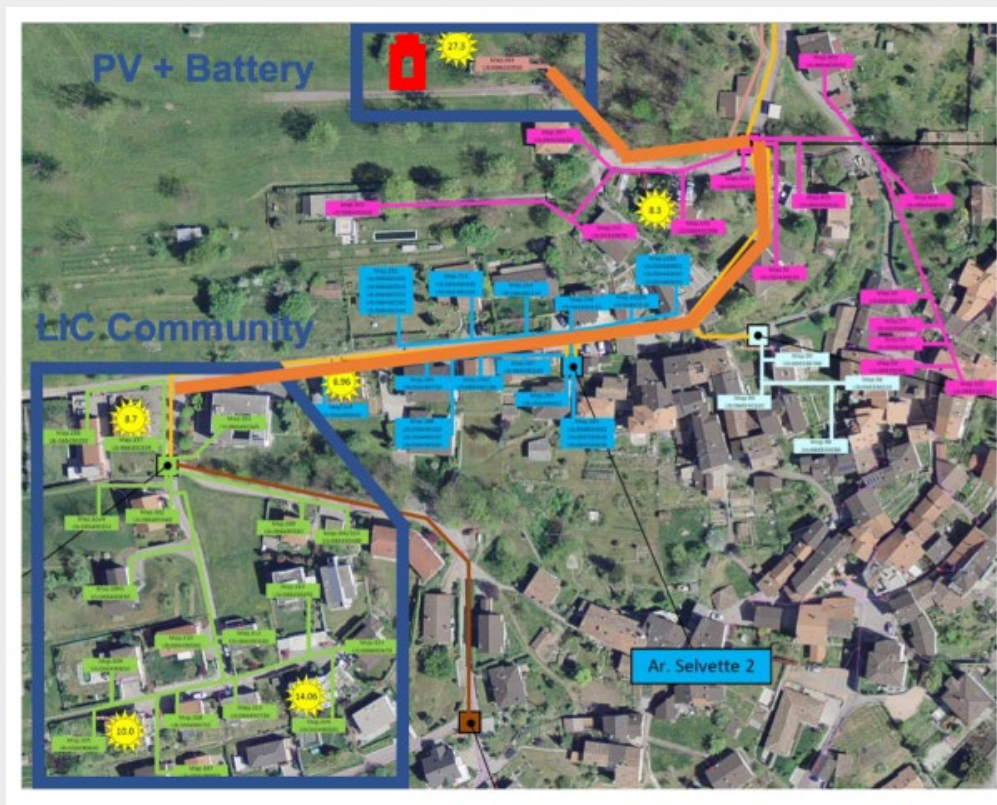


Figure 23: Luggagia Innovation Community (Source: SUPSI)

The eighteen households were recruited through targeted activities. They were first contacted by a written letter, sent by the DSO AEM with the support of the local municipality, which was accompanied by a flyer introducing the project, and followed by a meeting aimed at explaining the project goals, opportunities and risks (e.g. such that shortages of hot water and heating were very low) for project participants. When households requested it, individual follow-up meetings were organised as well, again by the local DSO AEM. The local kindergarten and the PV installation on its rooftop are owned and managed by the

Municipality of Capriasca, and were therefore included in the project as the municipality acted as project implementation partner. The rationale for automation for hot water, heating and the decentralised battery was communicated as 'to enable and maximise the self-consumption of the community that integrates the local PV on top of the kindergarten'. The benefits presented to the users were an increase in energy independency and the possibility to tangibly support the energy transition. An agreement was also signed with the local DSO, who committed to reimburse them in case the SCC electricity invoices were higher than the regular invoices by the DSO.

In the first case study, the solution consists of a centralised energy management platform which is controlled by the local DSO AEM and uses the existing smart meter infrastructure for sensing and actuation. In the second case, the solution implements a decentralised control approach secured by blockchain technology and requires the installation of computing and controlling units connected to the smart meters. In this case, the DSO does not have direct control and can only steer the behaviour of the SCC by proposing alternative tariff schemes. The electrical water heaters, heat pumps and decentralised battery are controlled via these two approaches. Other actors include technology providers Optimatik, which provides the product of smart grid solution, and HivePower, which is the developer of a turnkey solution for the creation and management of local energy community with this blockchain technology. SUPSI is the scientific advisor and the project manager. The Municipality of Capriasca acts as a public authority guaranteeing fairness and correctness of the whole SCC process.

The SCC operates in line with the law for the energy community to exist in Switzerland (Chapter 3, Art. 17 of Lene[108]), and the market rules are also defined by this law. The DSO plays a central role by directly controlling loads and the storage as a service to the community. For the blockchain-based solution being tested, it is not publicly accessible, and the data are anonymised using pseudonymisation which does not contradict with the current Swiss regulatory framework and could be applied in a real SCC setup. The users are organized in an energy community (EC). In terms of the market design, the goal of the community is to maximise its welfare, by reducing the costs for the consumers and increasing the revenues of producers. They set up an automated market making (AMM) mechanism; this is defined by a set of simple and interpretable price formation rules:

- The energy consumed from the external grid shall be paid for as if the consumer were not part of the community and the energy injected into the external grid shall be remunerated as if the consumer were not part of the community.

- The energy consumed from inside the community is paid for at a total price lower than the standard tariff of the energy supplier and DSO, with a discount proportional to the ratio of the total produced and consumed energy. The energy injected, which is consumed inside the community, is remunerated at a price higher than the standard tariff of the energy supplier, with a discount proportional to the ratio of the total consumed and produced energy.

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[108] The Chapter 3, Art. 17 of Lene. (https://www.fedlex.admin.ch/eli/cc/2017/762/it)

- The self-consumed energy is equally split among the community members proportionally to their consumption and production. The instantaneous buying and selling prices are dynamic, but for a given time slot they are the same for everyone. The difference between the community buying and selling prices covers the cost to set up, operate and maintain the community infrastructure.

The community administrator pays the bill at the coupling point, where the DSO's prices are applied and gets paid by the end-users according to the above-mentioned pricing scheme. The internal and external buying prices are CHF16 and 21 cts/kWh, respectively. The internal and external selling prices are 9 and 6 cts/kWh, respectively.

The district battery, heat pumps and hot water boilers are fully automated with no fixed maximum duration, but rather a minimum activation time is granted to the devices based on the usage profile, which is disaggregated from the meter readings. There were no fixed number of frequencies of automation, or fixed periods, and this completely depends on algorithm (the weather, grid needs etc.). The community members cannot override the automation. In terms of information provision and data sharing and user interaction with the automation system, there is a web portal built in to communicate the consumption and production of the energy of the users (each user can see only his/her own prosumption) and of the community, the activity of the community battery. The automation is not explicitly communicated as e.g. 'three times last Saturday', but they can interpret it from the visualisation of the consumption. The project is now also preparing a page to show the instant prices and financial figures. However, web portal is only for visualisation there are no options for overriding or modification. Finally, a biannual newsletter ensures communication of general project progress and activities and notification of project highlights to all members of the SCC and the actors involved. In terms of data storage, for the central management case study, it is stored in a centralised cloud within the DSO. For the decentralised case study, a private blockchain developed by the start-up Hivepower runs on the embedded computers connected to the smart meters.

## WARM UP

This project is a collaboration between Misurio and Elektrizitätswerk Der Stadt Zürich (Ewz). The project started in 2013 and will end in the beginning of 2018, comprising of three phases: Warm-up 1, 2 and 3. It has been piloted in the City of Zurich, where the automation was tested for a year. The project is funded by the is funded by the Swiss Federal Office of Energy. The Warm Up project aims to investigate how flexibility offered by thermal storages can be used optimally, by improving economic and ecological aspects as well as efficiency and comfort for space heating and hot water with heat pumps. The project aims also, through different phases, to facilitate the technological implementation of an optimising system to automate heat pumps in larger scales rather than an individual building itself. The second phase of the project is a proof of concept in which the findings of simulation findings Warm Up 1 are implemented in a building, and Warm up 3 applies the concept on one of the energy systems in the contracting pool of Ewz consisting of 15 buildings with 22 hot water storage fed by nine heat pumps.

There was already an automation control for the heat pumps and hot water boilers in the buildings, therefore this project just connected their new energy management system to the existing system (to run their new algorithm that overrides the old system) without the need to recruit new end-users. The rationale for automation is communicated as 'to maintain comfort in the building and at the same time improve efficiency, reducing costs for end users and the DSOs and decrease the ecological footprint of the electricity consumption of their heat pumps'. The purpose of the automation is quite holistic: to the minimise costs at day-ahead and intraday markets, minimise network charges and congestion (it is not a problem for the DSOs for the moment, but it could be in the future), to bring the flexibility necessary for renewables in the future and increasing the energy efficiency and the self-consumption of the buildings themselves (which automatically decreases the cost). The users are not expected to do anything; the system is fully automated. The algorithm's priority is always comfort, and then the algorithm for the optimisation weighs different goals equally in monetary terms, which are self-consumption, ecological (matching with renewables), energy market goals (cheaper electricity buying from the intra-day/day ahead market prices) and network goals (decreasing grid costs by reducing the congestion, matching with renewables). Smart heating system were installed on every building with temperature sensors in the hot water storage tankers and a measurement of the returning temperature of heat pumps and boilers accessed and controlled by the DSO and the Misurio energy management system.

Figure 24 below shows the actors involved in the Warm Up project and their roles and tasks in the project. Through a VPP, the aggregator Misurio (the developer and operator of the energy management system as well as doing the load forecasting, optimization controlling and monitoring) has a contract with the DSO Ewz. According to this VPP, the DSO operates, controls, and manages the flexibility activation.
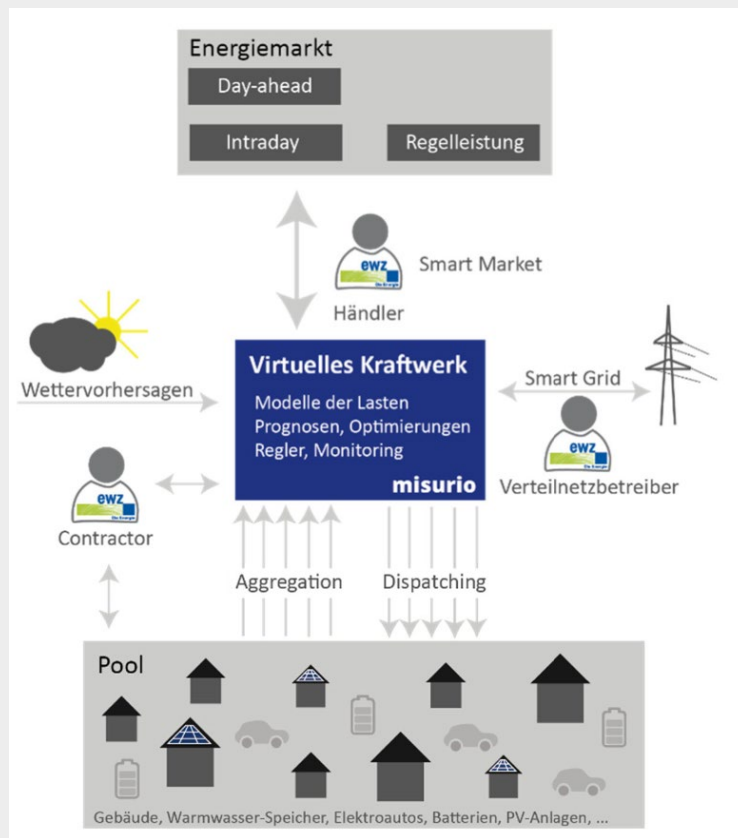
Figure 24: Actors in the Warm Up project, their roles in the project
(Source: Warm Up)

Ewz as the utility company (unbundled within the company), serves as i) an energy services (contractor) with the customers and the VPP operator and ii) distribution system operator that manages the congestion and frequency in agreement with the TSO, and as the iii) trade dealer / energy industry that buys and sells electricity through the EPEX spot. The VPP which optimises the devices and aggregates the flexibility has a contract for the automation with the Ewz (the contractor) as well, not directly with the consumers. People are charged according to this contract and pay their bills to the Ewz. According to the contract with the Ewz (energy services department), the VPP aggregates the flexibility and dispatches electricity accordingly. The optimisation algorithm functions depending on the prices traded with the EPEX spot, however comfort is the priority for the algorithm, and if there is a problem in the grid, the algorithm may not follow the market rules.

Heat pumps are controlled by the DSO according to the VPP automation system developed by the Misurio, algorithms run according to the inertia of the building and temperatures in the boiler, return temperatures and forecasting about weather, electricity prices at the EPEX spot and self-consumption (depending on the renewables). In other words, the price signals (real-time pricing) calculated depending on the EPEX spot (day-ahead and intra-day markets) are used in the model to optimise the automation given it provides the comfort limit and ecological goal (i.e. matching the PV production). For example, the heat pumps switch on to warm up the water (charge the water tank) when the prices are negative. However,

the system stability of the transmission network take priority depending on the network issues (for example negative price if the excess energy must be drawn off), then the algorithm prioritises this. All dimensions of the energy company (energy services, DSO, trader) involved in the Warm Up project belong to the same company (Ewz), so that the overall benefit stays in the company. Consumers gets charged according to the process (real-time prices) but since comfort, ecological and economically are favoured, they could save money.

In terms of information provision and data sharing and user interaction with the automation system, there is a web application which only shares money saved for the buy of the energy as well the price of power peaks for the users. The consumer data is stored in a server and used by the system driven by the DSO. The electricity market and TSO does not have any access to the personal data of users (boiler temperature and room temperature of households). The web-interface also allows the user to switch off the algorithm for their flat for a day.

## TIKO (BESMART PROJECT)

Tiko (BeSmart project), like the Australian project PeakSmart is a fully operational, technically and commercially project. BeSmart has been running since 2014 and performs three activities in the Swiss electricity chain. They control almost 10,000 devices, from heat pumps, electric boilers to EVs. They have the role of aggregator to i) balance group optimisation or peak shifting, and ii) day-ahead or intra-day optimisation to the utility company, when the energy retailer requests to switch off all possible loads, they use their own flexibility activation systems. Thirdly, they use these aggregated home devices as part of their VPP to delivery ancillary services to the TSO like frequency containment reserves (FCR) and automatic frequency restoration reserves (aFRR).

## OKEE (OPTIMIERUNG DER KOPPLUNG ZWISCHEN ELEKTROFAHRZEUGEN UND (GEBÄUDE-) ENERGIEMANAGEMENTSYSTEMEN)

The Optimierung der Kopplung zwischen Elektrofahrzeugen und (Gebäude-) Energiemanagementsystemen (OKEE) project is a led by two partners, Novatlantis GmbH and Paul Scherrer Institut (PSI), in collaboration with ADEV Energiegenossenschaft, Zürcher Hochschule für Angewandte Wissenschaften (ZHAW), and Stiftung Habitat and Smart Energy Control GmbH. The project started in 2019 and will end at the beginning of 2022. It has been piloted in the City of Basel, in the Erlenmatt Ost district where the automation was tested for two years. The project is funded by the Swiss Federal Office of Energy. The OKEE project aims to examine how new solutions for smart mobility can be developed for a site with multi-stakeholder management. The project manages a physical testing of an EV sharing system with two EVs in the district of 650 inhabitants, and simulation of the impact that would result from adding larger numbers of EVs (without car-sharing).

In the district, there are more than 650 inhabitants in 13 buildings (approximately 200 flats as well as a couple of commercial consumers). 650 kWp of PV panels are installed, and 13

decentralised heat-pumps (total 900 kW) with ground-water heat-recovery and thermal storage. There are two V2G EVs and EVTEC-charging stations. The recruitment was done through the apartment advertisement. The rationale for automation is communicated as 'to help renewables integration and reduce peaks', lower grid-charges were not communicated with the users.



Figure 25:A Nissan Leaf EV used in Swiss EV sharing project OKEE (Source: Novatlantis GbmH)

The EV charging stations are controlled by Smart Energy Control GmbH, which acts as an aggregator and controls the automated flexibility activation. ZHAW, as the research partner, calibrates simulations and improves load control algorithm. There is no protocol signed with the users as this is an EV sharing scheme: if people want to use the car they use it, if not they are not obliged to do anything. The aggregator Smart Energy Control GmbH communicates via e-mails (newsletters) and via post for the bills. This is a prototype, so not a standard market framework, but partially financed by outside funding. For billing the car charging, the following prices are applied, as determined by the aggregator:

- Peak charge: 8.51 CHF/kW = 34.4 CHF/kWh (applied to 15-min period with highest load)

- Normal charge: ~0.14 CHF/kWh (Mo-Fr, 6:00-20:00)

- Reduced charge: ~0.10 CHF/kWh (other times)

The fully automated EVs charging has no fixed maximum duration, meaning EV charging could be interrupted as long as it need to lower peak demand. The EV had to be 80-90% full at the time of departure. This means for EVs with a lower SoC, the interruption of charging is no longer possible during last hours before the scheduled departure time fixed via the app. There is no fixed maximum frequency (although in practice, it was maximum once per day), Similarly, there are no fixed activation windows - activations were allowed at any time (although in practice, activation mostly happened during evening hours, to avoid the daily peak load). Finally, when participants complained (via mail, phone), the automation was

suspended until the algorithm had been adjusted to avoid comfort loss. Similarly, users never received any notification of activation, nor had any right to veto the automation. In terms of information provision and data sharing and user interaction with the automation system, there is an online portal to book the EVs and indicate planned trips, and e-mail/phone contact information provided for complaints. However, no other information such as $CO_2$ savings or cost benefits are shared with the end-users, limiting the interaction with the automation system.

## 7.3 Lessons learned

**Lessons from the case studies**

- **Successful recruitment does not only depend on the DSM program design.** Percentage of engagement (i.e. rate of opt-in) in pilot projects varied between 28% to 50%. It was 100% for the energy communities, as the whole community was engaging in the project. These values are much lower than the percentages stated in the survey (i.e. rate of acceptance) conducted in Switzerland which varied between 45% to 90% for different devices.

- Decentralised batteries which are shared by the community and charge/discharge according to the community scale import/export are valuable in the sense that it certainly increases the community's self-consumption and leads to total peak reduction of the community.

- **It is evident that the profiles of the participants of the pilot projects are skewed.** They are mostly comprised of single-family households, which are early adopters of rooftop PVs, heat pumps, EVs, and batteries and/or already engaged in self-consumption communities. However, pilot projects rarely collected any information on the socio-economic characteristics (e.g. gender, age).

- **For energy communities, using the rationale of deploying automation to increase the self-sufficiency of the community is effective.** Households not only allowed the operators to fully automate their heating devices such as hot water boilers and heat pumps, but there was a clear observation that they also shifted other non-automated or semi-automated practices such as EV charging and the use of washing machines and dishwashers once they saw that the automation was in fact increasing the self-sufficiency of the community.

- **Showing the impact of automation of devices is key. For this, clear information provision and data sharing are key through several means such as interface, apps, portal, etc.** Specifically, data visualisation is important to sensitise people to their energy use and further encourage them to change other energy practices. For example, two studies, the Quartierstrom and GoFlex projects, though their household appliances such as dishwashers, washing machines were never fully automated, there was clearly a shift in use towards times of the day when there is PV production,

as households tried to increase self-consumption as a prosumer or as part of the energy community. Similarly, in the second project described above, Innovative Self-consumption Optimization for Multi-family Area, people shifted their non-automated devices such as dishwashers by checking the visualisation provided for the PV production of their building.

- **People do not understand what automation technologies do exactly.** In the second project above, Groupe E conducted a survey, and most of the participants indicated that their motivation to participate in DLC was to 'save energy'. In the GoFlex project, 88% of the respondents asked for further information on how the technology controls the homes devices and influence their energy use and the bills. Only 12% said they have enough information.

- **Business models and optimisation of automation tools do not have a holistic approach when automating the appliances**. They either focus on day ahead/intraday optimisation which is important for the retailer department, or grid solutions which are important for the DSO department. Only the Warm up project considered the alignment of several actors in the sector and defined so-called merit orders for optimising the devices (e.g. personal comfort, local PV production, market optimisation).

- **Utilities companies (either with the role of DSO or retailer) which work with third parties have more granular flexibility provision.** This is partly because the third parties i.e. aggregators, or technology providers have access to more information (e.g. EV state of charge, temperature of hot water tanks and room temperature), and DSOs have only the information of power demand reading. At the moment, DSO lacks information to create a bottom-up picture of energy consumption by end-users, and hence is limited in creating smart charging profiles, or heating patterns.

- **Peak reductions are achieved through either direct automation of devices 2 to 8% in the pilot projects or through batteries** which increased the self-sufficiency of the community. This implies benefits for the DSOs in terms of deferring the grid-reinforcement costs.

- **There is still less experience of automation related to EVs**. Projects unfortunately have very small numbers of EV users; therefore it is hard to draw any conclusions/lessons.

## Policy implications

- Policy-makers should provide a harmonised framework to have integrated solutions where the different interests and goals of different actors are aligned.

## Future trial and research needs

- More information should be collected about why people refuse to opt in to automated DSM projects, in order to form tailored business models to increase the engagement.

More integrated holistic solutions solving the future grid issues by aligning the interest of different actors are needed. For this, iterative exploration is required, especially in decentralised systems through theoretical studies supported by urban energy system models.

# PART 2: WORKSTREAM ANALYSIS

# 8. The User's Interactions with Automation Technologies

*Human-Computer Interaction (HCI) studies*

## 8.1 Introduction

In order to identify HCI-related acceptance factors for DSM 15 cases from 6 different countries (Austria, Switzerland, Germany, Norway, Spain and Australia) were analysed. The reduced number is based on a limited selection of cases which provided participants with dedicated interaction channels in the context of their project participation which was our condition for inclusion. In this process, the completed data collection templates for all cases identified as fitting this condition were scanned in detail and context and interaction factors were recorded systematically for a follow-up comparative analysis focused on noticeable differences of interaction aspects and relevant contextual factors with regards to automation level. The automation level of each case was chosen as the basis for analysis since it has a strong impact on expectations about active user participation and therefore can be expected to vary in what it needs to provide users with in order to further trust and acceptance. Six different detailed automation levels were distinguished:

- **Automation Level 1: Manual.** Load-shifting or shaving is done manually by the user (automation aspect only with regards to automated notifications regarding target consumption / peak shaving phases)
- **Automation Level 2: Manual automation.** Load-shifting or saving is done via manual programming of devices or systems by the user
- **Automation Level 3: Consensual automation with acceptance.** The user is actively contacted by the system and must agree to an automation event, or it will not be carried out
- **Automation Level 4: Consensual automation with veto**. The user is actively contacted by the system and offered the chance to veto the automation event; if they do not do so the automation is carried out.
- **Automation Level 5. Restricted automation**. The user has the possibility to restrict automation to specific requirements such as time periods or comfort zones and can monitor automation and interrupt it via the system if necessary
- **Automation Level 6: Full automation**. The user has no possibility via the provided interaction system to interrupt automation events.

For the purpose of the analysis these detailed automation levels were combined into more general ones as follows:

- **Low Automation Level:** AL 1 or AL 2
- **Medium Automation Level:** AL 3 or 4
- **High Automation Level:** AL 5 or AL 6

Table 5 below contains an overview and comparison of relevant case context criteria and interaction design aspects within used interaction channels and provided interfaces differentiating between different automation levels.

Table 5: HCI Overview and comparison of criteria and interaction design aspects

| Main Automation Level | Observations |
|---|---|
| *Number of cases per automation level* | *Four cases had a low automation level (AL) of 1 to 2 (typically both manual and manually programmed load-shifting were combined), 4 cases were medium AL (3 with AL 3 and 1 with AL 4), and 7 cases were high AL (3 with AL 5 and 4 with AL 6).* |
| *Secondary automation level* | *AL 1 and AL 6 most often combined; ALs 3-5 typically combined with each other. Single event automation (medium AL) can also be found often in high AL cases.* |
| *Countries* | *Low AL cases were from AT, DE and ES, medium AL cases from AU and CH, and high AL cases from AT, DE, CH, AU & NO* |
| *Housing* | *Low ALs were more often implemented in apartment blocks while high ALs were more often implemented in single family homes; middle level was mixed (but also less cases to draw from)* |
| *Loads affected* | *Affected loads tie strongly into automation levels. At low AL loads affected are appliances/devices, lights, and hot water. At medium AL there is the largest variety, ranging from appliances/devices, EV charging, heating, air conditioning to heat pumps and storage batteries.*<br>*At high AL affected loads are typically hot water boilers, heat pumps, and storage batteries as well as less frequently heating and storage heaters. Overall most commonly affected were appliances/devices and heating (7 and 6 cases, 47% and 40%, respectively) and further heating, heat pumps and storage batteries (all in 5 cases, 33%).* |
| Interaction channels | Most popular as a communication channel was the use of an app (11 cases, 73%; once provided on a dedicated tablet), followed by a web portal (7 cases, 47%). Less frequently used were text messages (3 cases 20%) and in 1 case an in-home-display was installed. Emails were frequently used as well but mostly employed for recruiting purposes, sending of newsletters/reports or for user research. Phone calls were used for similar purposes (excluding newsletters/reports) but were also offered as a last-resort possibility to veto automation in 2 cases (13%).<br>No noticeable preferences for channels could be observed with regards to automation level except that text messages were not used at the higher ALs. |
| Feedback | <u>General consumption feedback</u> was a very popular feature of interaction channels provided to users and could be found in 13 |

| | cases (87%). Most typically it included information on current status and consumption history with the possibility to specify the time period looked at, frequently the possibility to compare one's consumption to one's own consumption in the past, and sometimes concrete information on self-sufficiency in %. In 1 low AL case consumption was translated into tangible references (e.g. hours of TV watched). There are no noticeable differences regarding the provision of consumption feedback based on automation level. |
|---|---|
| | Device-specific consumption feedback: This was only employed by 3 cases (20%) which were medium or high AL and not at all at low AL. |
| | Production feedback: Production feedback was implemented in all 9 cases that included PV production at a user-awareness level. Production feedback (and related PV production) was more commonly implemented at high AL cases (6x) and was least common in low AL cases (1x). |
| | Smart home feedback: Smart home related feedback (mostly regarding sensor-based information such as temperature and air quality) was provided for the 5 reviewed cases that included a smart home system. Two of these were low AL cases, 2 high and 1 was medium AL. |
| | Battery status: Battery status information was provided in 2 high AL level projects (out of 5 projects that involved battery automation). |
| **Automation transparency** | Automation transparency possibilities also depend strongly on automation level. |
| | Information on smart home settings was provided in 2 low AL cases |
| | Tariff-related information was provided in 2 low AL cases |
| | PV production forecasts were provided in in 1 low and 1 high AL case |
| | Information on the beginning and end of events was offered at medium AL in 2 cases |
| | Information on automation parameter settings was provided in 1 medium AL case |
| | Information on flexibility use was provided in 3 high AL cases |
| | Information on energy flows was provided in 3 high AL cases and 1 low AL case |
| **Control options** | Many of the available control options were tied to the case automation levels. |
| | Consumption and comfort control via smart home settings was available in 2 low AL cases |
| | Interaction control (via setting of minimum savings potential to warrant a notification) was provided in 1 low AL case |

| | |
|---|---|
| | Price control was possible in 1 low AL case (tariff selection) and 1 medium AL case (setting of price at which to buy / sell locally produced energy) |
| | Automation control via single parameter settings was available in 1 medium AL case (automation was controlled via settings of single automation event conditions such as completion time of washing machine, dishwasher and EV charging) and 4 high AL cases (all relating to single event settings for EV charging) |
| | Consensual automation control was available in 3 medium AL cases, 2 of which involved active acceptance of automation invitations and 1 that involved the possibility to veto an automation in reply to the actively offered information of a planned automation |
| | Restricted automation control was available in 1 medium AL and 2 high AL cases in the form of general automation parameter settings concerning comfort ranges and in 1 high AL cases as possibility to veto an automation through the provided interface; *Phone-based veto was possible in 2 high AL cases but was not registered as restricted automation control since it was not handled through a dedicated and continuously used interaction channel but rather a last resort in cases of real issues* |
| | Interface-related control options were available in 1 low AL and 1 high AL cases in concerned in both cases the arrangement of the dashboard and offered in 1 case the possibility to nickname the appliances involved and in the other to influence the colour-based appearance |
| **Benefit information** | Savings in €/$ was the most popular form of benefits communication and employed in 1 low AL, 1 medium AL and 2 high AL cases (one of which split the feedback in general savings, savings due to battery & solar, and savings due only to solar) |
| | Savings in $CO_2$-emissions were communicated in 3 cases evenly distributed throughout the AL levels |
| | Savings in kWh were also communicated in 3 cases, 2 of which were low AL and one was medium AL. |
| | Savings potential was communicated in 2 low AL cases |
| | Out of the 15 reviewed cases 8 (53%) specifically did not communicate benefits at all through the interaction channels provided |
| **Privacy information** | Information on the privacy information provided to users was limited but privacy information was, in all analysed cases, only available in the form of a general privacy statement provided either as part of the contract originally signed and or within the web portal or app. It was specifically recorded in 2 low AL cases and 3 high AL cases. It does not seem that dedicated privacy related control options (e.g. which data is collected, who can |

| | |
|---|---|
| | access it, what is it used for) or transparency related information (where is data transferred to, who accessed it when etc.) was offered anywhere although participants were able to see some of their personal data in the form of feedback in most cases. |
| **Social information (comparison/community)** | Social comparison information regarding consumption was provided in 2 low AL cases (one on apartment building level) and in 2 high AL cases<br>Community level feedback was provided in 4 cases, 1 of which was low AL, 1 medium and 2 high. In 3 of those cases the feedback encompassed information on community consumption and production, in 1 it concerned only the status of the community battery<br>Out of the 15 reviewed cases 8 (53%) specifically did not provide any sort of social information |
| **Gamification** | Gamification was only employed in 2 low AL cases.<br>In one case this included an energy saving competition game on apartment building level<br>In the other the competition was based on the estimation of expected consumption for a day which included the possibility to 'top up' registered consumption via fictional running of appliances if the estimation was above the real consumption with the goal of increasing participant's energy literacy this way.<br>Eleven cases specifically did not involve gamification |
| **Actionable information** | Actionable information was provided in all 4 low AL cases.<br>In 2 low AL cases energy saving tips were provided<br>In 2 low AL cases target consumption periods were provided<br>In one low AL case target consumption shaving periods were communicated |
| **Direct interaction elicited by the system** | Direct interaction elicited by the system was noted only in low and medium AL cases<br>Text messages or push notifications with target consumption periods (aiming to encourage participants to shift their consumption into the indicated period) were provided in 2 AL cases; in one of these it was (almost) daily during the trial period – whenever notable PV production could be expected – while in the other one notification frequency depended on indicated minimum savings potential and varied from almost never to max. 3-5x a week.<br>Push notifications with target consumption shaving periods were used in low AL case 1-2x per week during the trial period |

## 8.2 User Experience Results

**Low Automation Level Cases:**
- *Interface Use:* In 3 of the low AL cases the interfaces provided were used to a very limited degree down to not at all. In the 4th case participants indicated high

engagement rates and behaviour change and it can therefore be assumed that the communication channels provided were used to a higher degree.

- *Interaction experience:* Overall feedback was well liked and deemed interesting although concerns about feedback accuracy were noted in 1 project. Consumption target phases were not a good match to flexibility in 1 project (apartments, low-income participants, where only electricity consumption was affected without heating or hot water) and it was specifically stated that an option to personalise flexibility availabilities would be helpful while in another project target phases were well taken up well (especially via programming). In the 2 projects utilising smart home systems there was interest in more remote-control options; in one, temperature settings were not well understood.
- *Project experience:* The project goal of load-shifting was for many participants out of mind due to poor management of communication at the beginning and/or too infrequent interactions. Further, the possible financial benefits communicated to them were too small to motivate behaviour change in 3 out of 4 reviewed cases and pronounced privacy concerns prevented use of the system provided in 1 project (in this project a dedicated tablet with the app installed was provided to participants). There was only one project that succeeded in engaging participants and recorded the majority of participants changing energy practices. This was a project in a pre-existing community of single-family home-owners with extensive benefit communication, an emphasis on the community aspect and a savings potential of up to €60 a year.

**Medium automation level**

- *Interface Use:* In one case the interface was used regularly by 50-75% of the participants, in the other cases the provided interfaces were used minimally. In one case we had no information available regarding this question.
- *Interface Experience:* Feedback was overall well received at this AL also and positive experiences were reported regarding control and transparency of automation. Suggested automation was only partly accepted (20%; 52%) and with high automation frequency (40% of the time upwards) vetoed 20-22% of the time. Single parameter setting was used more for devices (washing machines and dishwashers, approximately 50%) than for EVs (participants wanted an interface in the car instead of managing the automation setting via an app). Insufficient potential for personalisation regarding automation requests was noted and the benefits feedback in the form of kWh & $CO_2$-emission savings was not well understood (while the financial feedback was fine). In the automation veto rather than acceptance case (with a high experience impact, because a power board that for some users hosted electric heaters and / or IT equipment was impacted) there were complaints about a lack of automation transparency.
- *Project Experience:* Financial benefits were again limited for participants in most cases – only one project provided noticeable benefits (in the range of AUD10 per automation event). There was a noticeable decrease in experienced comfort in one project and in another automation was stated as noticeable by 24% of the participants, and in a 3rd case specific issues were reported concerning the unavailability of heating and loss of work / insufficiently charged laptop due to power board automation. A positive experience of increased independence and community experience was reported in one project.

**High automation level**

- *Interface Use:* Overall reported use as data is available was limited. The highest recorded number was up to 26% of the participants making use of the web portal regularly in 1 case (one with a relatively high impact experience due to the loads operated and transparency issues – see below).
- *Interface Experience:* Feedback as available was again appreciated and praised to increase awareness and understanding although usability was criticised in one case and in another was mentioned as not being particularly useful (in terms of actionability). In 1 case, participants felt they were not sufficiently informed of what was happening in the house and were missing information on the benefits from the automation that had occurred and the possibility to compare consumption with similar households. Interaction was also mentioned as too infrequent, leading to people forgetting about their project participation altogether. In another project the need for parameter setting was not sufficiently communicated to participants, leading to issues.
- *Project Experience:* Overall, participation was perceived positively to very positively and in most high AL cases there was no negative impact experience reported. Engagement depended on framing of the project and communication form and frequency with users. People participating in a case in which they were framed as a community were proud to be part of said community. One case failed to make the automation undertaken within the homes transparent to users, leading to the feeling of missing information and irritation among participants. In the same case users were concerned about a loss of comfort and an increased dependence on DSOs. In another project spillover effects from the increased awareness due to the provided feedback (such as efforts to conserve water and less travel by car) was reported.

Table 6 presents the results from a small survey of project partners which collected additional insights about interaction within cases. The survey included 4 qualitative questions for each case, 3 quantitative questions asking participants to rate their impressions regarding some traditional user experience factors and space for further comments. The collected data was again analysed based on generalised automation levels.

The qualitative questions of the survey to be answered in open-text format were as follows:

- "SUCCESSES: Did you have the impression that the user interface (web portal, app or similar) impacted acceptance? Which aspects do you think were most important?"
- "FAILURES: Are there any aspects of the interface that you feel really fell short and did not work as intended? Which ones and what was the problem?"
- "MISSED OPPORTUNITIES: Did you take note of any issues that end-users experienced that you think could have been (partly) resolved through an interface? Which ones and what do you think the interface could have contributed to resolve them?"

Table 6: HCI user survey results summary

| Automation Level | Results |
|---|---|
| Low Automation Level | *Interaction successes*: Most positively perceived in low AL cases was the provided consumption feedback, as well as |

| | communication of savings potential and of achieved savings. Further positively mentioned was the enabling potential of provided forecasts<br>*Interaction issues*: Issues noted were missing personalisation options to indicate flexibility potential at specific times, insufficient or completely missing benefit communication and an insufficient degree of interaction to motivate manual consumption shifting or shaving. Not including sufficient information in the notifications provided about saving opportunities to directly act on without visiting another platform also proved to be an issue in one case. A noted fail in one smart home context case was insufficient communication of data handling and privacy protection which led to an avoidance of the interaction platform. |
|---|---|
| Medium Automation Level | *Interaction successes*: Participants very much liked that they had so much control via acceptance/rejection and parameter settings. They liked the insights into what was happening via automation transparency and weekly reports, the possibility for detailed insights via feedback and the provision of market transparency in 1 case. Positively mentioned were also interface simplicity and the availability of multiple channels. In another case a LED indicated status of PV production which was also well liked.<br>*Interaction issues*: Only a limited number of people did actively accept automation and there were issues with understanding the provided $CO_2$-emission and kWh saving related feedback. Participants missed social comparison information, the possibility to indicate preferences for automation requests, more information regarding automation benefits achievable / achieved and more actionable information. In one case information on how automation would affect participants was perceived to have been insufficient |
| High Automation Level | *Interaction successes*: Participants appreciated the possibility of setting automation parameters when possible, the transparency provided on automation (mentioned most often) and communicated benefits. It was appreciated that an interface was available and multiple available channels were mentioned positively. It was underlined that the main value of the interface was to inform participants rather than encourage them to act. Overall, interaction was very limited at high AL (interfaces were not used much)<br>*Interaction issues*: There were struggles with automation parameter settings and in one case there were noticeable transparency issues, leading to complaints from participants not knowing/understanding what was happening in their |

| | houses. Benefits communication and social comparison information were noted as missing and in cases where no veto was possible participants missed a possibility to set parameters or veto via the interface. Issues regarding low usability were noted. |
|---|---|

The quantitative questions of the survey to be answered via a 5-point rating scale from 1 = very low to 5 = very high were as follows:
"How would you rate the PERCEIVED USEFULNESS of the interface?
"How would you rate the PERCEIVED USABILITY of the interface?
"Did the interface contribute to creating TRUST and how?
The mean rating results overall and differentiated between general automation levels can be found in the table below:

| Mean | Perceived Usefulness | Perceived Usability | Trust |
|---|---|---|---|
| **All cases** | **3.53** | **3.80** | **3.53** |
| Low AL cases | 3.25 | 3.50 | 2.75 |
| Medium AL cases | 4.00 | 4.75 | 4.25 |
| High AL cases | 3.43 | 3.43 | 4.00 |

Perceived usefulness received overall lower ratings than perceived usability, with its lowest rating average in low AL cases. Interface usability was rated lowest in high AL cases, pointing to the complexity challenge posed by ensuring automation transparency. Finally, the results indicate that in low AL cases the interface contributed the least to trust building and was also considered least useful, reflecting the very limited uptake of shifting / shaving based on the information provided.

## 8.3 Conclusion

The results on HCI-related acceptance factors confirm that how technology can best support acceptance by users through interaction features depends greatly on the level of automation implemented within a program as well as the affected loads, as these in turn are the deciding factors for impact of the load-shifting/shaving experience by the user and the effort investment required from the user to achieve it. Impact experience and required effort are at the heart of both interaction/engagement level requirements and benefits conceptualisation and communication as well as control needs:

- At **low automation** levels, if manual shifting or manual automation based on automated identification of optimised consumption curves is the goal, it is crucial to: Actively reach out to participants, provide actionable information on how shifting can be achieved, as detailed and time-near feedback as possible to increase energy literacy and self-efficacy feelings among end-users, and ensure that perceived benefits are sufficient to motivate participation as significant personal investment of participants is required for self-motivated behaviour change. Long-term behaviour

change is (except among highly engaged users) likely only possible through the building of new habits supported through the above-mentioned aspects as well as dedicated intervention strategies such as commitments, prompts, social norms communication and rewarded goal-setting until they are solidly formed. Within this process, people's realities regarding flexibility need to be considered through tailoring and personalisation options.

- With a subsequent increase in automation level and reduction in involvement of users towards **medium automation levels,** the need to actively reach out to users and the need for sizable personal benefits is continuously reduced. If users are not asked to involve themselves in shifting but can be expected to experience demand side management noticeably, transparency information on what exactly has been and will be done is crucial, as well as the possibility to set parameters and override actions if necessary. Strong benefit communication as well the communication of control is also still of great importance as these are the automation levels that are most likely to make participants feel interfered with and out of control.

- At **full automation** level with limited to no noticeable impact on users, the need to involve users actively and to provide personal, noticeable benefits is reduced greatly and the role of provided interfaces becomes one of reassurance and accountability that provides transparency through insights into what has been, is currently, and will be done as an offer to users who are interested or are experiencing issues. It is still recommended to clearly communicate what is automated and to provide regular feedback on what is achieved through the automation, as well as to provide consumption feedback.

With regards to channels used, apps are the most common and most successful channel since a large percentage of users always carry their phones with them, making accessing the interface and receiving notifications particularly easy. Web portals, however, often required additional sign-ins that function as a barrier. Emails are a good supporting channel for regular reports and to reach people who might have issues with the app or the notifications, providing a channel to sort these out.

Overall, it can be summarised that the role that HCI takes at different automation and experience impact levels for users changes most significantly regarding the need for and type of control options, provision of actionable information, active involvement of users and the frequency of these aspects. The tasks of providing transparency, benefit information and feedback for additional benefit creation do, however, remain continuous.

A mismatch has been noted between recorded participation motivations of users, in which environmental reasons tend to play a crucial role, and the extremely limited benefit communication regarding this point as communicated benefits most often focus on savings. Linked to this missing communication of self-transcendence-related benefits is also the under-use of a community perspective within interaction and benefit communication which has the potential to contribute to the development of shared green community identities and could therefore motivate people to take further, independent action towards a sustainable lifestyle.

Finally, it should be added that the role of HCI in DSM changes depending on automation level and the related impact experience and effort requirement. If automation level is low and

impact experience and effort requirement are high, HCI functions as helper, reminder, teacher, feedback-provider and encouraging agent. As the automation level rises, this task of engaging the user to act moves on through a key phase of control provision to one of providing accountability, transparency, and justification through the communication of achievements. Therefore, measurement of success of HCI within DSM changes away from active engagement with and response to provided interaction (channels) to the experience of trust due to the availability of the information and the option to monitor, set automation parameters and/or veto a flexibility activation if a participant experiences a particular need at some point.

# 9. Understanding the User's Household Energy Activities

*Energy Sociology*

## 9.1 Introduction

This chapter explores some of the activities in which energy is used in the home, investigating what these indicate about the flexibility of energy use and about the potential for automated DSM to enhance flexibility. By understanding the ways in which households go about activities such as laundry and dishwashing, and the priorities and considerations that underpin them, it is possible to better understand whether households will engage with automation technologies – from local programming of appliances to direct load control – to facilitate time-shifting. We understand time-shifting as the manual or automated rescheduling of household loads in deliberate response to external signals or control within a DSM program, however, we consider that hints about the potential for time-shifting can be found among the ways that people choose to schedule their energy activities outside such a program. The focus of this analysis is on the discretionary loads of EV chargers, washing machines and dishwashers, drawing on insights from a number of case studies in several of the participating countries.

The data sources analysed here include interviews with 16 households living in one-family buildings in southern Stockholm, Sweden. The area was selected because it was one of the first in Sweden to receive the second-generation of smart electricity meters. Two rounds of interviews were conducted with households, with the first focussing on their home, and the second on the newly launched mobile app from the electricity grid operator, Ellevio AB. Insights from participant interviews conducted in the Swiss case studies of the Quartierstrom peer-to-peer energy trading trial and two innovative self-consumption trials, as well as the RedGrid smart home trial in Australia, also supplement the analysis of activities that centre on home appliances.

The case studies of EV charging include interviews with 14 EV owners participating in a smart charging trial in Norway. The participants of the trial conducted by the Delft University of Technology in the Netherlands were interviewed before and after their use of V2G compliant charge points. Conclusive results from the first stage[109] and initial results from the second stage have  been presented here. In Australia, 18 participants of a study by the University of New South Wales and Solar Analytics were interviewed about their charging routines and whether they would consider participating in a managed charging program. Also presented here are the results of an onboarding survey of the participants of the Australian EV orchestration trial by retailer AGL, as well as interviews conducted with 12 of

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[109] K. van Heuveln, R. Ghotge, J.A. Annema, E. van Bergen, B. van Wee, U. Pesch. 2021. Factors influencing consumer acceptance of vehicle-to-grid by electric vehicle drivers in the Netherlands. Travel Behaviour and Society 24: 34-45, https://doi.org/10.1016/j.tbs.2020.12.008

these non-trial participants and 4 of AGL's non-trial customers on an EV tariff plan by consulting firm Perspicacious.

## 9.2 Energy activities in the home

This section examines some of the energy activities evident in the case studies, and the reasons or logics behind them.

**Electric vehicle charging**

### CHARGING ROUTINES

Across the cases in Norway, Australia and the Netherlands, users reported a common set of reasons for charging practices:

- *Charging to maintain battery close to full*
- *Charging at a certain minimum level of charge*
- *Charging when needed*
- *Charging by default*
- *Charging around other tasks*
- *Charging when solar energy is available*
- *Charging to minimise costs*

These reasons align with similar studies of EV charging. Franke and Krems describe the interaction of EV users in Germany with their batteries in terms of their awareness and understanding of battery dynamics to manage the limited energy resources available in the vehicle battery[110]. Based on the User Battery Interaction Style (UBIS), EV drivers are categorised by the degree of interaction with the charging of their EV batteries. Bunce et al. conducted a trial with 135 EV drivers in the UK, whose behaviour was categorised into three patterns as 'charging as a daily routine', 'charging when the SoC was low' and 'charging whenever the opportunity arose'.[111] Note that these practices might be employed by the same EV drivers at different times (e.g. some normally maintain their battery at a minimum level of charge but charge as needed ahead of a longer trip), and in combination at the same time. Certain practices have also been found to evolve with experience of the vehicle. New users typically charge at every opportunity, while more experienced users are comfortable with driving with lower states of charge. These charging routines are described below.

***Charging to maintain battery close to full****:* this approach is captured in the responses from the Australian UNSW study respondents that '*I like to have the feeling that it's got a full*

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[110] T. Franke and J.F. Krems 2013. Understanding charging behaviour of electric vehicle users. *Transportation Research Part F: Traffic Psychology and Behaviour* 21: 75-89. https://doi.org/10.1016/j.trf.2013.09.002

[111] L. Bunce, M. Harris and M. Burgess. 2014. Charge up then charge out? Drivers' perceptions and experiences of electric vehicles in the UK. *Transportation Research Part A: Policy and Practice* 59: 278-287. https://doi.org/10.1016/j.tra.2013.12.001

*charge in it*' and '*I hate leaving home when you could have charged and didn't.*' One described of her husband '*he is more comfortable with the idea that it's full, so he will charge it. He doesn't like to have it sit around at, whatever, 150 kilometres range*'. 27% of the Australian AGL trial participants stated in the onboarding survey that they tend to charge more frequently and for shorter periods because they prefer to '*keep the battery topped up as much as possible*'.

***Charging at a certain minimum level of charge:*** some EV drivers charge when their battery approaches or reaches a minimum state of charge they are comfortable with, with the objective to always maintain their state of charge above it. Provided that it is above that level, the state of charge does not matter. One UNSW study participant described how, following an early '*scare*', '*we just made sure [to] keep it between that 40 and 80 and then you're reasonably happy […] there is 200Ks in the car, you don't need to top it up. We don't need to drive that far tomorrow*'. Another participant reflected that she was surprised that she had adopted this rhythm:

> '*I thought we would come, bring it home every day, and plug it in, charge it like a phone […] whereas I've worked out that with the EV, we only need it with only 30 or 40 kilometres at the most […] So it's almost a bit like what you do with the petrol car which is not what I expected that I would do. So with the petrol car, you drive and you get to a quarter and you think, "Okay, I really need to start thinking about where to fill it up."*'

The minimum battery level with which AGL trial participants are typically comfortable with is 25-30%. Interviews with AGL trial participants revealed that they tend to maintain a charge 'buffer' in preparation for a variety of contingencies, including unexpected work meetings, spontaneous trips or anything 'impromptu'.

***Charging when needed:*** this is charging in anticipation of a particular identified need, such as a longer trip: '*we charge it as often as we need it*'; '*I've got a fairly big battery so it has a pretty good buffer in it. So I could charge it once a week if I wanted or […] if I needed to based on my sort of business*'. The prompt could include that the EV *might* be needed: '*sometimes if we're not sure what exactly what's happening the next day, then we might be more likely to charge it*'; '*if I'm on 60, I might go for a longer trip now, just to play it safe, I'll top up now*'. One of the Norwegian EV owners stated that he usually charges at work '*except on weekends or if I am low on battery at home*'. Another Norwegian interviewee stated that she chooses not to charge at work because she does not have a long commute distance and because there only a few chargers at work. She also how described how her co-workers have an unspoken deal that the EV owners that have travelled the longest distance would have priority access to the chargers.

***Charging by default:*** this is charging whenever the car is not in use, either at work or at home: '*whatever happens*'. One Australian UNSW study respondent said, '*So if you have a petrol car, you're going to bring it home, it's gonna sit in the garage. It made sense to have an electric car that's going to sit in the garage and charge anyway*'. This can become an unconscious rhythm: '*My wife knows that when she gets home and she just plugs the car.*

*And in the morning she unplugs it, that's it.*' This is commonly likened to automatically plugging in a mobile phone at night. 14% of the Australian AGL trial participants stated in the onboarding survey that they '*leave it plugged in [...] regardless of the charge in the battery'*. The Norwegian study respondents considered it somewhat of a hassle to plug the car in every time it was parked, so charging was mainly taken care of during the night. Access to charging at the workplace is greatly appreciated as pointed out by several of the Dutch V2G participants: '*V2G [charging] fits [my] work schedule*'. This is the case even when charging in the workplace is not essential for commuting home. This is because many EV users feel that it fits their routine, often like to have high states of charge and feel that the extended range gives them additional freedom. At the workplace, a participant in the Dutch trial seemed to plug it in each day and leave it till she got back, saying she '*always charged it for long periods of time*'.

***Charging around other activities:*** this is charging that fits around other activities in the driver's life according to necessity, convenience and pleasure. For example, according to the Australian UNSW study participants, charging may be made to fit around other family activities on a Saturday: '*And if it's charging for five hours during a Saturday or four hours, then it's not available for use, but we manage that around what we need to do*' or on a family roadtrip: '*the stops were not constrained by the charging speed of the car though but was blowing off steam for the kid*'. Charging can be integrated with necessary and/or pleasant tasks: '*we go to the Adelaide Central Markets once a week to do our main grocery shopping and basically, so Friday night, we park the car, plug in the EV, go out for dinner, go do the shopping, two hours later, come back, the car's full'*. Or charging is fitted in whenever it is convenient: '*it's not like going with the petrol car to the petrol station and filling up again because you ran out of fuel, it's topping up a little bit here and there whenever it's convenient*'. Similarly, in Norway, charging on the way to the holiday cabin is a part of road trips that can be combined with other activities like shopping, and also providing a break. One interviewee said '*(driving to the cabin) with the kids I knew I had to charge, so then I knew where it [a charger] was and then we also shopped while it charged*'. A few of the informants in Norway also revealed that they had in fact used shopping mall charging facilities at times when it was difficult to find parking spaces there. In these cases, they plugged the cable in to "*make it look like they were charging*", even though they had no interest in it beyond using the parking space.

***Charging when solar energy is available***: this is charging when solar energy is available either during the day or from a battery at night – an imperative which may take priority over the other objectives above. Some Australian UNSW study participants who charge from their rooftop solar systems adjust the charge rate to match their solar generation: '*So I'll plug it in and I will adjust the charge rate to match how much solar we're producing more or less, and then I go away*'. Another noted that after a weekend roadtrip that has depleted the battery, he staggers the recharging, reasoning that '*because I'm using the solar [...] it doesn't worry me if I take a day or two to finally catch up [...] it might get back up to 50% on Monday and then up to 90% on Tuesday*.' Approximately 20% of Australian AGL EV orchestration trial participants stated that they charge from their solar system. Participants appreciated the fact that solar charging was enabled by design at the workplace charging system in the Netherlands, particularly when coupled with the energy storage in the car: '*[I] believe ...*

*there is a big need for electric energy storage capacity as the amount of green energy increases. [I] like … the fact that the PV panels above the V2G station deliver energy'*; '*[I] like … that a big portion of the energy came from local solar cells.'*

***Charging to minimise costs:*** this is charging to use least-cost electricity. For some Australian study participants, it means home charging using off-peak electricity, often overnight, as an alternative to solar. '*Well, actually, cost-wise for us, there's actually no difference to do it with the sun or to do it overnight. And you can – it has a program that – so, it switches on at 1:00 AM and it switches off at 5:00 AM if it hasn't fully charged'*. For others, it involves seeking out public fast chargers that provide free electricity or deliberately leaving uncharged battery capacity to use free public chargers. In the Dutch V2G case, charging to minimise costs was coupled with discharging to earn revenue. As one participant in the trial put it, '*[V2G has] the potential to save money by charging the batteries when energy is abundant and sell energy when energy is in short supply'*. Rather than being profit-oriented, this charging behaviour was often described as socially responsible, contributing to the energy transition, solving grid balancing issues or environmentally friendly charging. Two of four Swedish study participants with an EV also charged their cars at nighttime to take advantage of lower energy costs.

## CHARGING WORK

Some of the Australian UNSW study participants note that EV charging is easier than they expected. They commented that they '*spend a fraction of the time I used to spend filling up my car with energy'*, '*really do like the charging because it is relatively quick*' and believe that people need to think of an EV like they do a phone: '*you put it on your bedside at night or in the garage, and you forget about it'*. One said that the amount of time spent charging is effectively the time it takes to plug the car in at home: '*I mean it's literally a few seconds and you're done. People often say to me, "How long did it take you to charge it?" Well, literally it's like ten seconds to plug it in, and that's it, I'll go to bed.  It's no hassle at all.'* A couple reflected that the convenience of EV charging, compared to ICE vehicle refueling, had come as a surprise: '*It's a lot more convenient'; 'I didn't think about that, to be honest, but it's so convenient to charge at home, of course, compared to a petrol car'*. Indeed, the ease of refueling is described as mitigating range anxiety: '*that's been interesting to go through that experience of having that maybe sort of reservation about what the range can or can't do, and then you realise you actually – instead of going to a petrol station once every few weeks or something, just plug it in at night and it sorts itself out'*. The insight that charging was easier than expected was also found with V2G charging. After the trial, one of the participants remarked that it wasn't as hard as expected. The V2G charge point was '*easy to use, and everybody should be able to use [it]'.*

However, there is work involved in EV charging. One aspect is the physical process of plugging and unplugging the charging cable that is not unlike the process of refueling at a petrol station. One Australian UNSW study participant said that, while they want to charge from their solar system, they do not go the 'bother' of unplugging the vehicle in the evening: '*we've got solar, as you know, and so we try to get as much out of that as we can during the day, but we tend just to leave it on even overnight, just because we can't be bothered going*

*out to the shed to turn it off. It's not that close to the house*'. Australian AGL trial participants have expressed that they need to be disciplined in order to not forget to charge their vehicles[112]. In the Norwegian study, one informant explained that "*charging is tedious when the weather is wet and cold*", as it takes time to plug the charger in and one would rather want to get inside. Manual plugging in has likewise been found in a Danish study to be '*generally experienced [by participants] as […] something extra to do and remember*'[113].

Coordinating the charging of the EV is another form of work. One of the Swedish study participants described the care of the EV as a 'pain' compared to that of ICEV: *"one wants to be nice to the battery, to have it charged between 80 and 30%, then the battery will last the longest. That aspect is much more of a pain with this than if you had a petrol car. Then it's just. You drive and then you're out and then you refill. That's how you would want it to be."* In particular, the balancing of various considerations – EV use, household energy consumption, cost – in decisions about when and how to use solar energy that were discussed above are described by Australian study participants as requiring effort: '*Then the last few months I've been trying to charge as much renewably as possible, so that that does take a bit of work*'. One UNSW study respondent said of taking into account solar generation, his time-of-use tariff and daylight savings shifts: '*It's complicated. You gotta keep thinking*'. Interestingly, one participant described no longer 'bothering' to monitor his solar generation and manually adjusting the EV charging rate accordingly: '*I guess, when I first got it, I was absolutely draconian about only charging it from our solar […] So I was trying to optimise it down to the last kilowatt hour. Now I'm like, "Great. Close enough, good enough"*'. The factors weighed up by the participants in coordinating their charging are outlined below.

**Use of home appliances**

Need, convenience and cost are among the main imperatives that influence households' use of discretionary energy-consuming appliances such as washing machines and dishwashers. An Australian trial participant simply said, '*If I need to use the washing machine, I'm going to use it*'. A household interviewed in the Swedish study reported that they turn on the washing machine and the dishwasher when going to bed around 11pm, out of convenience.[114] Other study participants have explained how they plan the timing of such activities to minimise costs by "*try[ing] not to do laundry when it's most expensive".* For example, a Swedish household reported that they deliberately do laundry and dishwashing at certain hours of the day: *"We do laundry and wash the dishes (...) after 10pm or before 6am because it's less expensive, and on the weekends"*. Another uses an app to see dynamic electricity prices to plan when to run the dishwasher or washing machine. The times at which people undertake these activities can vary considerably, depending on lifestyle, electricity tariff structure, and other factors.

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[112] Perspicacious, 'AGL EV Smart Charging Trial – Round One: Download of Findings', 5 August 2021
[113] F. Friis, T.H. Christensen, The challenge of time shifting energy demand practices: Insights from Denmark, *Energy Res. Soc. Sci.* 19 (2016), p. 218
[114] Interviewees were not asked specifically about their laundry and dishwashing habits. Instead, they were asked about responsibilities or 'domains' within the household, as well as whether they would be open to having electrical consumption automated by an external actor or by themselves.

## 9.3 Potential for time-shifting

This section explores the factors that shape the timing of people's energy use, to better understand whether people are able to time-shift these energy activities within the context of DSM, and why or why not. Such potential reflects their flexibility capital – not only their willingness to time-shift their energy activities, but their capacity to do so amongst their habits and routines, the social dynamics in the household, and the physical environment of the home.

**Electric vehicle charging**

The EV charging practices outlined above are underpinned by a number of considerations around the availability of rooftop solar energy, the cost of energy, EV driving plans and other household consumption needs. People may be open to – or indeed already are – changing the timing of their EV charging based on some of these considerations.

Many of the Australian UNSW study participants are committed to charging their EV with the energy generated by their rooftop solar systems. For them charging overnight from the grid is '*the last resort'*, or at least they '*prioritise when the sun's out*'. For many, this is motivated by environmental values. One participant commented that '*my conscience on those grounds is good, is clear, no matter what*' because she knows that she is using solar energy whether charging at home, at a local public charger, or at her workplace. For others, the installation of the rooftop solar system was a financial investment and access to cheaper energy is a motivation to charge from their solar system: '*A bit of cost, 'cause I guess I'd specifically put in an ample-sized solar system so I'd have extra capacity and rather than export it to the grid, I thought it was better to consume it myself.*' For yet others, it is important to charge from their rooftop solar systems for a combination of environmental and financial considerations: 'I just charge off the solar because I know it is the cheapest and it feels the best'.

Other participants habitually charge from the grid and have chosen tariff structures that enable them to minimise the cost of charging. Predictably, they vary in how careful they are to manage these costs. One participant mentioned that sometimes he '*leaves a bit of room*' in the battery after charging at home to be able to take advantage of free charging at shopping centres. On the other hand, another commented that '*if I had to charge it overnight – the cost that we're talking about is so small, it's not really worth stressing over.  I mean I like to save but, you know, if I need to charge, I let it charge*'. In Norway, EV owners who charge their cars at night have been found to be *'more aware of power consumption than non-electric car owners, while electric car owners who do not charge at night are the least conscious consumers'*[115].

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[115] Kjersti Vøllestad, R&D in ELVIA, 2021

The participants who seek to use their solar systems to charge their EVs, whether for environmental or cost reasons, are frequently balancing that imperative with other considerations. One such factor is EV use, when upcoming travel may require faster charging than is possible from a solar system or may require charging when solar energy is not available. Some Australian UNSW study respondents describe adjusting the rate of charging from their solar system based on how soon they next need to drive the EV. One said '*I'll plug it in during the day and it'll charge up. I can actually charge it at ten amps or six amps. So sometimes if I'm in a hurry, I would charge it at the ten amps and that takes five hours from empty to full*'. Another said '*So I would just have it on the solar mode. […] If I'm particularly low, I might override that and just go, look, I need to explicitly charge it to this level before I head off and I just let the charger manage that*'. Conversely, one participant recounted scheduling the use of his hybrid EV to allow him to charge from his solar system: '*I wanted to go out and do some stuff just locally, so – but I just waited an hour and a half for the charge so I'm using the battery rather than using fuel*'.

Another consideration that can be in tension with charging from a rooftop solar system is the consumption needs of other household loads, which can compete with EV charging needs in a context of limited solar generation capacity. On overcast days, for example, one UNSW study participant notes that she '*ha[s] to balance whether I'm gonna charge my car or run my air conditioner to heat the house, that sort of stuff […] And sometimes we get two or three overcast days and my batteries don't recharge to a hundred percent on those days. So it's a balancing act*'. Another with an off-grid property has to coordinate charging on overcast days in order to not '*drain […] the battery too much*' and take the energy required within her home. Some participants tend to not use the energy generated by their solar systems for EV charging at all because it exhausts their supply: '*if I've got something else going on in the house, when I plug the car in, instantly I'm drawing from the grid […] So I just stopped*'. They therefore prioritise household consumption, using solar energy for household loads and charging their EV from the grid.

Considerations of cost are at play in the choices of many of those participants who are interested in charging from solar energy, as evident in their often complex calculations around solar exports, solar self-consumption and retail tariffs. One UNSW study respondent adjusts her rate of charging to maximise solar export revenues:

> '*So if I wanted to plug it in now and juice it from the sun, it would probably only take just over an hour. But because I know I'm gonna be here all day, I'll do it a little bit slower […] I've maintained the high feed-in rate but in order to get that I've had to reduce my export. So I can only export 10 kilowatts instead of the network limit of 15. So if I charge really fast now, later on in the day, once the battery is full, then I can be still producing a shitload and not be able to get rid of it all.*'

Two of the Solar Analytics participants described changing their charging practices due to a shift in their import or export tariffs. One moved from a flat to a time-of-use tariff, prompting him to charge less in hours of sunlight and more in the off-peak period:

> *'I think probably what's changed is that our electricity tariff has changed in that period. So before – I think the first year we just had a flat tariff. So I think using electricity at home particularly during the daytimes, I was inclined to try to squeeze as much solar as possible, but now because the day time rates are actually the cheapest tariff rate, I'm a little bit more liberal in terms of the winter months just going, look, I'm actually okay for it to charge then because I know the majority of that is gonna be mostly solar because our grid is highly renewable anyway and I'm getting good price on it.'*

The other experienced a reduction in his solar feed-in tariff, prompting him to charge from his solar system rather than overnight: '*So it really has changed from 80% overnight when I was in this high feed-in tariff to now 80% during the day*'.

A further factor weighed against charging the EV from a solar system is simply the effort involved, as discussed above. One participant refers to the task of monitoring and managing unpredictable solar charging as onerous. She charges from the grid because 'then we don't have to predict, '*Is the sun gonna stay out? Are we going to continue to produce enough solar to charge it?" […] I'm not sure if that's <laughs> in the spirit of having solar panels and an EV*'.

Some EV owners use technology to support the work or managing all of these considerations. Interviews with Norwegian EV owners have revealed that they use an app or manipulate the settings in the car itself to avoid charging at peak hours, as this was considered *'unnecessary'*. Two of the four Swedish households with EVs had tried to schedule charging of the car through an app but were not satisfied with the result, and one of them had given up and was manually plugging in and unplugging the car. A smart charger that can be programmed is used to charge with the cheapest and/or most renewable energy available: '*the charger's actually part of the RV inverter for the solar system and the reason I was quite attracted to that was it actually has specific modes that you can set up so that it will only charge using excess solar so it wouldn't use any additional power from the grid. […] Yeah, I pretty much have my car plugged in, as I've said, all the time when I'm at home […] it charges when the sun is out and I'm generating excess solar*'. A Swedish household with a fully electric car has an app from their DSO and dynamic pricing scheme. The charging of the car is automatically scheduled by the interviewee: '*I have set it to always charge up to 20% of the capacity of the battery, even when the price is high. Between 20% and 80% it should only charge when the price is at its lowest, and it handles that automatically. And since I know that tonight at 2am the price will be much lower than now so we can wait until then. And then it knows how many hours are needed to charge the car, and if so it needs to start here. So it handles all of that automatically.*'

**Use of home appliances**

Some participants could see potential benefits in time-shifting their home appliances with the use of automation technology. One benefit is the possibility to control the appliance to run when it is most convenient. One Swedish household reflected, for example, that *"if we would*

*be in our country house, we might have loaded the washing machine before we left and then you could turn it on on your way home".* Among the Swedish households that reported already time-shifting, the most common reason was to take advantage of variable tariffs to plan the start of dishwasher and washing machine to when electricity prices were lower. The households in the town of Walenstadt participating in the Swiss Quartierstrom peer-to-peer energy trading trial have also reported that they have been time-shifting the use of washing machines and dishwashers to the sunlight hours in response to the data available to them about the monetary benefits of using local PV production. Some children among these Walenstadt households have reportedly also begun to charge their mobile phones during sunlight hours – presumably as they have understood that the highly novel trial is intended to maximise solar self-consumption.

Some households use technology to shift their energy activities to periods in which energy is cheaper. For example, one Swedish household checks the app from their DSO *"before doing laundry, yes now the cost is a bit lower and then I can turn on the machine, so I have been doing that"*. Another reports that he checks the electricity price *"almost every time, sometimes you have to do laundry even though it's expensive, but in 8 out of 10 I'll check the app and see that it's better to do it in a little while".* When introduced to a smart home app and asked which features they would like, the participants of the Swedish study indicated that they want to see their consumption in real-time. One of the reasons was that this would allow them to make adjustments and experiment with appliances to see what happens when appliances are turned off, *"because that would be of most benefit if one could see, oh, there is something here that is not right, something that consumes a lot."* Another household wished for the same functionality but for the purpose of changing one's consumption patterns in the moment, *"if I had a meter where I could see in real-time [the dishwasher], that connection makes it possible to affect one's patterns in the now.. (...) We turned off the heat, but we didn't see it".* Others want to be able to view how much electricity that is produced in one's PV panels.

In the Australian smart home trial by RedGrid, messages were used to prompt participants to manually shift the use of their washing machine or dishwasher in periods of either high solar energy availability or peak grid demand. About half of the participants perceived it to be easy to load shift, commenting that '*Most of the time it was easy*', '*I liked the time window, I tried to work around those times if I could*' and '*It was only rare situations when we couldn't work it in*'. One said, '*I don't have to do the washing straight away, if I can I'll do it later during peak renewables*'. The other half found time-shifting more difficult. This was because they have established routines for activities like laundry and dishwashing. One commented that it was '*very hard […] I only do my washing on a Sunday and the notifications weren't sent then so I couldn't do anything about it*'; another that '*Sometimes it said use the dishwasher in the morning but that doesn't fit in with our schedules. There's no dirty dishes in the morning*'. Some participants distinguished between the flexibility of different loads: '*It was good that it was only load-shifting devices like washing machines, not home office, I can't change when I work*', and '*I'm not gonna change my behaviour on a microwave so totally depends on the device*'.

The Swedish households likewise reflected that time-shifting was challenging because it was not – yet – part of their routines: *"I read somewhere that it was better to do laundry and run the dishwasher after 9pm (...) But we haven't started doing that because we're not used to that. So I haven't started thinking like that yet [laugh]"*. Another pointed out that although there is some room for shifting, it is within limits related to necessities of daily life: *"the difficult part is that clothes need to be clean and dishes need to be clean at a certain time so it is not possible to adapt too much. But if one could close that [thing] when leaving for work and then it could turn itself on at the right time, then things would be easier"*. These comments suggest that there is some scope for time-shifting with assistance from automation technologies if it can be made to fit in with a routine. There are other implications for the household, however, that cannot be overcome; for example, one household stated that they did not want to do laundry during the night because it makes too much noise.

## 9.4 Orchestration of energy activities

This section considers further whether people are open to third-party aggregators using automation technologies to manage these practices, including to time-shift them.

**Managed EV charging**

People are likely to be more open to managed charging if it supports, or at least does not disrupt, their charging practices and the travel needs that these practices serve. Among the AGL trial participants interviewed, the participants already charging at off-peak times were most confident that participation in the trial could accommodate their charging needs. Those who charge from their rooftop solar systems and/or who do not have a regular charging schedule were less confident.

Australian participants in both the AGL trial and UNSW study expressed the concerns that their EVs would not be sufficiently charged when required or that the managed charging would directly limit the travel possible. Participants believe that managed charging would require a flexibility not possible because they have '*lots of different schedules with [...] how I'm doing my line of work*', for example. Another participant said that a financial incentive could not entice him to compromise his freedom to travel: '*I charge my car, it cost me five bucks to get to Sydney and back. You tell me you can offer me that at half a price, it's $2.50, it'll take me a week. No, I don't want sign up for that*.' This perspective reveals an assumption that a managed charging program would materially constrain car use. As discussed above, AGL interviewees maintain a minimum level of charge for a variety of contingencies. The respondents not participating in AGL's EV orchestration trial were accordingly concerned that managed charging would leave them vulnerable in such contingencies. Most pointed to scenarios in which shift workers and others without regular routines could be left without a charged EV when they need it. Interestingly, when raising such possibilities to illustrate their concerns about managed charging they appeared to discount the extent to which their own travel and charging practices have taken on relatively

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predictable rhythms.[116] Participants in the Dutch trials were split in their responses on control of charging. Many expressed a fear of being caught with low range remaining, which was the main reason why they wished to retain control.

The EV drivers in the case studies were positive about mechanisms to limit or remove the chance that the EV would not be available to them when needed. The participants of one of the Swiss innovative self-consumption trials are able to input their departure time and travel distance into the smart charging system and have been prepared to allow their EV charging to be controlled accordingly. The main mechanism that came up in the Australian UNSW interviews was a manual override or other option to opt out of the charging event: *'This would have to be a system whereby you could choose to not participate'*; *'No, the only thing I thought of if you're really desperate like you need 100% for the next day for a big trip or something like that, but the fact that you could opt out, that was fine for me'*. This option to opt out is important to participants whether or not they are likely to need to use it: *'Yeah [he would want an override], but that - as I said, that's not everyday type thing and as I've said, I've got enough capacity in my battery to go for a number of days without having to stress about whether I'm charged or not'*. One participant reflected that this option would be necessary *'given the provider doesn't know my planned behaviour, for example, I guess, yeah, you would want to have this flexibility'*. Similarly, during a smart charging trial in the Netherlands, van Bokhoven and colleagues found that approximately half their participants each felt that a manual override was an essential option or that it was a useful option.[117] However, in practice, 63% never used it and 16% used it only out of curiosity. When asked if the possibility to specify a minimum level of charge within the managed charging program, most Australian AGL participants also responded emphatically that this is important to them. Various trials in literature refer to users wishing to have the option of minimum range, minimum state of charge or minimum energy content at the time of departure.

For some EV drivers, there are practical hurdles to overcome related to their charging infrastructure and parking arrangement. One Australian UNSW interviewee responded *'I probably would, but that would probably require a dedicated charger and we're just charging ad hoc with the emergency charger that comes with the car. So we'd need some more infrastructure in our house'*. Another commented *'Having your own secure garage, convenient garage facility, is probably the biggest challenge. […] a lot of the urban population would struggle to have that. It's not trivial for us. We have to move things about, we have to change a little bit about our living patterns if we were to garage the car every night. […] So for me, there's a mind shift in that.'* This reflects the observation in the sociological l literature that energy practices are embedded within – and their flexibility therefore constrained by – the material configurations of the home.[118]

[116] Perspicacious, 'AGL EV Smart Charging Trial – Round One: Download of Findings', 5 August 2021

[117] van Bokhoven, P., Gardien, L., Klapwijk, P., Refa, N., Berende, M., van Zante, A., Heinen, J. W., & Kats, R. (2020). *Charge management of electric vehicles at home: Testing smart charging with a home energy management system*. https://www.enpuls.nl/media/m41nbbcf/rapport_charge-management-of-electric-vehicles-at-home.pdf

[118] G. Powells, H. Bulkeley, S. Bell, E. Judson, Peak electricity demand and the flexibility of everyday life, Geoforum. 55 (2014) 43–52; T.H. Christensen, F. Friis, Materiality and automation of household practices: Experiences from a Danish time shifting trial, (n.d.); E. Shove, G. Walker, What Is Energy For? Social Practice and Energy Demand, Theory Cult. Soc. 31 (2014) 41–58; E. Shove, N. Cass, Time, Practices and Energy Demand: implications for flexibility, (n.d.)

While EV charging involves work, as discussed above, it is also possible for smart charging itself to create its own additional work for participants. In the Dutch V2G trial, several participants expressed that they were too busy to continuously manage the charging profile. They did not want to '*get notifications throughout the day*' but wished for a '*weekly or monthly report*'. The willingness to participate in a Swiss innovative self-consumption optimisation trial was conditional on it being simple to use. The requirement that the participants must indicate some information in their smartphone appeared to be a significant barrier for them: some complained about it and indicated that they would prefer an interface directly installed in the vehicle.

**Remote control of home appliances**

As has been reported in the existing literature, acceptance of remote control of home appliances tends to depend on a perception that it will not cause inconvenience.[119] Some of the Swedish households were more open to the possibility of someone else controlling their electricity use, *"as long as it does not create any inconvenience for us"*. Other households in the Swedish study were open to using automation for time-shifting, but not for the sake of time-shifting itself but rather because they could see that it could offer some added convenience, such as in the case of coming home to or waking up to a finished washing machine. The possibility to choose the parameters of the automation, monitor it and opt out is also important. The participants of one of the Swiss innovative self-consumption optimization trial indicated in interviews that heat pump and hot water automatic load-shifting is acceptable to them because they feel that they can influence the system (by inputting a temperature range that is accommodated by an algorithmic automation system for their who apartment complex), as well as because they do not experience any discomfort.

When asked what they think of letting someone else control their energy use for some appliances, several of the Swedish participants had concerns related to loss of control. Some were afraid of losing control in a way that suggested concerns about broader issues of national sovereignty: *"no, we want to control that ourselves. Otherwise, it might end up too far away from us. It's like with decisions being made in the EU that do not correspond to what Sweden thinks [...] And the same can happen if we let go of this control"*. Another interviewee was worried that this would mean a limit in their energy use, *"no, that is no fun. I am in charge here [laughter]. No, it should probably not be like that. You mean that if it reaches a certain consumption it will be cut off, or?"*. Another household was also worried that it might affect her chores or comfort, *"Someone else in control? Nah, that would be difficult if I cannot do laundry when I want to, or if they turn down the heat one degree and I'll be cold"*, although she was more open to monitoring and a push saying that 'now is an appropriate time to do laundry'. One interviewee could not see the reason for someone else controlling her home; "*I can't see why. If I or someone else in my family wants to control,*

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[119] K. Buchanan, N. Banks, I. Preston, R. Russo, The British public's perception of the UK smart metering initiative: Threats and opportunities, *Energy Policy*. 91 (2016) 87–97; M.J. Fell, D. Shipworth, G.M. Huebner, C.A. Elwell, Exploring perceived control in domestic electricity demand-side response, *Technol. Anal. Strateg. Manag.* 26 (2014) 1118–1130; Y. Strengers, Air-conditioning Australian households: The impact of dynamic peak pricing, *Energy Policy*. 38 (2010) 7312–7322

*then we should do it. Why should someone else decide how warm or cold I want it to be or when I should turn on the dishwasher? They cannot know what daily rhythm we have, when we want to charge the electric car?"*, concluding that it needs to be on their terms and that it should be easy to change one's mind. Another pointed to the practical limitations of remote control: *"one might choose to do laundry and dishes at other times.. but [the grid operator] cannot fill nor empty our washing machine. However, they could send out push notifications saying 'don't run [the machines] now, wait a bit' ... that kind of information would be good"*.

## 9.5 Conclusion

People are engaged in a number of activities in the home that use energy, all of which are influenced by configurations of social, cultural and economic factors and dynamics. This analysis has focussed on the routines that households have developed around EV charging and the use of home appliances, particularly washing machines and dishwashers. For example, various charging routines have emerged with the take-up of EVs, each of which has its own rhythms, including: charging to maintain battery close to full, charging when the battery has been depleted to a certain minimum level of charge, charging when needed, charging by default, charging around other tasks, charging when solar energy is available, and charging to minimise costs.

The considerations that are already influencing the timing of household energy activities include balancing need, cost, and the availability of renewable energy. Some households are effectively already time-shifting, or are open to doing so – in the ways that are possible in their specific circumstances. The example of the children in Walenstadt, Switzerland, who have started charging their mobile phones in sunlight hours illustrates that people may be motivated to change their energy activities in whichever ways are available to them, which differ for different members of households. Some people are already using technology to support their energy activity planning around these priorities and considerations, using the settings of their home appliances or EVs or associated apps to program start and end times. The ways that people are already using technology to support their planning offer insights into how automated DSM can be designed to fit into and support household activities. These include to monitor and calculate the cost of energy and availability of renewable energy and the physical work of turning appliances and chargers on or off.

People's responses to the possibility of automated control differ according to the energy loads affected and the routines and meanings associated with those loads in individual households. For example, some households that have established laundry and dishwashing routines were not receptive to suggestions that they operate their appliances in periods of high solar energy availability or peak demand, while those who said that they were able to do their laundry at various times were more open. On the other hand, those typically charging their EVs in nighttime off-peak periods were more confident that managed charging could accommodate their needs than those who charge on an ad hoc basis, because the managed charging would align with their existing routine. People are therefore more likely to be more open to automated DSM if it supports the existing approaches to energy activities in the home.

# 10. The Socio-technical Making of Automated Load Flexibility

*Science and Technology Studies*

## 10.1 Introduction

This chapter employs a socio-technical perspective to analyse how the social license to automate may be achieved. A socio-technical perspective, as developed within the field of Science and Technology Studies (STS), is particularly useful for understanding how technological artefacts and systems shape and are shaped by both technological and social factors that cannot be separated - or, as expressed by STS scholars, how they are *co-produced* (by cultural, political, epistemic and material elements and practises). For instance, building on such insights we may understand how entrepreneurs, engineers and their allies in the energy industry seek to build a 'social license to automate' based on smart technology through the process of 'translation'.[120] Translation is theorised as taking place in four stages. The first is the *problematisation,* in which the definition of the problem by an actor or a group happens through negotiations of what the problem is and how to solve it. The second phase, '*interessement'*, is about 'locking' others into roles that were proposed for them in order to solve the problem. This involves defining roles for them - which, in the case of automated DSM, includes the role of the energy user who is expected to provide flexibility through access to their devices for the automating party. *Enrolment* is the third phase, in which the definitions and interrelations of the roles established in the *interessement* phase are accepted. The fourth and final phase in this process is *mobilization,* in which the different actors and groups involved establish spokespeople to represent their interests around the new technology.

- In the case of automated DSM, analysis of the translation process may be useful to bring to the surface:
- How do different actors work to define the problem at hand - for instance, what problem is automated DSM solving?
- How is automated DSM translated and negotiated as the solution from the point of view of one or more actors?
- How do users' expectations and values align, or fail to align, with this vision of the solution?
- How and in what ways are actors being locked into certain roles - for instance, how are households being cast and enrolled as necessary flexibility providers in the energy system?
- Who are representing the different groups and who acts as their spokesperson?

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[120] Callon, M. 1986. 'Some Elements of a Sociology of Translation: Domestication of the Scallops and Fishermen of St Brieuc Bay'. In Law, J. (ed.) *Power, Action and Belief: A New Sociology of Knowledge?* Sociological Review Monograph 32.

Recent studies have introduced a vertical line into this understanding of the translation process, by highlighting the role of 'middle actors'[121]. Middle actors are actors that do different types of *articulation work* - that is, work needed to organize both the tasks and the relationship between actors.

Middle actors analysed in this chapter include:
- DSO customer service staff
- electricians
- smart home technology sales staff
- government agencies
- smart charger manufacturers
- the democratically elected housing board that represents all building residents
- regulatory authorities,
- National EV associations
- VPP developers

The processes of translation in the sphere of automated DSM have generated a variety of forms that it can take, including Direct Load Control of home appliances, smart EV charging and VPPs. Each of these contains specific understandings of the problems that need to be addressed and how automated DSM offers solutions. The discussion below examines each of these forms of automated DSM in turn. It is based on analysis of survey and interview data and published reports from selected case studies and related literature, primarily located in Norway and Australia. The STS concepts introduced above are employed where they are seen as bringing more nuanced understandings of the data.

## 10.2 Home appliance DLC

**Introduction**

The discussion below draws from trials in Norway and Australia of home energy management and automation systems, as well as from several air conditioning control programs and trials in Australia.  The Australian case studies are based on empirical data from interviews with the trial and program teams, published reporting, and - in the case of home automation trials - data from surveys and interviews conducted with the household participants. The Norwegian study builds on the interviews and observations of the 'middle actors' involved: the individuals involved in translating information about the rationale of the pilot to the participants.

The Norwegian smart home pilot, Flekshome, features smart hubs that can control slow loads like floor heaters, heat pumps and hot boilers. The household participants receive access to an app in which they can customize their own set-ups and add other smart house equipment. In this pilot it is an interface to the devices set up to be controlled remotely, providing notifications and allowing participants to opt in or out.  The Australian smart home

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[121] Parag, Y. and Janda, K.B., 2014. More than filler: Middle actors and socio-technical change in the energy system from the "middle-out". *Energy Research & Social Science,* 3, pp.102-112.

trial by RedGrid includes smart plugs that can be connected to various devices in the home and controlled through software technology. An app was developed over the course of the trial that would enable households to set the parameters of the DLC of their appliances but, as in the Norwegian case, was initially used to provide users with information about their energy use.

The air conditioning DLC trials and programs in Australia consist of ad hoc activation events in which the output of the household air conditioning unit is reduced for a period of some hours. They vary in the amount of information provided to households in advance of or during events, and whether they offer participants the possibility to opt out of the event.

**Articulating the problem and the solution**

The primary objectives of the smart home projects in Norway and Australia are to show how users can better distribute electricity consumption throughout the day without a loss of comfort. To encourage householders to opt in to the project the Norwegian DSO articulates the reason for smart home equipment and automation on their webpage as a way to avoid grid expansion: *"If we do not use all electrical devices at the same time or charge the car immediately after work, we do not have to expand the power grid just to cover the power demand during 'rush hours'"*. The air conditioning DLC programs and trials in Australia are likewise directed towards alleviating peak demand to manage wholesale price fluctuations, and as an alternative to increasing network capacity. One of the Australian air conditioning DLC programs has similarly employed the analogy of busy roads during peak traffic hour to communicate the problem of peak electricity demand to the public.

While the problem to be addressed is peak electricity demand, the solutions of peak shaving and peak shifting are connected to other rationales, appealing to various motivations on the part of energy users. In the Norwegian Flekshome pilot, participation is presented as a way to help '*save the community*' by making the grid '*a little smarter, more flexible*'. It is also a way to '*save the environment*' by making '*an important contribution to the green shift*'. The cost of electricity is offered as another reason for participation, with the promise that '*it will be easier for you to use the electricity more efficiently and get a lower electricity bill*'. Reduced electricity costs are also a prominent feature of the participation rationale in the Australian DLC programs. Some offer bill credits for the automation events participated in, which adds to the benefit of the energy saved during the more expensive peak period. RedGrid's trial in Australia explicitly brings together the environmental and economic motivations by stating in a video on their website '*We are here to help Australian households save money on their energy bill and save the environment at the same time [...] 'It really is about putting the environment and the economy together. For too long they've been pitted against each other*'.[122]

The solutions of peak shaving and peak shifting are presented as having no negative impact on users, and indeed as accommodating their needs. This can be seen in the following excerpt from the website of the Norwegian smart home technology provider:

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[122] RedGrid, trial introduction video, 2020, https://redgrid.io/getting-started-archive-2/ (accessed 4 Oct 2021)

*It may sound difficult to move your normal power consumption from one time of day to another, but it does not have to go beyond your comfort. [...] the home will adapt to your routines and needs. If you use the oven in the afternoon, the electric car can be switched off and started later or the water heater can turn off for an hour. All this can happen automatically without you noticing the comfort.*[123]

In other words, this technology is presented as being user-focused and making the user comfortable, because it is the home that adapts to the user rather than the other way around. In an air conditioning DLC trial in Australia, the automation technology is seen to support users to shift and shave their loads. In an interview, the trial team commented that 'You have two choices as a customer: do it all yourself or allow us to help you'. Automation figures here as an alternative to manual or behavioural demand response.

These constructions of the automation solution hint at a vision that goes beyond the immediate peak shifting and shaving trials. They anticipate a future in which flexibility is an essential part of energy use. The RedGrid smart home trial team articulated one form of this vision explicitly in an interview when they described their technology as a step towards a future in which households are empowered to participate in micro-transactions of energy in decentralised markets, and thereby claim power - in both senses of the term - from traditional actors in the energy system. There appears to be a tension here, however, between the function of automation to support or 'help' users to achieve load-shifting or shaving, and the promise of 'empowerment' and participation in demand response - as will be discussed below. Furthermore, the smart grid vision, and its accompanying promise that automation technologies need not have any negative impacts on comfort in the home, can be seen to obscure the alternative possibility that electricity consumption ought to be reduced to achieve environmental sustainability.

**The role of middle actors in translating DLC into users' homes**

Beyond the articulations of the problem and the solution by DSOs and the other companies that initiate automated DSM programs and trials, a variety of middle actors are involved in translating these articulations to users and negotiating their participation. These middle actors are engaged in crucial translation work through the processes of recruiting participants and installing smart home equipment.

*Building trust in automation through relations: engaging household participants*

In the Norwegian trial, customer service staff at the DSO recruited households to be part of the pilot project. In interviews they described beginning the negotiation of the household's participation in the following way: '*You have to listen to them [...] If you notice stress then you call them back. If you call someone and they are in the car, with low blood sugar and children in the back seat, then you can rather call back.*' This quote illustrates how the articulation work begins at the moment when the household is first contacted and the

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[123] Futurehome, 2021, https://join.futurehome.io/skagerak-nett/ (accessed 4 Oct 2021)

customer service staff start to develop an understanding of how to best reach the household. Thus, the first part of building trust is by listening to the customer. This also means there is no point in trying to get the customer to opt in if he/she is busy.

After establishing a relationship on the phone they can start talking about electricity consumption and what the automated DSM solution would offer for them and the DSO: *'We try to establish a relationship of trust, and that we need the customers' help. And then we tackle what are the disadvantages and what's in it for us'.* Good and thorough training in conversation techniques was seen as central, and one staff member also highlighted that her training in autism communication had proven useful in building trust and communicating with pilot users. She explained the method as being '*to simplify, not dumb down'.*

In the Australian case studies, it has similarly been found that the *'person in front of the customer when the decision is being finally made has a very powerful voice*', as one interviewee put it. Among the air conditioning DLC programs and trials, different middle actors have been enlisted to facilitate the recruitment of household participants, representing another dimension of negotiation and translation work by the DNSPs leading these programs. The recruitment of household participants by air conditioning retailers has been trialled and found to be challenging, largely because considerable engagement information, training sessions and store visits were necessary, which extended beyond the resources of these DNSPs. Recruitment through electricians who are installing new air conditioning units in homes and could activate the built-in demand response capability if the household chooses to opt into the program has been found to be more effective. This is because the electrician is a trusted figure and their advice to join or not to join is a key influence at the moment of the household's decision.

In the Australian smart home trial by RedGrid, building and maintaining personal relationships with the participants is considered important to its success. Phone calls with prospective participants got an 'overwhelmingly positive' response compared to email communication. Throughout the trial, different modes of communication - including email, SMS message, web app and phone call – were used depending on the information being conveyed and the response from the user that was required. The team member who managed communications with the trial participants tested the effect of different modes of communication and found that the responses elicited from the user varied according to who the message appeared to have been sent by. For example, the participants would reply to his SMS messages if he used his own name and sent direct requests, asking *'Do you mind if we do this?'*, while notifications that did not require a response could be sent from a more anonymous account representing RedGrid. The RedGrid team admits that it is not clear the extent to which their engagement and relationship-building efforts had influenced the participants' acceptance of control over their home appliances, and whether they would have accepted the automation to the same extent without it.

*Building trust in automation stepwise: introducing smart home equipment*

A variety of approaches have been trialled to support household participants in the onboarding and installation phases of the automated DSM programs, particularly in the

smart home trials. To engage the users in the Norwegian Flekshome trial, social media and tutorial videos on how to install technology or the functions of the app were used. They also explained the automation of electricity use by referring to household technologies, such as house security and fire alarm systems, that many people already use. In the Australian RedGrid trial, online videos and manuals were also provided to support the household technologies themselves, but as was the case in the recruitment process described above, direct calls from the trial team proved more effective, halving the set-up time. These calls were described by the RedGrid team as a good way to build rapport with users, receive feedback and educate them on the benefits of the technology.

The web certification for installers conducted as part of the trial included slides instructing the electricians to focus on the customers' needs, as illustrated by the following quote from one of the electricians: "*The first thing you need to know is what kind of customers are you installing [the technology] for.  Is it a technical advanced person? Is it for your grandmother? A family with children? Yourself? All have different preferences based on their life situations*". The electrician used

 Figure 38: Futurehome certification course material for electricians as a reminder of how to think about customer needs:

The electricians did not find it hard to explain to the users what to do with the app, but they had to tune into the customer's needs. One described explaining only the minimum that the user needed to know if he perceived that the user was not interested to learn more: '*Basically, you only need to relate to the front page [of the app] [...]. I often say, either to those who have difficulty understanding or those who are uninterested, that your front page is all you need to think about'. None of the other buttons (in the app).* If they were interested, however, he would show them more. Understanding the needs of individual users was thus seen by the middle actors of the Norwegian trial as a key prerequisite for being able to translate the technology.

The sales leader at the smart hub technology firm engaged in the Norwegian pilot explained their strategy to enrol users in the automation of smart homes as a stepwise process: '*We believe it is important that customers grow into this step by step, and are happy to start with simple things like setting the heat control themselves in the app, then they can move on to more and more automated control'.* This user-centric approach with not too much information and letting the users get used to simple solutions before making it more automated was one strategy of getting the trust of the end-users. Half a year into the pilot the DSO sought to make the role of the participants more active. This involved the renegotiation of the role of participants which was facilitated through an information video explaining the functions and possibilities of the smart hub and app.

RedGrid's smart home trial in Australia also employed an incremental approach to progressively lock participants into more active roles. In the first phase, the trial team automated the energy use of home appliances without notifying the participants, which they described as a 'low touch/impact scenario for the users', before they invited the participants to take a more active role in defining the parameters of the automation of their appliances by setting their preferences.

**Alignment with users' values and expectations**

The participants of the Australian smart home trial by RedGrid reported being primarily motivated by the potential to save money. Other reasons given included an interest in the technology, including an expectation that it '*will make my life easier*', as well as environmental considerations. The main motivations for participation in the air conditioning DLC trials are likewise to save money, followed by interest in technology. The RedGrid team commented that 'the motivations have to be in line with the participant and what's being automated', and that participants need not understand the details of how automation is serving these ends.

Participants of the RedGrid trial were eager for information about the energy consumption of their household appliances and how they can change it to reduce their energy bills. They were not notified of the automation of their appliances, however, and the RedGrid team maintains that it is not necessary to make everything transparent to the participants, especially for incremental changes to small loads. They argue that what proved to be most important to the participants throughout the trial was information about how different aspects of their participation in the trial translate into the rewards they are receiving (such as bill credits).

A large air conditioning program in Australia likewise does not provide notification of upcoming automation events to its participants and reports low levels of participants either noticing any change or making complaints. However, when asked if they want such notifications, participants typically indicate that they do. A survey of air conditioning DLC trial participants asked them which functions they would find useful to use if they were provided with a smart phone app to monitor and control their air conditioner. The most popular function was the ability to monitor their air conditioner usage in real time followed by the ability to estimate their electricity costs. Interestingly, in the same trial notifications were provided to participants in one geographical area, but not in another, and it was found in surveys that those who had received notifications valued them, while those that had not received notifications did not indicate a strong preference for such notifications.

As discussed above, part of the promise of automated DSM, as presented by program and trial managers, is to 'help' household participants by doing 'work' that would otherwise be left to them. A recruitment video on the website of the RedGrid trial invites participants to '*Let us do the work on the back end*', for example[124]. Indeed, positive feedback in the course of the trial was that participants 'Haven't had to do too much', and the interviews conducted with participants revealed that most had not noticed or were not affected when their appliances were remotely turned off.

At the same time, **a sense of being in control[125]** – and in particular the possibility to opt out of an automation event - is always found in research with energy users to be important to

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[124] RedGrid, trial introduction video, 2020, https://redgrid.io/getting-started-archive-2/

[125] See Adams, S., Kuch, D., Diamond, L., Fröhlich, P., Henriksen, I.M., Katzeff, C., Ryghaug, M. and Yilmaz, S., 2021. Social License to automate: A critical review of emerging approaches to electricity demand management. *Energy Research & Social Science*, 80, p.102210.

them[126]. What is more, the vision of smart home energy management in some ways envisages *more*, not less, engagement for users. A Norwegian smart home trial resisted the possibility that the smart home technology would require effort, and questioned its value: '*What can I use this for? Lots of power saving, apps and [...] I would rather sit and read a good novel. I have big plans for books I want to read rather than struggle with technology'.* The RedGrid team described how they discovered that they needed to move away from the 'willy-nilly' control of appliances undertaken in the first phase of the trial, to giving more control to the user by allowing them to set the parameters in which their devices can be turned off in later phases. This is because 'the user understands how their household uses energy, when they use certain devices and they can then apply our technology [...] to the best suited time for their households'. The team concluded that 'the user has to be in control'.

**Conclusion**

The control of household appliances is seen to address the problem of peak demand, enabling a more flexible and renewable grid as well as achieving financial savings for users in compensation for their contribution. It is often presented, in other words, as having complementary community, environmental and economic benefits. It is also presented as having no impact on comfort, and as carrying out the management of energy that would otherwise be required of the user. In the cases of the Norwegian and Australian smart home trials, the translation of the automation solution to trial participants was oriented towards the needs of the participants and hinged on building relations and gradually introducing the technology and only as required and desired by the user. DLC appears to be highly accepted by the participants of these trials and programs, reflecting that these programs are perceived to help them achieve their goals of saving money and contributing to the energy transition.

## 10.3 Smart Electric Vehicle charging

**Introduction**

This section explores how EV charging is being articulated as both a problem and a solution in various ways across several charging contexts: in detached homes; in shared residential garages; and in the promise of V2G charging. It primarily includes analysis of case studies in Norway and Australia, as well as a Dutch V2G case study.

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[126] X. Xu, C. Chen, X. Zhu, Q. Hu, Promoting acceptance of direct load control programs in the United States: Financial incentive versus control option, *Energy.* 147 (2018) 1278–1287; R. Smale, B. van Vliet, G. Spaargaren, When social practices meet smart grids: Flexibility, grid management, and domestic consumption in The Netherlands, *Energy Res. Soc. Sci.* 34 (2017); A.-G. Paetz, E. Dütschke, W. Fichtner, Smart Homes as a Means to Sustainable Energy Consumption: A Study of Consumer Perceptions, *J. Consum. Policy.* 35 (2012) 23–41; S.J. Darby, I. Pisica, Focus on electricity tariffs: experience and exploration of different charging schemes, in*: ECEEE Summer Study Proceedings*; M.J. Fell, D. Shipworth, G.M. Huebner, C.A. Elwell, Public acceptability of domestic demand-side response in Great Britain: The role of automation and direct load control, *Energy Res. Soc. Sci.* 9 (2015) 72–84

Norway has a national strategy to electrify the transport sector and there has been a strong state-led push for EVs visible in a comprehensive package of national and local economic incentives. These include purchase tax subsidies to bring the cost BEVs in line with comparable ICEV. road toll and registration fee exemptions, and financial support for the development of charging infrastructure. With fully electric EVs accounting for 13.64% of all passenger cars on the roads in June 2021[127], EVs have become mainstream and normalized elements in Norwegian mobility culture, and Norway appears to be on track to meet the target in the national strategy that from 2025 all new cars sold are emissions-free[128]. In 2020 85% of EV or PHEV owners charged their EVs at home[129], presenting the challenges of managing electricity demand in detached homes and access to charging in apartment buildings, as discussed below.



Figure 26: Norway new passenger car registrations by fuel type (source: @robbie_andrew
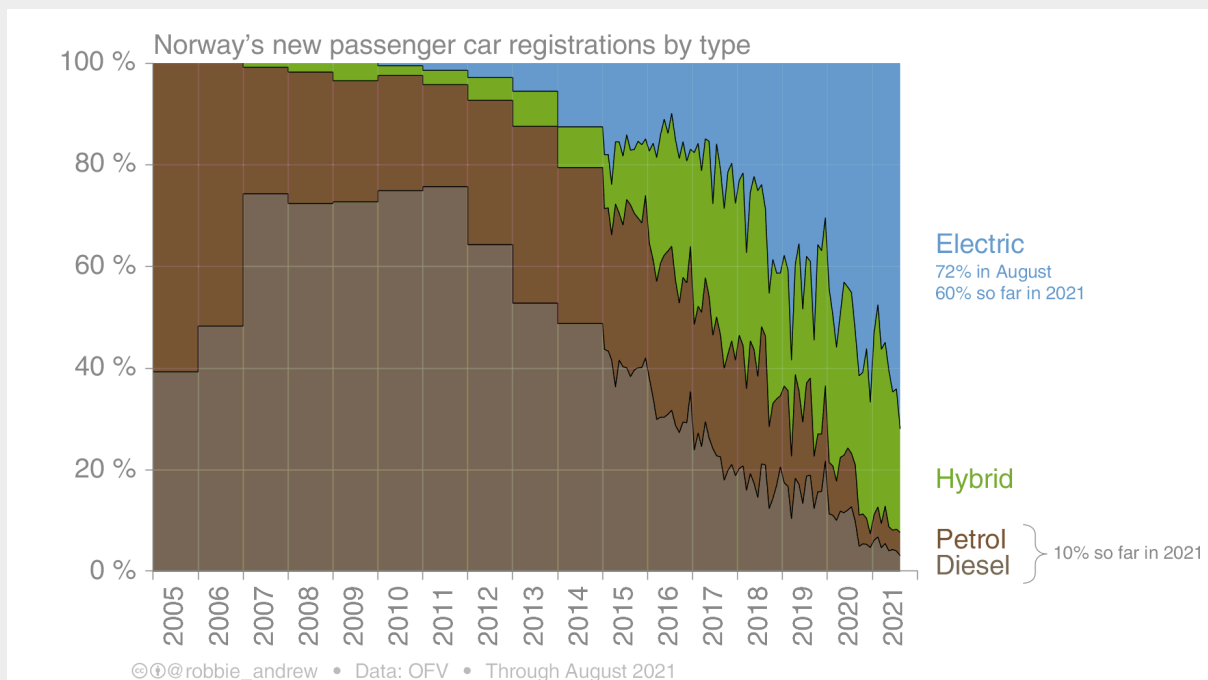
By contrast, only 0.1% of the ~20 million vehicles registered in 2021 in Australia are battery EVs, with petrol and diesel still dominating car sales and registrations (Figure 26). Australia's low EV uptake reflects its contested status in public policy. EVs have been the object of political point scoring, with conservative Prime Minister Scott Morrison infamously claiming in 2019 that the opposition party's policy would 'ruin the weekend' - a tagline taken up ironically

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127 https://elbil.no/om-elbil/elbilstatistikk/elbilbestand/

128 Ingeborgrud L and Ryghaug M. 2019. 'The role of practical, cognitive and symbolic factors in the successfully implementation of battery electric vehicles in Norway'. *Transportation Research Part A: Policy and Practice* 130: 507-516.
129 Sæle, H. 2020. 'Flexibility potential at Norwegian households – customer evaluations and system benefits'. Paper presented at the 2020 17th International Conference on the European Energy Market (EEM). DOI: 10.1109/EEM49802.2020.922191

by EV drivers[130] - while raising issues related to fuel excise revenue ($11bn), the cost of rolling out charging stations and practicalities of charging for apartment residents. More recently, the Australian government's future fuels strategy has articulated that its highest priority is the roll-out of EV charging infrastructure where it is needed[131]. Many electricity system operators are concerned about the potential impacts of peak charging on the electricity grid, and the Australian Energy Market Operator has recommended the urgent development of a register of all EV supply equipment - much of which operates behind the meter and is invisible to networks - to help inform network modelling and planning[132].

**Smart EV charging in detached homes**

The problem that initially saw EV charging become a concern in Norway was the **risk of fire** associated with charging directly from ordinary wall sockets. The Norwegian Directorate for Civil Protection and Emergency Planning[133] and the Norwegian Electrotechnical Committee developed[134] a recommendation on the safe charging of EVs that suggests the use of a dedicated charger and dedicated electricity circuit. The recommendation established dedicated chargers as a necessity but did not specify whether charging should be *smart* or not, resulting in subsequent debate about the need for smart charging.

Invoking charging in the home as a potential problem for the electricity grid, the Norwegian Water Resources and Energy Directorate (NVE) sought to encourage EV owners to shift charging to nighttime or off-peak periods in order to avoid grid capacity problems. A new time-of-use price scheme is likely to be implemented to encourage this. Also, the NVE noted that households are likely to be able to save money on the electricity bill from 2021 due to the implementation of AMS meters that will bill customers more correctly (according to time-of-use rather than average kilowatt hours used).[135] Smart charging that automatically charges EVs in off-peak hours is therefore promoted as a solution to the problem of potential power capacity problems (partly induced by electrification of the transport sector).

Manufacturers of smart charging technology have portrayed the benefits of smart charging in different ways, reflecting alternative understandings of the problem to which it is directed. A smart charger is described by EV manufacturer BMW as enabling households to charge safely: '*You charge safely and securely with the charging box and avoid the risk of overloading the main fuse*'[136]. Smart charger manufacturers that are not connected to EV manufacturers need to sell their chargers more actively and have introduced an economic rationale with reference to variable electricity prices. One promises that:

[130] https://thedriven.io/2021/04/06/electric-car-owners-poke-fun-at-morrison-say-evs-ruined-their-easter-weekend/
[131] DISER, 2021, Future Fuels Strategy https://consult.industry.gov.au/future-fuels-strategy
[132] AEMO 2020, Integrated System Plan https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2020-integrated-system-plan-isp
[133] https://www.elsikkerhetsportalen.no/wp-content/uploads/2019/06/elsikkerhet-91.pdf
[134] https://www.nek.no/info-ams-han-brukere/
[135] Ministry of Transport & Climate and the Ministry of the Environment. (2019) https://www.regjeringen.no/contentassets/67c3cd4b5256447984c17073b3988dc3/handlingsplan-for-infrastruktur-for-alternative-drivstoff.pdf
[136] https://eondrive.no/rask-og-sikker-hjemmelading-til-din-nye-bmw/

*'By planning and controlling when your electric car will be charged, Tibber[137] can buy electricity in a smarter way. You can take advantage of the fact that the electricity price is lower some hours a day, and that you get an extra discount to balance the electricity grid. In practice, this means that instead of starting charging as soon as you connect the charger, we plan to start charging at a later time'.[138]*

The EV association in Norway, which is a representative organization for all EV owners, also has a statement in relation to smart charging on their webpage:

*'In the future [...] it may be wise to have a smart charging box that at any time allows you to decide how much power your electric car should have and when it will be most appropriate to charge the electric car, both for the fuse box, the grid, and for the EV owner's wallet.'[139]*

Here the EV association, which has been an important middle actor in the mobility transition in Norway, can be seen to promote smart charging, not because it has a direct interest in its uptake, but because it is a further step in the successful deployment of EVs in Norway.[140] Other actors that are likely to play a role in translating smart charging as a viable and necessary solution that lock EV owners into the role of flexibility provider are car dealers and the electricians who install smart charging technology. However, the necessity of smart charging is still being debated and negotiated.

In Australia, home charging is seen as a challenge for the electricity grid, and as is the case in Norway, smart charging technology is viewed as a means to relieve pressure on the grid by shifting EV loads to periods of high solar generation and/or the off-peak period at night. The orchestration of EV charging by aggregators is additionally seen as itself a solution to other energy system challenges, potentially supporting grid stability through participation in ancillary markets, although this is yet to be trialled. The AGL EV orchestration trial articulates the benefits to prospective participants as threefold:

- 'Help save the planet: Your charging emissions will be Carbon Neutral at no extra cost, as certified by Climate Active.
- Manage your charging: See your charging schedule, preferences, and receive notifications about managed charging events, all in a handy app.
- More cash in your pocket: Get up to $200 in bill credits each year [...] for participating in managed charging events, surveys, and questionnaires throughout the trial.'[141]

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[137] Tibber is a digital electricity company that 'uses smart technology to buy power automatically.' They claim to have developed an interface between the AMS meter and the smart home equipment where an app gives the end-users time-of-use data, electricity prices and the possibility to manage their own electricity consumption through smart homes equipment like EV chargers Easee. Their business model also has the potential to be an aggregator in the long run. Their website claims 'Tibber is changing the electricity market' https://tibber.com/en (accessed 3 Oct 2021).

[138] https://tibber.com/no/produkt/easee

[139] https://elbil.no/lading/lade-elbilen-hjemme/lade-med-hjemmeladeboks/

[140] Ryghaug, M. and Skjølsvold, T.M. 2019. Nurturing a regime shift toward electro-mobility in Norway. In: Finger, M. and Audouin, M. *The Governance of Smart Transportation Systems*. Pp.147-165.

[141] https://www.agl.com.au/get-connected/electric-vehicles/smart-charging-trial

Upon entry into the trial, the participants of the AGL trial most commonly selected '*to support programs that help electric vehicles become a better option for Australians*', ahead of receiving a free or discounted charger or bill credits, as their main reason for joining the trial. One commented that given that '*people don't like being told what to do*', '*if [managed charging is] to have any chance at all, it needs to be a social proposition, not an economic one*'.[142] When asked whether they would be willing to join in a smart charging program, a few of the Australian UNSW study participants responded positively, giving reasons that focused on the benefits for grid management rather than the individual EV driver. One said, '*I think that would be a great idea that the operator would say, "Okay, let's charge all EVs and get this peak down." Of course. Why not?' […] if I can see a clearer benefit for the provider/the wider community, absolutely*'. Another responded '*Yeah, I think that's fair. I definitely think that that should actually be happening already*'. One participant appeared to be open to the suggestion because he is familiar with the direct load control of air conditioning in Queensland: '*It's very much like air conditioning where you can actually – where they switch off air conditioning at peak times, so a bit that sort of thing. I haven't got that here, but I would consider it*'.  As the AGL trial team notes, responses of these kinds are typical of the early adopter cohort but cannot be expected from later adopters, meaning that the right incentives will be required to attract their participation.

Participants of a Norwegian smart charging pilot report having been attracted to it for a range of reasons similar to those cited by the Australian study participants. These include an interest in technology, either for the practical functions they can be used for, such as to prevent fire (reflecting the Norwegian problem framing described above) or to achieve efficiency in the home, or for sheer pleasure in their use. These users may achieve load-shifting through the applications of the technology, but it is not a motivating factor. Some interviewees were also aware that Norwegian electricity prices are likely to increase in the future and that changing their time of use of energy could relieve pressure on the grid.

Willingness to participate in smart charging programs is likely to be highly conditional, however – and especially so among later adopters of EVs. Some AGL customers with EVs who are not participating in the EV orchestration trial indicated in interviews that they do not perceive tangible benefits in participating. Most UNSW study participants indicated that they would consider participating in a managed charging program, subject to the terms of the program. Their willingness to participate will depend on a perception that the benefits outweigh any disadvantages, as reflected in the following comment:

> 'If I could see the benefit to the grid or the operations and the burden I was creating, then, yeah, I wouldn't have a problem with it.'

This is more likely for those drivers with limited driving needs and/or an EV with a greater range, as is evident in the response that '*I'm not a driver that's really heavily discharging the battery every single day […] So if I don't charge today, it's not a massive deal. I just need to kind of – for me, I'd rather do the right thing by the environment or charge at low cost*'.

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[142] Perspicacious, 'AGL EV Smart Charging Trial – Round One: Download of Findings', 5 August 2021

The value that people perceive in such a program is related to the value that they perceive in owning an EV. Many of the UNSW participants reported that they were motivated to purchase an EV for primarily environmental and/or cost reasons, in addition to an interest in technology. As described in Chapter 9. Understanding the User's Household Energy Activities', consumers seek to realise their environmental and cost expectations through the ways they source their power. They may therefore be interested in smart charging where they perceive that it could help to satisfy these objectives. One participant described navigating the constraints of charging based on their preferences for renewable, off-peak energy – '*I'd rather not do that during a peak period and if I know it's not a windy day or a sunny day, I particularly don't wanna do that*' – and commented that '*if there was a solution where it was literally like "Here's the plug, you plug it in, and we will charge you either a variable tariff or an extremely cheap tariff, but we control the behaviour 100%," I will be pretty cool with that*'. Conversely, participants are less inclined to see how such a program could hold value for them at present if their current charging arrangements already satisfy their objectives: '*yes, I would [interested in participating], but at the moment, because of the feed-in tariff and the off-peak rate, we're happy with it how it is*'.

Another way in which smart charging can hold value for participants is evident in the way that it offers a 'solution' in the words of the participant quoted above. As discussed in Chapter 9, charging involves forms of work, including physically connecting and disconnecting the charger, as well as the monitoring and calculation of when to charge based on a variety of factors related to availability of renewable energy, cost of energy, and upcoming EV driving plans. Many UNSW participants already have forms of monitoring in place for their charging and were eager to join the study to acquire a solar generation and consumption monitoring device to assist in decision-making about EV charging. For the EV drivers who enjoy these tasks, managed charging is unlikely to hold additional value, as captured in the comment '*I can already manage these things myself, so there have to be some reason why I'd hand that over to another party […] I don't really see this as a chore*'. But, to the extent that participants would welcome the opportunity to be relieved of this work, they may be open to participating in managed charging. This is a finding consistent with the academic literature, which suggests that the automation of demand side management is most acceptable to households where it 'take[s] over some of the planning otherwise left to the householder'.[143] Further, given that early adopters express as a motivation for EV purchase their interest in technology, and express enjoyment of the tasks of monitoring and managing their EV charging, there may be more willing participants of managed charging programs among later adopters.

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[143] N. Verkade, J. Höffken, Is the Resource Man coming home? Engaging with an energy monitoring platform to foster flexible energy consumption in the Netherlands, *Energy Res. Soc. Sci*. 27 (2017) 36–44. p. 40; A.-G. Paetz, E. Dütschke, W. Fichtner, Smart Homes as a Means to Sustainable Energy Consumption: A Study of Consumer Perceptions, *J. Consum. Policy.* 35 (2012) 23–41; M.J. Fell, D. Shipworth, G.M. Huebner, C.A. Elwell, Exploring perceived control in domestic electricity demand-side response, *Technol. Anal. Strateg. Manag.* 26 (2014) 1118–1130; T.H. Christensen, F. Friis, M. Ryghaug, T.M. Skjølsvold, W. Throndsen, S.R. Fernandez, E.S. Perez, Recommendations and criteria for the design of smart grid solutions for households: Lessons learned for designers and policy makers from the IHSMAG project, (2016); Adams, S., Kuch, D., Diamond, L., Fröhlich, P., Henriksen, I. M., Katzeff, C., Ryghaug, M., Yilmaz, S. (2021). Social license to automate: A critical review of emerging approaches to electricity demand management. *Energy Research & Social Science*, 80, 102210

Users' acceptance of smart charging is also likely to be conditional on a sense of control over the conditions in which the charging of their EV could be controlled remotely. As was discussed in Chapter 9, the possibility to opt out of an automation event is considered crucial. The Norwegian smart charging trial participants indicated that they would be open to such remote control, but only if they could opt-out whenever they deemed necessary. Asking one end user to expand on their thoughts about submitting to curtailment caused them to consider how this would be defined or agreed upon with the DSO: *"No, I need to be able to overrule the primary functions of the house. […] I would not relinquish any control - and the same goes for the car. It is more - like when you input some settings, this is OK, right. So, if you define it as giving away control… I wouldn't put it that way."* This response offers insight into the negotiation process that takes place when users consider the idea of DSM. Initially, the idea of having any control over household electricity consumption taken away is deemed out of the question. However, once the respondent considers that they might be able to '*input some settings*' to define the scope of the remote control, they become more open to it. Importantly, they would not consider this '*giving away control'*.

For some users, however, there are no circumstances in which they would be willing to allow their EV to be remotely controlled. One UNSW study respondent simply said '*No. It's my $70,000 asset, back off*'. For participants with such an attitude, the terms of the smart charging program and the incentives offered may not influence them, especially when no other transport options are available to them (for example if they live far from public transport connections): '*it would have to be a really big financial incentive, and I don't think they can offer you one big enough to let someone else control my charging. I'm really happy for them to offer me incentives, but the decision needs to be mine because it's my car.*'

The nature of the EV as the load under remote control appears to be important to these participants' feelings about control. One contrasted managed EV charging with hot water control: '*Like I would push back very heavily on it being treated like my hot water […] with my hot water, that's the only way it gets hot, I have no other option. For the car, that wouldn't work for me at all, absolutely no way.*' The AGL EV orchestration trial team drew a similar contrast: the '*big difference is, the hot water system is a storage device that you don't need to drive around*'. Similarly, a UNSW respondent compared EV charging with participating in battery VPP, noting that he accepts he cannot opt out of participation in the latter: '*I've agreed in advance and I don't get a choice […] Whereas with the car, you would want to have a choice because you can live without the few dollars of electricity going out to the grid while you can't live without the car if you need the car tomorrow*'. This reflects a view of the private vehicle as a flexible form of transport that is subject to 'individualistic timetabling' and is therefore, unlike many other forms of transport, available on demand[144] . This is an expectation with which managed charging must align if it is to be successful, especially where car-dependency has become embedded in wider residential planning.

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[144] Urry, J., 2006. Inhabiting the car. *The Sociological Review*, *54*(1_suppl), pp.17-31

**Smart EV charging in shared residential garages**

In urban areas in Norway many people live in different types of apartment buildings that are often collectively owned, maintained, and managed. Many of these buildings have a shared basement space where the apartment residents have dedicated parking lots. Access to dedicated parking lots, whether shared or private, for many households in Norway has led to a widespread expectation that it is possible to charge in the home. Constraints in the local grid capacity to host EV charging in shared garages has emerged as a problem, however. This problem has brought together a range of actors, including the EV owners, non-EV owners, the democratically elected housing board that represents all building residents, electricians, the regulatory authorities, the Norwegian EV association and the DSO.

This problem has been articulated by many of these actors as one of fairness. One electrician stated '*In a shared space it needs to be fair and equal for all. […] Imagine how wrong it would be if only half of the apartments were given proper access to TV and internet signals and the rest did not get the same'.* Another electrician more cynically commented that he sees smart charging as the solution to the problem of access in shared garages because people are preoccupied with fair and equal access to charging for all households: "*I recommended switching to a locked system, a system of shared loads. Because people are so f\*cking concerned with equality*".

In this context, then, smart charging is a shared infrastructure that allows the charging of individual EVs to be managed within certain parameters, such as when the price is low; with an effective billing system; and with vehicles organised into a queue. Interestingly, these quotes suggest that this solution is being negotiated in anticipation of further EV uptake in the apartment building in future, and it is considered essential to accommodate more EVs as a matter of principle, whether more EVs are owned by the building's residents in future. One electrician, who was working as an account manager for an electricity company and consulting to housing boards, presents it as the only option:

> '*[Smart charging] forces itself through in the end because it is so unfair if fifteen out of fifty apartments install EV chargers, and the grid operator says "No! Now [the rest of] you cannot connect any more EV chargers because we have no more capacity". This is very unfair. What should the board say to its residents?'*

This case study analysis revealed that the local DSO and smart charger salespeople also had an important say when different charging solutions were considered by the housing board, actively targeting the board with the problematization above focussed on equality and fairness. This solution framing was aided considerably by the passing in early 2018 of national regulation, advocated by the Norwegian EV association, that stipulates that a housing board cannot refuse EV owners the right to charge their EVs at home. Smart charging has thus emerged as a crucial element of the shift from chaotic and dumb to fair and equal charging opportunities and has since been introduced in many shared garages.

In comparison, public debate about EVs in Australia tends to neglect the circumstances of EV owners without easy access to charging in a detached home with a private garage or carport. While the largest proportion of Australia's residential dwellings are detached houses, some 10% are semi-detached or terrace houses, and a further 30% are apartments[145] – currently the fastest growing form of housing. Among these housing types, some households simply lack off-street parking that can support home charging, and those with access to shared garages in apartment buildings can face impediments in getting approval for the installation of private chargers. Collective smart charging solutions such as those in Norway are yet to emerge in Australia.

One interviewee living in an apartment had sold his Tesla, in part due to difficulties accessing charging facilities. When reflecting on the slow uptake of EVs in Australia, one UNSW study respondent expressed awareness of this issue: 'if you don't have a garage or a place you can charge at home, actually charging is quite problematic'. As long as chargers in the workplace remain uncommon and public chargers require time, he argued that EV charging is less convenient than refuelling an ICE vehicle at a petrol station. The lack of access to EV charging in apartment buildings or homes without off-street parking will continue to pose an obstacle to EV uptake and undermine equity of access for residents across different housing types. For this reason, 'conservative' and 'progressive' visions of electric vehicles[146] have tended to divide the problem of charging along quite different business models: the former assuming the car and charging assets owned by the householder; while the latter sees a flowering of *servitisation* business models that detach use from ownership. Ridesharing, shared access through services such as GoGet and similar forms of common custody of vehicles provide an alternative approach that would have radically different implications for charging. For example, car sharing members may wish to finance their fleet by accessing frequency control or peak demand services in exchange for reduced availability at certain times.

**Vehicle-to-grid technology**

In the Netherlands, V2G is seen as part of the solution to several problems. The Dutch V2G trial shares the value of idle cars with their large batteries and sophisticated control systems with multiple stakeholders. Table 7 documents the most commonly mentioned value propositions for V2G in expert interviews[147].

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[145] https://hia.com.au/-/media/HIA-Website/Files/IndustryBusiness/Economic/discussion-papers/the-changing-composition-of-australia-new-housing-mix.ashx

[146] Milton, A, 'Visions of Electrification and Potential for Decarbonisation: The Absence of Ridesharing and Carsharing in Australia's Electric Vehicle Policy' *Environment and Planning Law Journal* 38

[147] Başer, E. (2020). Key Components for Potential Sustainable Vehicle-to-Grid Business Models within the Netherlands: A qualitative research to explore the components for sustainable Vehicle-to-Grid business models by conducting semi-structured expert-interviews [Delft University of Technology]. https://repository.tudelft.nl/islandora/object/uuid%3Aaa8a3893-7901-496b-b33c-9c88995e8e7d

Table 7: Value propositions of V2G according to experts interviewed

| | Beneficiary of V2G operation | Value proposition |
|---|---|---|
| 1 | Building managers, especially office buildings | Peak shaving, lower electricity costs |
| | EV fleet operators | Peak shaving, lower electricity costs |
| 2 | Home owners | Increased solar self-consumption, lower electricity costs |
| 3 | DSOs | Congestion management |
| 4 | TSOs | Frequency, balancing services |
| 5 | Energy traders | Additional flexibility within the portfolio of assets |

It is worth noting that the beneficiary of V2G operation in terms of energy services typically results in compensation to EV users, EV leasers (generally companies in the Netherlands) and commercial EV fleet managers. Further, bundled services are often mentioned by experts, describing several different services to different stakeholders, offered as an integrated package to vehicle owners. Private EV users in the Netherlands were found to be interested in compensation provided for V2G services. However, they were also motivated to participate in V2G for environmental reasons (contribution to the energy transition) and for social reasons (to protect a shared resource: the electricity grid). Aside from stacking value, the bundling of services also simplifies the communication with private and commercial EV owners, most of whom express curiosity about the end-benefits and end-beneficiary of the use of '*their energy*'.

In Australia, V2G trials are currently commencing to explore this new frontier of smart charging. This is seen to leverage EVs - which are 'essentially batteries on wheels'[148] - for greater demand response, not only by time-shifting load, but also by providing power and other grid services. A unique form of value that distinguishes V2G from the participation of a stationary battery in a VPP, for example, is the possibility to also place-shift. Bi-directional DC charger manufacturer JET Charge suggests to EV owners that '*Your supermarket or workplace could be your main source of power each day*', for example, and that the charger '*will transform how we view vehicles, transport and energy*'[149]. V2G offers EV owners' economic opportunities directly, through the potential to generate revenues that would reduce the cost of car ownership, and less directly, through the potential of reduced electricity costs. There is only one fully electric vehicle available in Australia offers V2G capability: the 2019, or second generation, Nissan Leaf. One part of AGL's EV orchestration trial is exploring V2G viability and commercial value in a subgroup of 50 Nissan Leafs.

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[148] https://thedriven.io/2020/11/18/agl-arena-to-conduct-first-trial-of-using-electric-vehicles-to-power-homes/
[149] https://jetcharge.com.au/services/vehicle-to-grid

Several of these AGL trial participants see V2G as a part of the future of EV charging in Australia and bought that particular vehicle in anticipation of V2G. Some Solar Analytics study participants see vehicle-to-grid technology as an appealing alternative to a home battery. One said, '*I think vehicle to grid's quite exciting technology and, yeah, I'd be quite interested in where that goes and that could be contributing to the piece [the question of whether to get a battery]*'. Another commented '*we were talking earlier in the conversation about whether the next vehicle would be an EV as well. It would probably be one that can feed back into the grid and therefore, like as in buy a battery that's part of a car <laughs> if you get what I mean so that we kind of get the double whammy, but at the moment, we don't think we would get value out of a battery*.'

**Conclusion**

This section has shown how EVs are framed as both problems and solutions in various ways and across different charging settings. Across the various country contexts examined, EV charging poses challenges for grid management, and the automation of charging to shift EV loads is seen to offer the solution. In Australia and the Netherlands, smart charging and emerging V2G technology are also seen as a tool to address other challenges. The translation of the smart charging solution involves different actors in different contexts, which have generated different questions and issues to be negotiated – such as that of fairness of access to charging for households without private parking facilities, which in Norway has been negotiated by electricians, housing boards and the residents they represent (and made salient by regulations stating that all apartment buildings need to facilitate charging) , while in Australia it remains an issue yet to be collectively engaged. Acceptance by EV owners of the smart charging solution is likely to depend on a perception that it aligns with what is important to them - the environmental or financial reasons for purchasing an EV, or the possibility to assist the EV owner in managing their charging. V2G technology may likewise appeal to those EV drivers who see it as aligning with their existing interest to purchase a home battery, by offering the same functionality and more.

## 10.4 Battery Virtual Power Plant

**Introduction**

VPPs involve the aggregation of DER that are too small to individually participate in energy markets. Aggregation makes them appear as a single, dispatchable unit. Within this broader definition, what precisely constitutes a VPP remains contested[150]. This section is based on analysis of several residential battery VPPs in Australia, including interviews with the DNSP

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[150] For example, whether Frequency Control and Ancillary Service offers determined through remote battery charge signalling meets the definition of VPP is contested. Such terminology may matter by opening or closing future market and regulatory access for aggregators. The development of 'comparison tables' by websites such as Solar Quotes and regulators such as the AEMC help to create markets in different aggregation and third-party control offerings. See Solar Quotes, https://www.solarquotes.com.au/battery-storage/vpp-comparison (accessed 2 Oct 2021)

Ausgrid and retailer AGL running two of them. It also draws from the Solar Analytics study with interview and focus group respondents – none of whom have participated in a VPP, and most of whom do not own a battery – about their perspectives and willingness to participate.

**The Virtual Power Plant solution**

VPPs are presented by their advocates as possible solutions in a rapidly changing energy system context in which, as anticipated by AGL, *'the needs of the wholesale energy market will increasingly be supplied through a proliferation of DER'*[151]. VPPs are situated among, and as a potential alternative to, other demand management initiatives that are being used to address some of the challenges of increasingly variable and intermittent supply in this context, as well as peak demand. The potential role of VPPs is considered particularly relevant to address the '*particular energy security position*', characterised by inadequate grid resilience and reliability, in South Australia[152]. In this sense South Australia is seen to be experiencing some of the challenges that may be faced elsewhere in the country as Australia's renewable energy transition progresses and is therefore a testing ground for the solutions that could be relevant elsewhere.

VPPs are a means by which to undertake the necessary coordination of growing quantities of DER to make the grid more efficient – and ultimately to '*enable[e] higher penetrations of renewables in the grid*'[153]. Importantly the VPP is seen to realise the intrinsic value of batteries for households as well as other stakeholders, '*sharing the costs and benefits of that storage amongst all stakeholders*'[154]. This is expected to occur through 'value-stacking', whereby a household makes their battery available for multiple applications: to the market operator to provide broader system stability support; to network service providers, to address a network constraint; and retailers in response to market price signals to manage the cost of electricity.[155] The value generated for households in this way is expected, in turn, to incentivise battery purchase by providing 'additional' value beyond that value that households might already perceive in batteries.

The central role of the household participant in the VPP is seen to reflect a changing role for users in the energy system more broadly. VPP participation is also presented as '*empowering customers*' with '*choice about the way they share their electricity*'[156]. Participating in a VPP is seen by a couple of the Solar Analytics study respondents as '*empower[ing]*' and about reconfiguring their role in the energy system: *'What we're not waiting for is for the bigger companies to be putting in massive batteries. I see it as the individual joins with its community to take charge of its destiny in electrical supply systems*

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[151] AGL, Virtual power plant in South Australia, Stage 1 Milestone Report, 31 July 2017, https://arena.gov.au/assets/2017/02/VPP-SA-Public-Milestone-1-Report-Final-for-issue.pdf (accessed 2 Oct 2021)

[152] Ibid

[153] Ibid

[154] Ibid

[155] Ausgrid's Virtual Power Plant, Progress Report, November 2020, https://www.ausgrid.com.au/-/media/Documents/Demand-Mgmt/DMIA-research/Ausgrid-Battery-VPP-Progress-Report-November-20.pdf (accessed 2 Oct 2021)

[156] Ausgrid, 'Creating a greener future with Virtual Power Plants', 28 March 2019, https://www.ausgrid.com.au/About-Us/News/VPP (accessed 2 Oct 2021)

*and doesn't wait around for the politic[ians] or the big corporates'*. It is also seen to represent a reconfigured relationship with industry: '*it does flip that relationship […] we're paying customers to be able to use their assets – we are their customer, basically*'[157].

In these ways the aggregation and orchestration of batteries and other DER have been established as ways to manage the proliferation of DER, maximising their value for a range of stakeholders *and* incentivising their further uptake. Here, narratives of both common and private benefits are crucial to understand in their various settings. This means that articulating the '*why'* is just as important as 'how' for the development for VPPs, like other forms of automated DSM.

### The enrolment of participants

Research on VPPs and willingness to participate in VPPs has found that understanding of what a VPP is, and what participation involves, is relatively limited. The Solar Analytics study of non-trial participants found that one participant understood a VPP as orchestrated batteries, another as someone managing the power so that the grid works. However, the rest of the participants (even those self-selected participants drawn from the highly engaged cohort of Solar Analytics customers) had little to no understanding of a VPP. Several interpreted a VPP to be a local microgrid or P2P local energy trading, others confused it with a community battery, while two thought that a VPP is synonymous with 'prosumer: '*I feel like a power station'*, '*My understanding of a VPP is literally I'm a power station and I send power to the grid when it's requested, if I have excess, and I get paid for it*'. A common perception is that a VPP is about sharing energy and, more specifically, sharing excess solar generation with other customers, perhaps in the local area. Low levels of understanding among prospective VPP participants is considered to present a challenge to recruitment and onboarding, because '*Consumers need to engage with and have a level of understanding of what a VPP is*'[158]. But the depth of understanding that is necessary or valuable for prospective participants is likely to vary, and to depend on the reasons for their interest in VPPs.

The participants of VPP trials to date are generally described as early adopters with an interest in technology. Some enjoy actively monitoring the participation of their battery in the VPP, and '*wanted some data to put into their spreadsheets, particularly retirees who just really wanted to dig into the detail*'[159]. The main reasons that VPP participants have given for signing up include '*It helps the electricity grid to be managed more efficiently*', which was selected by 43% of respondents of an Ausgrid survey; '*It is better for the environment*', selected by 20%; and receiving a financial reward, selected by 18% of the group respectively.[160] In contrast, participants of AEMO's VPP demonstrations have responded that they were driven by bill savings, selected by 42%; to take advantage of a discount on

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[157] Interview with AGL
[158] AEMO Virtual Power Plant Demonstrations, Knowledge Sharing Report #2, https://aemo.com.au/-/media/files/electricity/der/2020/vpp-knowledge-sharing-stage-2.pdf (accessed 2 Oct 2021)
[159] Interview with AGL
[160] Ausgrid's Virtual Power Plant, Progress Report, November 2020, https://www.ausgrid.com.au/-/media/Documents/Demand-Mgmt/DMIA-research/Ausgrid-Battery-VPP-Progress-Report-November-20.pdf (accessed 2 Oct 2021)

battery purchase, selected by 19% – ahead of because 'it seemed like the right thing to do (e.g. for the country/future)', selected by 9%; or because they are 'interested in lower carbon/environmental impact energy sources' (8%).[161] The subsidies that some participants of these VPPs have accessed to support their participation may influence the motivations they give, as financial costs and benefits of participation may be less significant for them.

The Solar Analytics study explored whether and why respondents who are not currently participating in a VPP might be interested to do so. Economic benefit, expressed as bill savings or income, was cited as a reason to participate. For some, this entailed making profit from participation while for others compensation for lost income and/or battery degradation would be sufficient, provided the VPP is achieving other community or environmental benefit. Others saw VPP participation as an opportunity to overcome the financial barriers that have prevented battery purchase, stating, for example, that '*to have something like that to actually actively assist in the payback of the battery would be fantastic*'.

The Solar Analytics interviewees mentioned different types of common benefit as motivating factors. For some, supporting management of the grid is understood as contributing to the community through:

- Grid management (e.g. voltage control) can be understood as a safety issue which may justify giving up some level of control: '*I'm okay with allowing some level of control to make sure that things are not dangerous for me or for other people*';
- Reduced energy costs for everyone is cited as a reason for participation (and indeed failure to achieve that as a deal-breaker) by a couple of participants;
- Preventing blackouts was another reason for participating, especially for research participants based in South Australia – although, conversely, being located in an area with a high frequency of blackouts was a reason for some participants to be wary of loss of control of their battery through participation in a VPP.

Environmental benefit was also important for many of the Solar Analytics respondents, and for some the most important factor. Although the VPP proposition can sit at odds with some people's reasons for having purchased a battery (see discussion of this below), one participant stated that '*the other reason that we have solar is also the clean energy aspect of it. Yes, the savings and costs go that way, but I also would prefer to see clean energy. And I think that this would be a way as well of having more clean energy generated for all*'.

The Solar Analytics respondents' willingness to participate in a VPP was strongly mediated by the reasons that they had purchased, or would wish to purchase, a home battery. In other words, the value that people see in participation in a VPP is connected to the value they perceive in having a battery. The most commonly expressed motivations for battery purchase were energy independence, increased self-consumption of solar and security of power supply, with financial factors cited less frequently. VPP participation was understood by some participants to undermine these benefits, which made them less inclined to wish to participate. One participant stated that '*I'd really wanna look at my own figures first […] 'cause the whole point of having solar and having a battery would be to maintain your own personal power supply*'. This issue is particularly pronounced among participants who

[161] CSBA, Virtual Power Plant Consumer Insights Interim Report, February 2021, https://aemo.com.au/-/media/files/initiatives/der/2021/csba-vpp-customer-insights-study-report-feb-2021.pdf (accessed 2 Oct 2021)

experience blackouts frequently: '*What happens if you get a blackout?  If […] you're out for a couple of days with no power*.' One participant referred to the VPP proposition – investment in a battery for a financial return – as being completely different to buying a battery for household use and using a VPP to deliver additional value. Similarly, some Solar Analytics study respondents believed that participation in a VPP might undermine their environmental reasons for battery purchase if it would require them to draw electricity '*from the grid because I don't know where that's coming from. If that's coming from coal-fired power station then I don't want to do that.*'

Unwillingness to participate in a VPP is often expressed as an unwillingness to cede control of the battery, reflecting the value of energy independence and self-sufficiency for many respondents. A 2016 survey by Ausgrid of households found that 59% of respondents with a battery would not consider participating in a battery demand management program for a financial incentive or payment, and the predominant reason selected by 54% of that group was they would 'not want to give over operation of my battery system to anyone else'.[162] Reservations of Solar Analytics respondents were widely articulated as a concern about loss of autonomy or control over their battery: '*I'm not sure how much control we would have to give over*'. One participant described this tension between the motivations for battery purchase and VPP participation outlined above in terms of the desire for control that solar owners have already demonstrated, in so far as they have taken control of their electricity costs and would not then want to give up this control by participating in a VPP: '*I think by virtue of me wanting solar takes some control of what I'm paying, and then to feel like at this stage hand balling that away and losing it again seems counterproductive*'.

Trials and research have shown that the possibility to retain a portion of battery's capacity for household use is important to maintain a sense a control on the part of the participant. This is likely to be all the more important for households that purchase batteries for largely non-financial reasons and who therefore '*want to make sure we have enough left over*', in the words of one Solar Analytics respondent.  AGL reports that '*the majority of sales conversations began with customer expecting that the installed energy storage system would provide backup power. Many customers placed a high value on the backup functionality*'[163]. This may be less important for participants of VPPs who are motivated by collective rather than individual benefits, as suggested by one of the AGL participants who reportedly did not want to have back-up battery capacity because he was proud of South Australia's high renewables penetration, considers VPPs as part of the solution, and did not want insurance against blackouts if others did not have it.[164]

The cost of battery purchase and the feed-in tariff that households receive for solar exports also mediates that value that people perceive in VPP participation. VPP trials that have offered subsidised batteries upon entry have found cost to be a significant barrier to

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[162] Ausgrid, Household Solar Power and Battery Survey, Interim Report, March 2017, https://www.ausgrid.com.au/-/media/Documents/energy-use/Household-Solar-power-and-battery-survey.pdf
[163] AGL, Virtual Power Plant in South Australia, Final Milestone Report, October 2020, https://arena.gov.au/assets/2020/10/virtual-power-plant-in-south-australia.pdf (accessed 22 Sept 2021)
[164] Interview with AGL

successful recruitment, despite the discount.[165] Until battery prices come down, battery costs are likely to become an even greater barrier to participation in VPPs in the absence of such subsidies. Prospective VPP participants have been unwilling to forfeit high feed-in tariffs in order to participate, but as premium feed-in tariffs phase out and market feed-in tariffs decline, VPP participation may be become more attractive to these participants motivated by the financial benefits that can be derived from their batteries.

**Challenges in translating the value of VPPs**

There has been a high level of retention and reported satisfaction among participants of VPP trials involving early adopters to date.[166] However, experience to date suggests that there are a number of challenges in communicating value for the participants of VPPs. Targeted marketing, individual discussions with interested participants and a relatively lengthy recruitment process has been necessary in trials.[167] This is because recruitment to a VPP is the sale of a technical product and a new and innovative service, rather than the sale of conventional commodity with which energy users are already familiar.[168] Complicating the value proposition for households are the uncertain and contingent factors affecting exactly how much value VPPs might hold for them, as discussed above.

Transparency is likely to be critical to the success of VPPs in Australia, raising consumer rights and similar regulatory issues that are becoming increasingly prominent in household solar PV.[169] AEMO has noted that its demonstrations have shown there is willingness to participate among energy users, but that the value for participants remains 'opaque and may in many cases be a non-financial benefit'.[170] Prospective participants are eager to understand the VPP concept and the financial, environmental and community benefits that a

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[165] Simply Energy VPPx, ARENA Stage 1 Knowledge Sharing Report, February 2019, https://arena.gov.au/assets/2019/06/simply-energy-vppx.pdf; AGL, Virtual Power Plant in South Australia, Final Milestone Report, October 2020, https://arena.gov.au/assets/2020/10/virtual-power-plant-in-south-australia.pdf (accessed 2 Oct 2021)

[166] Ausgrid's Virtual Power Plant, Progress Report, November 2020, https://www.ausgrid.com.au/-/media/Documents/Demand-Mgmt/DMIA-research/Ausgrid-Battery-VPP-Progress-Report-November-20.pdf (accessed 22 Sept 2021); AGL, Virtual Power Plant in South Australia, Final Milestone Report, October 2020, https://arena.gov.au/assets/2020/10/virtual-power-plant-in-south-australia.pdf (accessed 22 Sept 2021); Simply Energy VPPx, ARENA Stage 1 Knowledge Sharing Report, February 2019, https://arena.gov.au/assets/2019/06/simply-energy-vppx.pdf (accessed 22 Sept 2021); CSBA, Virtual Power Plant Demonstrations Consumer Insights Report, September 2021, https://aemo.com.au/-/media/files/initiatives/der/2021/csba-consumer-insight-final-report.pdf?la=en (accessed 4 Oct 2021)

[167] AGL, Virtual Power Plant in South Australia, Final Milestone Report, October 2020, https://arena.gov.au/assets/2020/10/virtual-power-plant-in-south-australia.pdf; Simply Energy VPPx, ARENA Stage 1 Knowledge Sharing Report, February 2019 https://arena.gov.au/assets/2019/06/simply-energy-vppx.pdf

[168] Simply Energy VPPx, ARENA Stage 1 Knowledge Sharing Report, February 2019, https://arena.gov.au/assets/2019/06/simply-energy-vppx.pdf

[169] See Temby and Ransan Cooper, 2021, 'We want it to work': understanding household experiences with new energy technologies in Australia' Final Report of Victorian Energy and Water Ombudsman's Investigation of Consumer Experiences https://apo.org.au/node/313616, and Bainbridge, A, 2021 Rooftop Solar Reforms After Clean Energy Regulator Review, ABC News https://www.abc.net.au/news/2021-09-16/rooftop-solar-reforms-after-clean-energy-regulator-review/100463648

[170] AEMO Virtual Power Plant Demonstrations, Knowledge Sharing Report #3, February 2021, https://aemo.com.au/-/media/files/initiatives/der/2021/vpp-demonstrations-knowledge-sharing-report-3.pdf

VPP may deliver.[171] Solar Analytics study participants also indicated that they would require detailed information before signing up – and in particular information about what is at stake for them, i.e. both impacts and benefits. They want to know '*what am I giving up?*', and they want to see the wider implications and '*who else is benefiting*' evidenced – for example, that '*a 30% uptake of people into this scheme would mean […] we might not have to build another power station or something*'. These respondents would require the assurance that the VPP is operated in such a way '*that the person who has the battery isn't disadvantaged*' before they would be willing to sign up. The sense of not knowing how it operates and would impact them – and the suspicion that they may be taken advantage of in the absence of more information and transparency – was a strong one among participants. They stated '*I need to understand who is benefiting from this*' and asked '*Is there any way it can be used… against me?*'.

The translation work that is involved in providing the information that participants require has been described by AGL as providing information about how a VPP operates and then '*telling the story of what this means in practice*' or '*translating that into what it actually looks like for […] the battery owner as a part of our VPP […] that's the translation that they need*'. There is a need for simplification in this process. However, AGL have found that they have had develop a '*more nuanced and detailed message now around FCAS [Frequency Control Ancillary Services] and energy*' to meet participants' needs. Indeed, conversations with the Solar Analytics respondent indicated that too much simplification can generate scepticism among some participants wary that they are being taken advantage of, as described above. These conversations also showed that when exposed to more detailed information about the wider challenges in the energy system that VPPs address, some respondents felt more comfortable about compensation models that would involve less autonomy of their battery and greater access for the VPP operator.

Visibility of VPP operation, and when and how a battery is participating, is also likely to be important. This gives households the '*comfort of knowing what's happening to their asset*'.[172] Ausgrid has reported that 92% of VPP participants surveyed agreed that they found receiving a notification about the event useful – although, interestingly, only 71% recalled receiving app notifications, perhaps suggesting that access to information is important in principle, regardless of whether the information is accessed and used.[173] Solar Analytics study participants expressed that they would want to be able to view information, perhaps through a simple interface, about energy and financial flows, as well as loss of access to a proportion of their battery use (conveyed as time, energy, and number of occasions). Some expressed a wish to be able to monitor exactly when and how their battery is participating in a VPP at any given time: '*I want visibility [to know] exactly what you're doing with my battery*'. One or two others noted that they would not want to have to monitor it constantly, however. AGL makes the case that electricity retailers are well placed to play a dual role as

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[171] CSBA, Virtual Power Plant Consumer Insights Interim Report, February 2021, https://aemo.com.au/-/media/files/initiatives/der/2021/csba-vpp-customer-insights-study-report-feb-2021.pdf
[172] Interview with Ausgrid
[173] Ausgrid's Virtual Power Plant, Progress Report, November 2020, https://www.ausgrid.com.au/-/media/Documents/Demand-Mgmt/DMIA-research/Ausgrid-Battery-VPP-Progress-Report-November-20.pdf (accessed 4 Oct 2021)

aggregators because they can help participants understand both how their battery is being orchestrated and the impact on their bills.

The kinds of information required are still being established, however. AGL notes that its VPP participants did not express an interest in advance notice of battery orchestration events. This may reflect a difference between the automation of household batteries and that of other household loads discussed in section 10.2 Home appliance DLC above. Transparency about the number of orchestration events in a year and other parameters may be more important. AGL foresees that specifying 'boundaries' around the VPP provider's access to household batteries and demonstrating to households that those boundaries have been observed, will be necessary to build participants' trust. Interestingly, however, in the context of AGL's trial with subsidised battery purchase, the participants were not presented with such boundaries in order to enable more flexible trialling of VPP. This means that the experience of participating in a VPP trial will differ from that of participating in an ongoing VPP program.

**Conclusion**

Battery VPPs are seen to be both ushering in and addressing the challenges of a more distributed and renewable energy system. The trials examined here have, in the words of AGL, '*begun to inform and indeed challenge grid operators, market operators and policy-makers about the potential for energy storage systems to support the growth of renewables in the grid*'.[174] The analysis suggests that people who have purchased their PV system or battery for environmental or financial reasons may be willing to participate if the VPP has been presented to them as a way to advance these values. On the other hand, those who were motivated to purchase a battery to achieve greater energy independence or security are more likely to see a VPP as undermining their objectives.

## Conclusion

This chapter has explored the translation of automated DSM, from the establishment of the problem to which it is addressed, through the articulation of the automated DSM solution by the actors involved and their appeals to the interests of the household participants, to how these participants have accepted or resisted the solution. The case studies examined here, which include trials, ongoing programs and studies with households participating in DSM in Norway, the Netherlands and Australia, all address electricity grid limitations through the orchestration of DER and all promise to advance the renewable energy transition and save their participants money. While the visions of the energy future represented in these automated DSM solutions are compelling, it is worth noting that each excludes alternative visions. For example, the promise of automation to manage energy consumption in the home with no loss of comfort, and indeed through the introduction of electronic devices that themselves consume energy, obscures an alternative vision in which environmental

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[174] AGL, Virtual power plant in South Australia, Stage 1 Milestone Report, 31 July 2017, https://arena.gov.au/assets/2017/02/VPP-SA-Public-Milestone-1-Report-Final-for-issue.pdf (accessed 12 Jun 2021)

sustainability is achieved by focusing on reducing energy consumption, and having fewer rather than more electronic devices. Similarly, the vision of EV smart charging and V2G perpetuates a 'business as usual' understanding of mobility rather than an alternative vision centred on shared and intermodal electric mobility.[175]

The way that the translation of these solutions occurs varies according to context, and a variety of actors are involved in its negotiation, which can include electricity retailers, network operators, aggregators, customer service representatives, electricians, automation technology manufacturers, vehicle manufacturers, consumer representative organisations, housing boards, and even energy users not participating in DSM. The contextual specificity and contingency of the translation process must be considered when assessing and seeking to learn from the outcomes of trials and programs. For example, the Australian home automation trial team acknowledges that personal engagement and relationship-building with the participants had been crucial to the trial's success. It is not known whether the technology would be as accepted by households if the program was scaled up and the same degree of personal engagement not undertaken in future.

The participants of the trials and studies examined here have been, by definition, interested to trial these technologies and/or to talk to us about them. They have given a variety of reasons for their interest, which fall into the categories of interest in new technology, financial motivations, environmental concern, and community orientation. The voices not heard here, however, belong to people who may never wish or have the opportunity to engage with these technologies. These are people who lack the time and resources, or the 'flexibility capital'[176] to engage, and that may be prone to 'flexibility poverty'[177]. It is crucial to consider who is not being reached or included, and how these technologies, in being designed and refined for the participants of these trials and studies - early adopters in many, although not all, cases - could exclude them in their very design. Some of the research methods employed in these case studies were more inclusive of such participants - such as the focus groups conducted in the Solar Analytics VPP study with randomly selected people without batteries or any particular interest in energy issues, who were compensated for their time. Similarly, in the case of EV charging in shared garages in Norway, both EV owners and those that did not own an EV, both old and young people, both those interested and uninterested in technology, all had to make collective decisions about whether to install smart EV charging infrastructure. Further research should identify which groups do not opt into these trials and programs, and why they do not opt in. This is important in order to build a social license to automate that includes people that are the late majority, laggards[178], or simply not interested.

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[175] Milton, A, 'Visions of Electrification and Potential for Decarbonisation: The Absence of Ridesharing and Carsharing in Australia's Electric Vehicle Policy' *Environment and Planning Law Journal* 38

[176] Powells, G. and Fell, M.J. 2019. Flexibility capital and flexibility justice in smart energy systems, Energy Res. Soc. Sci. 54:56–59. https://doi.org/10.1016/j.erss.2019.03.015.

[177] Ingvild Firman Fjellså, Marianne Ryghaug & Tomas Moe Skjølsvold (2021) Flexibility poverty: 'locked-in' flexibility practices and electricity use among students, Energy Sources, Part B: Economics, Planning, and Policy, DOI: 10.1080/15567249.2021.1937403Fjellså,

[178] Rogers, Everett M. (1983). Diffusion of innovations (3rd ed.). New York: Free Press of Glencoe. ISBN 9780029266502.

The analysis presented in this chapter shows that energy users take up automated DSM solutions, and the new or changed roles envisaged for them, to the extent that they see value in them – either at a collective or individual level. Their willingness to participate in these automated DSM solutions reflects the extent to which these solutions align with the users' motivations and priorities around energy, including the extent to which respondents expect automation to relieve them of energy management work they would prefer not to do. Positive responses from the participants of home appliance DLC related to the possibility that it could achieve financial savings for them and/or advance environmental sustainability, or that it would, in line with their expectations of technology, '*make my life easier*'. Respondents were interested in smart charging where they perceived it would assist them to charge their EVs renewably or cheaply or with less effort directed towards coordination and monitoring, or where it can deliver equitable access in the shared garage context. Respondents of VPP trials and studies were likewise most interested in participating in a VPP where they perceived it to be able to serve the community, environmental and/or economic ends important to them - and were less interested if they perceived it to conflict with their interests if their primary motivation to purchase a home battery had been energy independence.

The degree of alignment is influenced or mediated by core factors, the importance of which varies for different users, and will therefore depend on context. First, people's **understanding of DSM** and the challenges it seeks to address tends to influence the extent to which they see the value of automated DSM and how it might align with their interests. The concept of 'grid sensitivity' refers to how the energy system, most of the time highly backgrounded in routinized, everyday life, can come to the fore.[179] Often this occurs through the experience of a blackout, for example, which forces access to energy to be no longer taken for granted. Increasing grid sensitivity is also part of the translation and negotiation process of the automated DSM solutions discussed here, as participants become more familiar with, explore, make sense of issues in the energy system that they perhaps had not been aware of previously.  For example, the various actors engaged in negotiating access to EV charging in shared garages in Norway acquired greater grid sensitivity as they gained an understanding of the limitations of the local grid and the automation solution that might accommodate equitable access within those constraints.

It is not possible to know the extent to which the 'grid sensitivity' of the participants of the trials and studies examined here may have been increased through the process of entering these trials and studies or, indeed, the extent to which there may be a self-selection bias towards more grid-sensitive participants. However, increasing 'grid sensitivity' appears to make some participants more open to automated DSM solutions. As mentioned above, in the Solar Analytics VPP study in Australia, focus group participants were initially shown some hypothetical compensation models, before the wider issues in the energy system that VPPs might help address were discussed with them. They were then asked if a better understanding of some of the challenges in the grid changed their perspective. For some, it made them willing to give up more control of the battery: '*it swayed my decision a little bit*

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[179] Skjølsvold, T.M., Ryghaug, M., and Throndsen, W. 2020.European island imaginaries: Examining the actors, innovations, and renewable energy transitions of 8 islands, Energy Res. Soc. Sci. 65: 101491. https://doi.org/10.1016/j.erss.2020.101491

*through the spectrum… it's moved me more towards the VPP having a greater control of the system*'. Others remained unmoved in their willingness to participate and preference for the compensation model.

**Visibility of how their DER is being controlled** is another factor that influences whether people see automated DSM as being in their interests. Participants of the DLC and VPP trials and studies examined here have articulated that it is important to them to be able to monitor how their air conditioner or battery is being deployed. Some indicate that they would not want to have to monitor it constantly, however, and there appears to be some discrepancy between their preference to have access to information and how much they use the information. This suggests that having access to information is important for participants, whether they actively and regularly access and use it. It is important to participants, in other words, that the operation of the automated DSM is transparent to them and that they *could* access information about their involvement whether or not they actually choose to do so at any given time. This points to another relevant factor that emerged in this analysis, the work involved in engaging in automated DSM, for monitoring takes time and effort.

**Control over how their DER is being orchestrated** is another factor that influences the value that people see in automated DSM. The participants of trials and studies about all forms of automated DSM responded, if asked, that they want to be able to override or opt out of automation events. The control that is of value to participants needs to be understood more broadly than merely the capacity to opt out, however. It is, rather, control over the parameters of their participation - which again reflects the value that participants see in automation for them. If participants see value in automation taking work off their hands, they may be open to participating and engaging in automated DSM, and to doing so less actively, e.g. with less of the monitoring discussed above. If, on the other hand, participants have an interest in technology and see themselves as active managers of their energy according to financial or environmental considerations, they may wish to engage more actively. As has been discussed throughout this chapter, automated DSM is envisaged as having the potential *both* to 'help' and relieve participants of energy work, *and* to enable them to be empowered, active participants of the energy system. It can offer people either - or indeed both - ways of engaging, depending on how they wish to engage. Most important is that they have choices about the scope and terms of their participation. As became apparent in the interviews with Norwegian EV drivers discussed above, what might have appeared to be 'giving up control' of their DER is not necessarily tantamount to a real loss of control, provided that people can control the settings and thereby exercise such choices.

# 11. Institutional roles in automated DSM

*Institutional and policy studies*

## 11.1 Introduction

This chapter explores the institutional settings of automated DSM projects in Australia, Austria, Norway and Switzerland. We map the institutional settings of planning and implementation of automated demand side management projects. This mapping comprises (i) which actors are most frequently involved in the initiation and implementation of automated demand side management projects, (ii) discussion of how these actors are taking up positions which allow them to undertake certain actions in line with their interests in the project.

Our analysis enables comparison between institutional settings within and across countries. To provide a full picture, we also offer an overview of the regulatory context related to automated DSM to better explain the interests of the actors, and how actors gain agency from these regulations, rules, and policies to perform automated demand side management projects and run businesses.

By analysing the case studies from four different countries, this chapter therefore addresses the following research questions within and across the countries:
- Which actors are involved in automated DSM projects in different countries?
- What roles do various actors (DSOs, aggregators) have and which actions do they take in automated DSM projects and practices?
- What interest do various actors (retailers, DSOs) have and/or see in the future for automated DSM projects?
- How do ownership structures and accessible information (i.e. power demand readings, temperature at homes) influence the forms of engagement of the actors and the governance of the automated DSM projects?

By answering these research questions, we provide empirical evidence for researchers, policy-makers and regulators from existing experiences of four different countries in trialling or rolling out automated DSM programs. The analysis provided below is based on case study reports of four trials and one program from Australia, four pilots from Austria, three pilots from Norway; and seven pilot projects and one program from Switzerland as well as official government documents in particular related to the regulatory framework.

## 11.2 Context: rules in use, practices, narratives

In this section, we synthesise institutional configurations for each of the four countries through institutional modes (rules, practices and narratives) and scales (local, national).

Table 8: Institutional configurations of rules, practices and narratives in Australia, Austria, Norway and Switzerland's automated DSM programs

| | | Australia | Austria | Norway | Switzerland |
|---|---|---|---|---|---|
| Regulatory context related to DSM (Rules) | National levels | Transmission networks are monopolies that were uniformly owned by State governments until recently when some (NSW, South Australia) were sold to private consortia or merged with distribution companies (WA, Tasmania). The role of the transmission network service provider (TNSP) is to keep the demand and supply physically in balance in the transmission grid. Reviews of the Regulatory Investment Test for Transmission (RIT-T) have, over the last decade, excluded wider economic benefits from the evaluation framework. The Australian Energy Market Operator (AEMO) runs balancing markets, rather than TSOs. | Monopoly National Grids play the role of transmission system operators (TSOs) in European countries, notably Austrian Power Grid, Statnett, SwissGrid, for Austria, Norway and Switzerland, respectively. The TSO's role is to keep the demand and supply physically in balance after the market close (i.e. gate close) in the transmission grid. Contractual relationships with the TSO exist through possible bidding with large industry (storage dams, suppliers) that provide flexibility via DSM with a condition of minimum amount of power as balancing groups. They can provide ancillary services to meet the operational requirements such as frequency containment (maintaining frequency at 50 Hz every second across the European interconnected system). Aggregators through their VPPs could take the role of ancillary service providers. | | |
| | State and Local level (distribution networks, LV etc.) | DNSPs still hold a conventional distribution network role with a reactive or passive network (accepting bulk power from the transmission system and distributing it, down the network, to consumers). There is no local level management nor control of generation assets or resources. There are 22 electricity and gas network businesses in Australia with a mix of public and private ownership: 100% privately owned electricity networks in Victoria, South Australia; 100% government owned electricity networks in Tasmania, | DSOs as part of the unbundling (almost) of utilities have the task to securely operate and develop an active distribution system comprising networks, demand, generation and other flexible DER. Customers can choose an independent aggregator without consent from the existing supplier (EU Clean Energy Package. The aggregators can negotiate in a transactive, market-based manner with the utility company (trader role) and perform balance group optimisation or peak-shifting in order to solve distribution grid congestion. Secondly, they also do the automation to provide day-ahead or intra-day optimisation to the utility company. | | |

| | Western Australia, Northern Territory and Queensland; and, in NSW, one electricity network is privately owned, two are 50.4% privately owned and one is fully government owned. The Australian Capital Territory's electricity network is a joint public and privately owned entity. | | |
|---|---|---|---|
| | **Australia** | **Austria** | **Norway** | **Switzerland** |

| | Australia | Austria | Norway | Switzerland |
|---|---|---|---|---|
| Existing Automation | Ripple control hot water was an especially important complement to the largely coal-fired fleet developed from the 1950s onwards. In the early 2010s, a range of DSM initiatives have been developed to control air conditioning loads, especially. These were incentivised through time-of-use tariffs and the Demand Management Innovation Allowance (DMIA) scheme. In recent years, this has expanded to the initiatives we have analysed in this report, such as VPPs and battery technologies. | Network operators offer interruptible tariffs for certain electrical appliances in households and businesses, for instance for heat pumps. This is usually done via a ripple control system. In return, monetary incentives (such as a reduction in the system usage fee, the electricity price or a positive refund) are offered. | It is only through various R&D projects and pilot projects that the DSOs have actively regulated the electricity consumption of end-users in Norway. Norway does not have any ripple control systems. | DSOs have been carrying out automated DSM for approximately 50 years with a self-given privilege to use their ripple control on demand side resources. The current revision of the energy law foresees an obligation to ask the owners of the assets that should be controlled (e.g. the respective customers) for consent and remunerate them adequately for participating in ripple control. |
| Narratives | Energy Networks Australia, the peak body for distribution companies, produced the | One narrative is to increase | The narratives are to enable the | The narratives are to enable the grid |

| | | *Electricity Network Transformation Roadmap* that flagged the need to 'navigate to a customer-oriented future'. | consumption of locally produced energy and through this facilitate the integration of renewable resources in the grid. Another one is to enable financial savings by improving self-consumption on household or building block level and supporting the energy tradition through this. | grid security and system voltage stability in distribution networks and to avoid costly grid upgrades, as well as to ease the integration of distributed renewable energy. | security and system voltage stability in distribution networks. |

## 11.3 Grids in transition: institutional interests

Across the four countries we analyse here, network infrastructure - the poles, transformers and substations that connect grid users - has been recast. Whereas previously it conveyed electricity from suppliers through high voltage lines to users, decarbonisation and decentralisation have recast networks as intermediaries in two-way energy systems and markets including at lower voltage local networks.

In Europe, the role of DSOs, in their legal position[180] as the system operator of the distributed networks, is critical. They have, firstly, a high level of interest in using flexibility as a resource to avoid local congestions, stabilise voltage and reduce network losses. Secondly, **huge investments in the grid are required to host increasing load from new technologies (e.g., EVs, PVs, and heat pumps) by upgrading or even completely rebuilding existing transformer stations** (also known as 'secondary substations') and reinforcement of the lines (also called grid reinforcement). Such investment could cost the DSOs[181], and finally affect the electricity bill of end-users. DSOs need to carefully plan and study flexibility measures for the deployment of PV, heat pumps and EVs to ensure a smooth and cost-effective energy transition. Across the jurisdictions analysed, there is a transition to DSOs. Many in the Australian energy industry are starting to look to new management models for DNSPS to ensure the reliability and efficiency in the operation of systems centred on DER.

In both Europe and Australia, thanks to digitalisation (smart meters and new platforms) and new regulations, new business models are emerging to manage demand with new actors such as flexibility services distribution market operators, aggregator services and forecasting service providers (i.e. weather forecast, load forecasting etc.). Different companies could take the role of **'aggregators'** and develop **VPPs** offering flexibility for ancillary services to the TSO or other frequency control operator. VPPs are also being developed for peak load and distribution networks and/or participating in the balancing markets. Other technology providers can simply develop technologies and sell as white labels to utility companies to optimise grids with the sold algorithms and energy management systems.

## 11.4 Institutional settings in automated DSM: case studies

In this section, we identify and provide empirical data on which institutional settings (e.g. the actors, and the relationship of these actors to one another) exist in local automated DSM projects in Australia, Austria, Switzerland and Norway. This involves **qualitative comparative case study analysis** by drawing insights from the **Institutional Analysis and**

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[180] European DSOs have been distinct in their scope from the UK distribution network operator.
[181] 375-425 billion euros of investments in the power distribution grids will be needed in EU27+UK in 2020- 2030 Deloitte, commissioned by Peak DSO body EurElectric https://www.eurelectric.org/connecting-the-dots/ (accessed 4 Oct 2021)

**Development (IAD) Framework**, developed by Elinor Ostrom[182], specifically focusing on the analytical concept of 'action situation' from a governance perspective. The IAD framework allows us to decompose complex action situations into individual components and, as a result, facilitates the analysis of institutional settings as well as comparison between institutional settings. The 'action situation' is defined as the social space where individuals or groups of actors interact, and outcomes are produced. This perspective overlaps with the findings presented in Chapter 10. The Socio-technical Making of Automated Load Flexibility' insofar as it helps to identify patterns in how various actors align to enable automation at the household level.

The action situation can be further broken down into working components consisting of actors who take up various positions, where any given position allows the participant to undertake certain actions that are dependent on how much information they possess about each available action, and how actions are linked to potential outcomes. This section is concerned with mapping the institutional settings (action situation) of planning and implementation of automated DSM projects, we therefore focus on the elements inside the action situation. Nevertheless, we will include the points from regulatory contexts such as the rules in use, which are the backbone of the institutional settings, however, we will not explicitly discuss how the various elements in the action situation are influenced by these variables. Finally, the interest of each actor will be discussed under the actions for each specific project.

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[182] Ostrom, E., 2007. Challenges and growth: the development of the interdisciplinary field of institutional analysis. *Journal of Institutional Economics*, *3*(3), pp.239-264; Ostrom, E., 2011. Background on the institutional analysis and development framework. *Policy Studies Journal*, *39*(1), pp.7-27

Table 9: Pilot automated DSM projects in Australia and their institutional settings with rules in use and information access

| | Project name | Who controls the automated flexibility activation | Actors involved: positions and their tasks/actions | Interests of the actors | Specific rules between actors, market and regulatory framework | Information access |
|---|---|---|---|---|---|---|
| 1 | Energy Queensland's Peaksmart air conditioner DM program | DNSPs | DNSPs Ergon, Energex: 'set and forget' DR via DRED interface in air conditioners during peak demand events. | The federal Australian Energy Regulator's (AER) Demand Management Innovation Allowance (DMIA) allows DNSPs to trial new technologies for future benefits. The PeakSmart program evolved from previous DMIA trials but is now funded through operational expenditure. | Operational peak DM programs are typically funded via operational expenditure. In some instances trials are funded by DMIA. In addition and where applicable, some demand-side engagement projects can gain cost recovery via the AER's Demand Management Incentive Scheme (DMIS), that allows DNSPs to earn payments for deferral of network upgrades. | As a peak DM program, the key success metrics are based on DR measured at substation level. EQ access to individual customer data does not include whether an air conditioning unit is on and has responded to an event (with exception to a sample set of participants that have additional monitoring equipment). |
| 2 | Ausgrid Coolsaver trial | DNSP | DNSP Ausgrid: Control over DRED interface with air conditioning units | The CoolSaver trial was funded by customers via the DMIA governed by the AER. Use of the solution post-trial for a real network need received a regulatory incentive through the AER's DMIS. The purpose of the DMIS is to encourage greater use of non-network solutions to meet network constraints. | Reporting of innovation research outcomes is public through the annual DMIA reports to the AER, Ausgrid's own published reports and industry seminars. | DNSP only |

| 3 | Ausgrid VPP trial | DNSP and VPP aggregators | DNSP Ausgrid and VPP providers Reposit Power, Evergen and ShineHub | Research project funded by Demand Management Innovation Allowance (DMIA) mechanism | Ausgrid is regulated through the AER and is subject to National Electricity Rules. Ausgrid has both organisational and regulatory incentives to explore and implement efficient solutions such as VPPs. Regulations for the VPP provider include market operator rules and customer obligations. | Between DNSP and aggregators only. DNSP receives full battery state details. Customer energy data is confidential and not shared without consent. Outcomes of the trial for aggregators are commercial. Outcomes for the DNSP are shared widely through published reports on the AER and Ausgrid websites and industry seminars/information sharing. |
| 4 | AGL EV orchestration trial | Retailer | Retailer AGL: EV charging orchestration; ChargeFox: developing EV charger aggregation software to manage data, send controls and provide an interface for charging schedules; Schneider supplies the 'smart' wall chargers | Funded by ARENA | | Commercially sensitive, so only between retailer and commercial partners. |
| 5 | AGL VPP trial | Retailer | Retailer AGL; Sunverge, LG Chem, Solar Edge, Tesla: battery storage hardware partners; Enbala: control software provider | Funded by ARENA | AGL is regulated through the AER. The final report articulated 6 areas of reform to 'unlock the value' of battery VPPs in the energy market[183]: | AGL accesses PV production data and battery status. Although SAPN was not accessing household level data, 'AGL undertook a targeted deployment of solar and energy storage systems on substations/circuits |

[183] AGL, Virtual Power Plant in South Australia, Final Milestone Report, October 2020, https://arena.gov.au/assets/2020/10/virtual-power-plant-in-south-australia.pdf (accessed 22 Sept 2021)

| | | | | · Reforming network connection and access arrangements to incentivise networks to support DER participation<br><br>· Standardising the valuation of network services in the AER's network investment assessment framework<br><br>· Transitioning towards dynamic export limits<br><br>· Reducing the regulatory investment test for distribution (RiT-D) threshold to better support non-network solutions.<br><br>· Improving network visibility on the low voltage distribution network to facilitate DER participation.<br><br>· Technical standards should serve as an enabler of the market by promoting open access and interoperability | within SAPN's network that were identified as sites that could be subject to thermal and voltage constraints in the future, or had an existing metering capability that would allow the impact of the network service to be monitored.'[184] |
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[184] Ibid

Table 10: Pilot automated DSM projects in Austria and their institutional settings with rules in use and information access

| | Project name | Who controls the automated flexibility activation | Actors involved: positions and their tasks/actions | Interests of the actors | Specific rules between actors, market and regulatory framework | Information access |
|---|---|---|---|---|---|---|
| 1 | SCDA | DSO: Wiener Netze (using energy management system developed by AIT) | Wien Energie: Supplier Siemens: Component Manufacturer Käfer Haus: Construction planning Research Institution AIT: Engagement & Interface Design and Evaluation, Privacy Experience Evaluation (Center for Technology Experience), Optimization Development of local grid (Center for Energy), End User Communication & Support Partners: Transition Partners Joint venture ASCR between Wiener Netze, Wien Energie & Siemens | All involved partners were interested in how the energy grid in urban areas could be set up regarding optimised self-consumption, involvement of new technology and involvement of end-users and the goal was to explore a potential approach within the project and evaluate. | Consortial agreement between project partners ASCR as joint venture between Siemens, Wien Energie & Wiener Netze End User contract with building cooperative | Both DSO and supplier had access to consumption patterns and the supplier had access to price signals. The ASCR had access to sensor and setting information and transition partners had access to detailed consumer information. |
| 2 | Leaf project | DSO: (i) Salzburg Netz GmbH, (ii) Netz Oberösterreich GmbH, | TU Wien - Energy Economics Group (EEG), Energieinstitut an der Johannes Kepler Universität (EI-JKU) as | UC in Eberstalzell: Enhance self-consumption of the households at times of most solar production (>600W/m^2). | UC in Eberstalzell: Activate devices during 'sun bonus' hours (10c discount on grid tariff). | The DSO has access to power demand readings of the smart meters. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | (iii) Energienetze Steiermark GmbH is sending setpoints End-users for the manual and semi-automated load-shifting. | Research Institutes for scientific advice. Fronius International GmbH (FRO): Component manufacturer Siemens AG Österreich (SIE): Component manufacturer Moosmoar Energies OG (MME): Component manufacturer | Other UC: DSO could send setpoints for voltage control with battery storages. | Boilers are also activated during sun bonus hours. Other UC: DSO could use batteries for voltage control, participants could keep the devices, for instance. | |
| 3 | Flex+ | Aggregator through VPP operator: World direct | Supplier: TIWAG, aWATTar Balancing service provider: TIWAG IT-service provider: World direct (Flex+ platform) Research institutions: AIT, EEG (TU Wien), SCCH, design and running of the optimisation algorithms Component manufacturers: Austria Email (boilers), IDM (heat pumps), neoom(EVs), Fronius (battery storages) | Performing optimisation of day ahead/intraday + extra revenues from secondary and tertiary balancing. Schedules are sent via the Flex+ platform to the suppliers and balancing providers. These include the amounts which should be traded at day-ahead and intraday markets, as well as capacities which are reserved for balancing calls. | Consortial agreement between project partners Bilateral contracts with users with the allowance to test devices, More in a testing phase, balancing bids are for instance not really traded at markets, because the pool is still so small, but all necessary data transfer processes are already established. | Boiler: Optimisation based on typical consumption (used as a simple forecast). Heat pumps: Weather forecasts required. For the building model, people also have to add some information from the energy certificate. EV: charging levels, expected time to leave again Battery: PV forecasts |
| 4 | P2PQ | Decentralised control by blockchain | Supplier: Wien Energie End User Communication Partner: VMEC | Evaluate potential of blockchain in local energy | Consortial Agreement | All 3 project partners had access to the |

| | | technology: Riddle & Code | Research Institution: AIT: Engagement and Interface development and implementation (Center for Technology Experience), Optimisation development (Center for Energy) | provision in the context of energy communities | | consumption and production data. |
|---|---|---|---|---|---|---|

Table 11: Pilot automated DSM projects in Norway and their institutional settings with rules in use and information access

| | Project name | Who controls the automated flexibility activation | Actors involved: positions and their tasks/actions | Interests of the actors | Specific rules between actors, market and regulatory framework | Information access |
|---|---|---|---|---|---|---|
| 1 | H2020: INVADE | DSO: Lyse with smart innovation Norway. | Smart Innovation Norway: as the technology provider developed the platform. Schneider: developed the EV Charging box. | DSO: to maintain stability of the distribution grid i.e. managing peak capacity. End-users are interested in a dedicated charger box because of fear of fire. | Normal customer contract that made the pilot project optimise charging at the end user level. | The DSO, the platform developer and the end user (via an app). |
| 2 | H2020: ECHOES | Technology provider: Zaptec with its energy management system | Housing boards of co-ownership: Owner of the private parking lot where the charging occurs, which needed to argue for an automated billing system and load control. Zaptec: could serve as an aggregator potentially, not yet active in the Norwegian market. DSO: electro AS is key in management of charging infrastructure in co-ownerships/cooperatives | Zaptec could potentially sell their infrastructure as a solution to the housing board now in 2021 who are required legally to handle increasing EV charging on a local level. | In 2018 a new regulation/law stated that housing-boards in co-ownership buildings could not refuse residents permission to charge their EVs at home.

In 2021 a new regulation/law states that housing boards in cooperatives could not refuse residents permission to charge their EVs at home. | The EV owner can see charging status and the housing board can charge all EV that the owners want to be charged, the boards also get a billing system that makes the administration for charging easy. |
| 3 | Flekshome | Lede: DSO, End-users: set automation | Smart home developer. | Pilot project to test the feasibility of the technologies, apps etc. | Nothing specific. | The DSO owns smart meters. End-users have data access and one can opt-in and out in the application. The DSO has access |

| | | settings through an app. | | | | to power readings and can automate load such as hot water boiler, heating cables and EV. |

Table 12: Pilot automated DSM projects in Switzerland and their institutional settings with rules in use and information access

| # | Project name | Who controls the automated flexibility activation | Actors involved: positions and their tasks/actions | Interests of the actors | Specific rules, market and regulatory framework | Ownership structure/ information access |
|---|---|---|---|---|---|---|
| 1 | Innosuisse Decentralised flexibility | DSO: Groupe E | University of Geneva: scientific advisor (running surveys, interviews with participants for program design etc.) | DSO interested to manage congestion on distribution level to avoid grid reinforcement.<br><br>End-users' interests include lower electricity bills, and contributing to network stability. | DSOs have the full authorisation to perform automated DSM projects with the condition of remuneration. Contracts between the end-users and DSO exist in this project with approximately CHF60 direct incentive. | The DSO owns smart meters, relays connected to the smart meters to curtail the electricity to devices to perform the automated DSM and have access to the information of power demand (smart meter readings). |
| 2 | Innovative self-consumption optimization for multi-family area development with local electricity exchange | DSO: RTB Möriken-Wildegg – (owns smart energy system of the technology provider that provides the smart algorithms) | Self-consumption community: the program participants who receive automation.<br>Smart Energy Engineering GMbH: technology providers for optimisation of automation. | DSO earns money with real-time pricing that reflects the true cost of the grid . Also accommodating PV in local areas for network management (not a problem now due to low deployment but will be in future) and indirectly avoiding grid reinforcement.<br>Self-consumption community to increase self-sufficiency with its PV installation i.e. cheaper electricity. | DSO has contracted the self-sufficient community and runs the automation programs according to a real-time pricing market. | The DSO owns smart meters, PV installation in the community as a contractor, and the smart energy management system. Nevertheless, by law the DSO has only access to the information of power demand (smart meter readings), not the PV. On the other hand, the technology provider for the smart algorithm has access to household, water, and boiler temperature as well as to PV |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | production and charging power of cars. |
| 3 | Quartierstrom | Decentralised management by blockchain technology developed by ETHz laboratory 'Bits to Energy Lab' | ETHz laboratory 'Bits to Energy Lab': The technology provider for the blockchain. The block chain system (installed conjointly with a ETHZ lab and the EW Walenstadt (the DSO)), which function in a decentralised way through the public grid infrastructure. | More of a feasibility study (blockchain company developing white label product, business model to charge by trade) but indirectly solving the problem of DSO accommodating PV in local areas for network management (not a problem now due to low deployment but will be in future). Community: Managing their community in a completely decentralised manner without the DSO (democratisation) | Contract customer & DSO in the form of an electricity supply contract if electricity bought outside the community. Additionally, a contract between prosumers, DSO, and consumers with the platform operators. The P2P market is managed by a blockchain technology to charge electricity within the community. | None of the actors see the measurement of other parties, not even with pseudonyms. The technology provider for the decentralised battery has access to community-wide consumption and production rates. |
| 4 | GoFlex | Aggregator: (Kibernet/INEA (new name) | Kibernet/INEA: VPP operating a market to provide flexibility services in the balancing market for the DSO. This system of GoFlex can also be seen as a local market operator as the FMAR manages the local balancing market for energy flexibilities for DSO. | Kibernet/INEA: Both the VPP operator and also the provider of the energy management systems to the factories. This is a pilot project, therefore trying the technology<br><br>ESR (role of the retailer): to reduce the corrective costs (day-ahead and intra-day market), a | There is a contractual agreement with the customers and the DSO for buying and selling flexibility as part of the local market created. | Energy management systems have access to all the information in the house, temperature sensors of the hot water and room temperature. ETREL and Robotina have access to car charging levels.<br><br>Kibernet/INEA as the VPP only have access only to buy/sell flexibility commands (i.e. within this period you can |

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| | | | ESR (new name Oiken-Sion): is the utility company and involved in the project both as DSO and as the retailer. HES-SO: Project manager and coordinator of the pilot project. Technology providers: Kibernet/INEA: provider and installer of the component FEMS to the factories as well as HEMS in the household for them to follow the dynamic pricing tariffs. AAU: developer of the CasaApp smart plug-in for the washing machines. ETREL: provider of the CEMS (charging energy management system;. ROBOTINA: provider of the component of V2G which cis called charging discharging energy management system (CDEMS). | | | curtail or switch on the appliance). |
| 5 | Luggagia Innovation Community | Case 1: central management by the DSO: AEM | SUPSI: scientific advisor and also the project manager. | DSO interested to manage congestion on distribution | Self-consumption community regulatory | Case 1: DSO owns the smart meters, the decentralised battery and has access to |

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| | | Case 2: Decentralised management by the blockchain technology by HivePower | Municipality of Capriasca: acts as a public authority guaranteeing fairness and correctness of the whole SCC process. Technology providers: Optimatik which provides the product of Smart Grid solution HivePower: developer of the blockchain technology. Energy community with its consumers, prosumers (both residential and kindergarten) as a whole– engagement in automation | level to avoid grid reinforcement. Self-consumption community to increase self-sufficiency with its PV installation i.e. cheaper electricity. Hivepower: test the feasibility of blockchain technology to sell a white-label product (B2B). End-users' interests include reduced bills, high self-consumption for those who are prosumers. | framework (Loi sur l'énergie art. 16-18): Contract between end-user & DSO in the form of an electricity supply contract if electricity bought outside the community. Contract between end-user and community according to the internal market developed for the community. | power demand (smart meter reading) and battery charging levels. Case 2: Hivepower owns the tokens to activate the flexibility, have the access to power demand (smart meter reading) and battery charging levels. |
| 6 | Warm-up | Aggregator: Misurio as, VPP operator with a contract with the utility company | Misurio: the VPP developer and operator which activates and controls the automated flexibility activations and aggregates the flexibility for the DSO. Ewz acts in this project in multiple positions: i) Smart energy contractor which contracts the Aggregator for energy services, ii) holds position as the energy dealer | Aggregator: earns money by performing the day ahead/intraday optimisation to the utility i.e. utility sends signals to the VPP pool to provide flexibility (reduce consumption during peak price hours or increase it during low price hours). Retailers earn money with real-time pricing that reflects the true cost of supply in the wholesale market (Intra-day | Mutual contract between the Aggregator & DSO, sending signals for the energy management of the buildings. | Aggregators (Misurio) have access to power demand, household temperature, and hot water boilers. The DSO only to power demand readings of the smart meters. |

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| | | | (supply & trade) with the EPEX spot and iii) DSO, distributor that communicates with the TSO<br>Consumers with their hot water tanks and heat pumps – engagement in automation programs. | market), decreasing the corrective costs.<br>and indirectly avoids grid reinforcement. | | |
| 7 | Tiko-BeSmart | Aggregator (Tiko) | Tiko: the VPP operator and the aggregator aggregates flexibility to deliver ancillary services to the TSO such as frequency containment reserves (FCR), automatic restoration reserves (aFFR) (qualified by the TSO).<br>TSO: receives the ancillary services.<br>End-users: customers, prosumers etc – engagement in automation programs. | Tiko earns money by offering aggregated flexibility through its VPPs for ancillary services to TSO via auctions.<br>End-users' interests include reduced bills, high self-consumption. | Ancillary services defined by Swiss Energy laws: Tiko bidding weekly/daily in auctions for the ancillary services. Signed contract/protocols between Tiko and consumers, producers to automate their devices. | Tiko as the aggregator/VPP operator has access to power demand readings, household, hot water and boiler temperature and PV production of the prosumers. |
| 8 | OKEE | Aggregator (Smart Energy Control) | ZHAW: scientific advisor - calibrate simulations, improve algorithms.<br>ADEV: Energy supplier<br>End-users: engagement in smart charging. | The aggregator can earn money by participating in the balance market (testing its management system in this project). | There is no market or contract as this is a car sharing (by reservation to user's discretion). The national regulation allows the | Aggregator has the information of planned trips, EV connection status, power demand as well as charging levels of cars. ADEV (energy supplier) has access to the |

| | | | | aggregators to aggregate flexibility and offer this in a balancing market without the consent from the supplier. | power demand of the charging stations. |
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**Actors, positions, actions**

In this section, we provide an overview of which actors are involved most frequently in the initiation and implementation of automated DSM projects and discuss how these actors take positions which allow them to undertake certain actions in line with their interests in the project. Table 9, Table 10, Table 11 and Table 12 outlined these details for each project in each of the four countries. The results for each element of the action situation are explained in the following text; naturally overlaps between sections are evident due to the interrelation of elements.

Firstly, the analysis shows that **initiating actors mostly concerned a coalition of stakeholders, and only in some cases individual entities.** The most frequently seen coalition involves DSOs in Europe and DNSPs in Australia, partnered with research centres or academic bodies, and/or technology providers to initiate the projects with governmental and international funding. In almost all automated DSM projects, the DSOs/DNSPs were involved from the beginning actively in the design process as well as in the implementation i) controlling the automated flexibility activation themselves through their own cloud systems, or ii) owning energy management systems developed by technology providers or smart algorithms designed and provided by research bodies[185]. Their interests and business models (if available) include the network (peak) capacity management, and their actions therefore included peak shaving by curtailing highly intensive loads (either EVs or heating devices, or air conditioners in Australia) in certain periods, or trialling real-time pricing to improve system efficiency. This will indirectly save costs by deferring grid reinforcement needs into the future. In Australia, the 22 DNSPs can directly earn payments for deferral of network upgrades from the DMIA scheme, which is overseen by the AER. Network problems related to voltage fluctuations are not part of the design of the automated DSM programs since this is not yet sufficiently a problem in distribution networks given the relatively low deployment of rooftop PV installations in most of these jurisdictions.

**Secondly, the most frequent actors were the retailers with supply assets (energy suppliers) coupled only with aggregators through their own operated VPPs.** Almost all retailers and suppliers' interests were to improve the real-time management of demand and supply via automated DSM to reflect the intra-day market which then reduced the corrective cost (difference between day-ahead and intraday market). The aggregators help the energy suppliers with contractual agreements and optimise the load to provide day-ahead or intra-day optimisation for the retailer. In other words, they aggregate flexibility depending on the price spreads on the energy exchange market where the retailer can send a signal to the VPP operator to reduce consumption during peak price hours or increase it during low price hours.

**Thirdly, the aggregators were also the sole actors involved in the projects with their VPPs to control the automation which they can potentially earn money from by offering flexibility in imbalance settlement periods in the balancing markets.** Three

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[185] Willems, B. and Zhou, J., 2020. The Clean Energy Package and Demand Response: Setting Correct Incentives. *Energies*, *13*(21), p.5672

projects in which two technology providers automate EV charging (OKEE in Switzerland, ECHOES in Norway, and Flex+ in Austria) could be examples of this. These technology companies are trialling their technologies through the pilot projects. One DSM program in Switzerland which is run by the aggregator Tiko aggregates flexibility and provides ancillary services to TSO such as frequency containment reserves (FCR) and automatic frequency restoration reserves (aFRR) after the pre-qualification by the SwissGrid. Similarly in Austria, World Direct automates the smart boilers for FCR and automatic & manual frequency restoration reserve. Similar actors, actions and relationships are still in the demonstration stage in Australia where retailers and VPP operators are collaborating to 'stack' the value of flexibility in electricity markets.

Municipalities were rarely involved in initiating or implementing the project except for one case study: the Luggagia Innovation Community in Switzerland. The municipality of Capriasca owns the public kindergarten and the rooftop PV which were part of the DSM project with its assets. They also acted as an implementation partner from the start of the project, supporting the DSO recruiting end-users for the project and acting as **'sort of a public authority guaranteeing fairness and correctness of the whole process'**.

Projects where flexibility is activated via **blockchain** technology are also emerging. There are three pilot projects in which flexibility activation was done by blockchain technology (two from Switzerland and one from Austria). From Switzerland, the projects include Quartierstrom discharging/charging the decentralised battery with blockchain developed by the ETHz laboratory 'Bits to Energy Lab' and Luggagia Innovation Community in their second case study, with blockchain developed by Hivepower. These actors' interest is to earn money by providing flexibility services through contracts with the DSOs for the optimisation of distribution networks. In Austria, the P2PQ project aims to develop and validate blockchain applications in real operation for optimising the self-consumption of PV-generated energy within urban quarters by enabling P2P relations among energy prosumers based on blockchain.

Other main actors take the position of technology providers to realise automation. These include providing and selling to the DSOs smart management energy systems such as smart plugs, interfaces, software and algorithms which are connected to the devices (heat pumps, EVs) to perform the automation. The tasks/actions of these actors mostly consisted of installation, maintenance, and the operation of energy management systems in case of a failure in the algorithms.

In terms of end-users as actors, both prosumers and consumers were individually recruited by the project managers. In contrast to other countries, energy communities as a whole single entity (ZEV/RCP)[186] exist in Switzerland, which can then be recruited as a community to the project by the project manager (as in Project 5: LIC and Project 2: Innovative self-consumption optimisation in Switzerland). In almost every project, end-users are involved late in the projects, i.e recruited after the design process therefore mostly passive. In other

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[186] The new rules for implementing groupings for self-consumption are in force since 1.1.2018 (loi sur l'énergie art. 16-18). RCP stands for regroupement dans le cadre de la consommation propre (RCP) and ZEV stands for ZEV (Zusammenschluss zum Eigenverbrauch).

words, their actions do not go beyond just accepting the automation project/program and participating in the project. The majority of the end-users' interests were to have cheaper electricity bills and increase self-sufficiency as a prosumer and as a community.

**Information access**

Access to information often determines which actions are possible, and which are not. Similarly, actions are dependent on what kind of information is shared among the actors. Moreover, it is possible that an actor has incomplete information due to a certain rule. For example, in project 'Decentralised flexibility' in Switzerland, guaranteed charging levels for EVs were not offered because, according to the rules, the DSO would not have the access to this information as there is no protocol that exists between EV companies and the DSO itself. In all these projects, DSOs indeed only had access to smart meter power demand readings, not any other data (household temperature etc.). This is a good illustration of how the accessed information has an impact on the actions that a DSO can take in automated DSM. Their actions are limited to fixed parameters (i.e. period for curtailment) rather than sophisticated algorithms that optimises temperature, charging levels, etc.

Those projects which collaborate with third parties as technology providers on the other hand have more granularity as these third parties have more access to information (household temperature, charging levels, pre-set options by the end-users). Therefore, they could develop their own energy management systems that could perform automation with more sophisticated algorithms depending on temperature sensors, charging levels, PV electricity production, etc.

## 11.5 Policy implications

- Separation of energy (the focus of retailers and aggregators) and grid (the focus of DSOs) during liberalisation contradicts holistic solutions in some areas, therefore most of the projects had a one-sided focus (either energy or grid) depending on the actor involved. Therefore, finding ways to bridge this gap and incorporate both aspects into program design is an important future task for businesses and regulators to consider
- It is currently unclear who determines how the flexibility will be governed - for example, how different goals will be weighted or with which boundary conditions
- Business models that make their optimisation solely dependent on the energy market will not solve the problems in the local grids.
- DSOs must increasingly collaborate with other actors to realise smart grid innovations.

Empirical evidence from different automated DSM pilot projects and programs shows that there are a diverse number of actors involved in automated DSM projects with diverse roles,

capabilities and interests. The legal task of a DSO in Europe and DNSP in Australia is to maintain a stable electricity grid, and their interests in automated DSM projects are translated as managing (peak) capacity and voltage control arising from high demand of heat pumps and EVs. Other stakeholders such as retailers, suppliers and aggregators have other interests such as balancing demand/supply, energy communities and prosumers to maximise the use of renewable energy and TSO frequency containment. All these interests need to be aligned with the heating, mobility and other practice needs of the consumers, prosumers and communities.

It is evident that the **separation of energy (the focus of retailers and aggregators) and grid (the focus of DSOs) in the course of liberalisation contradicts holistic solutions in some areas, therefore most of the projects had a one-sided focus (either energy or grid) depending on the actor involved.** With a one-sided focus there is a risk that business cases will suddenly disappear. Aside to the pilot projects presented here, experience showed that many load management projects have focused strongly on control power and are now facing challenges because the prices for control power have fallen sharply.

**It is currently unclear who determines how the flexibility will be governed - for example, how different goals will be weighted or with which boundary conditions.** For example, for EVs, how the battery of the electric car is used for 'smart charging' when someone connects his/her car to several initiatives, and which initiative takes precedence is unclear. The aggregator may be concerned with load-balancing (control via the charging point) while the end-user might have given the supplier/retailer permission to use the car on TSOs reserve markets (control via the car). For heat pumps, similar issues can arise. For example, in Europe since energy prices are strongly linked to the situation in neighbouring countries and not to local conditions, this can mean that electricity can be purchased cheaply even in times of locally high network loads from PVs. **The business models that solely depend on their optimisation on the energy market will not solve problems in local grids.**

These calls for separate optimisation platforms and harmonised frameworks to have integrated solutions, where different interests and goals are aligned. However, evaluation and assessment of network issues, or other goals in monetary and non-monetary (i.e. comfort) terms or device efficiency (battery charge/discharge and coefficient of performance of heat pumps) requires a lot of expertise. Projects that include iterative approaches especially in decentralised systems through theoretical studies should be encouraged and funded by government bodies to develop a conceptually unified framework where all the different goals be adhered to during the optimisation in a holistic manner.

**DSOs must increasingly collaborate with other actors in order to realise smart grid innovations.** They typically acquire technologies related to energy management systems in one-off transactions or have simpler designs for their programs where the devices are curtailed for a certain period rather than optimised, but the innovative nature of smart grid may require more collaborative relationships. Policy-makers should consider stimulating

long-term relationships between DSOs and third parties, because such relationships are more likely to produce incentives for collaboration.

# 12. Conclusion

## Lessons from the case studies

- Public support for renewable energy does not translate straightforwardly into support for demand side management programs. The question of which changes automated DSM will bring to energy users' lives is crucial to a social license to automate, rather than whether the amount of renewables is increasing.
- A history of automation in DSM (especially ripple control of household loads such as hot water systems) aids distribution service operators in successfully developing automation programs across all countries.
- Better penetration of smart metering facilitates automation pilots and programs but does not also lead to a social license to automate. Smart meter roll-outs raise further issues for energy users that do not necessarily lead to acceptance of automation.
- Assumptions about the context of automation, and the framing of the problems to which automated DSM is directed, are embedded in culturally specific planning systems. These systems carry different assumptions about how to live well, and what *should* be shared. The relationship between the built environment and framing of problems to which automation is addressed is a key distinction across the countries. For example, in Australia, 'end-of-pipe' automation technologies directed to users in detached households are prominent, whilst energy communities are increasingly the locus of automation technologies in Europe.
- There are no simple lessons about user acceptance at different levels of automation.
- **Articulation of shared problems** underpins a social license.

The Human-Computer Interaction analysis (Chapter 8) revealed that what is required to build a social license depends on the level of automation. How technology can best support acceptance by users through interfaces and system interaction features depends greatly on the level of automation implemented.

- At **low levels of automation**, which involve manual shifting or manual programming of devices, actively reaching out to participants and providing them with actionable information and feedback are crucial. These can support long-term behaviour change, as will dedicated intervention with strategies such as commitments, prompts, social norms communication and rewarded goal-setting. Furthermore, interfaces need to provide users with ways to indicate preferences and specify available flexibility.
- At **medium levels of automation**, which involve participants' active opt-in by providing consent, or active opt-out by veto, the need to actively engage participants is reduced, but the importance of transparency about the automation increases and the need for personalization options to accommodate the preferences and lifestyles of users remains.

At **high levels of automation**, which may or may not allow participants the possibility to restrict automation to particular parameters, the importance of actively and regularly engaging participants and providing personal noticeable benefits is reduced once they are onboard with the program objectives. Providing the option of control through a possibility to veto still reassures participants and aids trust at this level, even though it can be expected to be used only rarely.In other words, the importance of frequent communication to actively engage participants and provide them with actionable information varies across these levels, declining with greater automation. Crucial at all levels of automation, however, are the communication of benefits and transparency about the scope of the automation. The role of HCI in DSM therefore changes depending on automation level (and the related impact on and effort required of participants), shifting from one of helping, reminding, teaching, providing feedback and encouraging, to one of reassuring, justifying, and providing transparency and accountability.

The energy sociological analysis (Chapter 9) revealed how the prospects for a social license vary for different energy activities in the home.

This analysis explored how people are engaged in a number of activities in the home that use energy, focussing on EV charging and the use of home appliances, particularly washing machines and dishwashers. For example, various charging routines have emerged with the take-up of EVs, each of which has its own rhythms, including: charging to maintain battery close to fully charged, charging when the battery has been depleted to a certain minimum level of charge, charging when needed, charging by default, charging around other tasks, charging when solar energy is available, and charging to minimise costs.

The considerations that are already influencing the timing of household energy activities include balancing need, cost, effort and the availability of renewable energy. Some households are effectively already changing when they use appliances for various reasons, and some are using technology to support their energy activity planning around these priorities and considerations, using the settings of their home appliances or EVs, or associated apps, to program start and end times. The ways that people are already using technology to support their planning offer insights into how automated DSM can be designed to fit into and support household activities.

Peoples' responses to the possibility of automated control differ according to the energy loads affected and the routines and meanings associated with those loads in individual households. This aligns with earlier findings about the importance of 'flexibility capital'[187] to participation in DSM. People are more likely to be more open to automated DSM if it supports the existing approaches to energy activities in the home. Furthermore, monetary incentives alone are insufficient for participation, given the range of household, social and material factors that influence the capacity of householders to shift their use of energy to other times of the day.

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[187] Powells, G. and Fell, M.J. 2019. Flexibility capital and flexibility justice in smart energy systems, Energy Res. Soc. Sci. 54:56–59. https://doi.org/10.1016/j.erss.2019.03.015

The Science and Technology Studies analysis (Chapter 10) explored the problem and solution framings of automated DSM, and how the technology and the solution framings aligned with the interests and values of users. Such framings vary for direct load control, smart EV charging management and VPPs.

The analysis followed the translation process from the establishment of the problem, the articulation of the automated DSM solution by the actors involved and their appeals to the interests of the household participants, to how these participants accepted or resisted the solution. Automated DSM is primarily seen to address challenges for grid management, and is seen as a step towards a decentralised energy future.

The way that the translation of these solutions occurs varies according to the context and actors involved.  A variety of actors are involved in the negotiation processes related to automated DSM. This includes electricity retailers, network operators, aggregators, customer service representatives, electricians, automation technology manufacturers, vehicle manufacturers, consumer representative organisations, housing boards, and even energy users not participating in DSM programs or projects. Thus, the contextual specificity and contingency of the translation process must be taken into account when assessing and seeking to learn from trials and programs.

The case study participants gave several reasons for why they wanted to participate in the trial or program. Some of the reasons given were interest in new technology, financial gains, environmental concern, and community orientation.

Energy users seem to take up automated DSM solutions, and the new or changed roles envisaged for them, to the extent that they see value in them – either at a collective or individual level. Their willingness to participate in these automated DSM solutions reflects the extent to which these solutions align with the users' motivations and priorities around energy, including the extent to which respondents expect automation to relieve them of any energy management work they would prefer not to do. Thus, the STS analysis reveals that the extent to which users see value in automated DSM solutions tends to be highly influenced by:

- **their understanding of DSM and the challenges it seeks to address, including *why* it is important and *who* benefits**. The case studies examined in various ways how to increase 'grid sensitivity'[188] as participants became more familiar with these challenges in the energy system.

- **visibility of how their DER is being controlled**. Access to information proved important for many users - even if they do not actively or regularly use it.

- **control over how their DER is being orchestrated**. The ability to override or opt out of automation events is seen as important by trial and program participants. However, energy users want control that goes beyond the option to opt out: as they

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[188] Skjølsvold, T.M., Ryghaug, M., and Throndsen, W. 2020.European island imaginaries: Examining the actors, innovations, and renewable energy transitions of 8 islands, Energy Res. Soc. Sci. 65: 101491. https://doi.org/10.1016/j.erss.2020.101491

want to control the parameters of their participation - such as the timeframes or battery range within which their EV must be charged, for example. Automated DSM has the potential to 'help' and relieve participants of energy work *and/or* to enable them to be empowered, active participants of the energy system, depending on their preferences and how the program is set up. Most importantly, the participants in automated DSM trials voiced the need to influence and even choose the scope and terms of their participation in automated DSM programs.

The institutional and actor analysis (Chapter 11) showed that many actors are required to make automation work successfully.

Where the Science and Technology Studies analysis examined the relationship between the users and the problem formulation and framings in the field of automation, the actor analysis provided evidence that **automation trial programs are profoundly collective endeavours**: initiating actors were coalitions of stakeholders, and only in some cases individual entities. DSOs often partnered with research organisations and nascent aggregation businesses specialising in communication systems and remote operation.

Second, the **most common actors across the case studies analysed were vertically integrated retailers** with supply assets. Energy retailers coupled with aggregators through VPPs to help manage price volatility across day-ahead and spot markets and take advantage of low price periods. Thirdly, the **aggregators were also the sole actors** involved in the projects with their VPPs to control the automation that can potentially earn money by offering **flexibility on imbalance settlement periods** in the balancing markets.

Municipalities were rarely involved in initiating or implementing projects. Further research could look at local and municipal governments and their renewed role in energy service provision. In Australia, for example, organisations such as the Moreland Energy Foundation (now Australian Energy Foundation) and Yarra Energy Foundation are well placed to become a form of communal aggregator considering their longstanding engagement with energy efficiency and household PV systems.

**Information access** to granular household level comfort and other information profoundly affects the quality of predictions, however its relationship to user acceptance is complicated. Our case study analysis does not support specific rules prohibiting any specific forms of data from being shared. In many of the cases, DSOs only had access to smart meter power demand readings, without access to any other data (household temperature, etc.) that might enable more accurate automated control algorithms to reflect household comfort, etc.

## Policy implications

The successful projects analysed in this report:

- developed and communicated a clear goal shared by the energy users (e,g. avoiding blackouts during peak periods) following informed consent protocols,
- compensated in ways that were deemed fair by the users, and
- updated users about progress of the trial or program in a suitable manner.

However, we have found **there are no 'one size fits all' solutions** to successful user engagement for automated DSM programs directed at issues such as frequency control, peak load management, voltage management and grid augmentation. Obtaining a 'social license to automate' will need to be adapted to local, regional and national concerns, as well as to the technology domain of automation.

**A gap between the visions held by the energy sector and the realities of household users remains**. For this reason, the achievement of a 'social license to automate' according to parameters of user acceptance and energy efficiency achieved will require frequent deliberation and revision, as this will not be something that can be obtained as a one-off. **Users are also citizens, engaged in energy policies as well as energy systems.** Energy use should therefore be understood as being connected to energy users' values and interests. This connection makes visible the relationships between the wider policy environment, human and non-human elements in the households that structure everyday life.

**There is no one simple hierarchy of energy loads that are more or less amenable to automated control**. Acceptance of the automated control of household loads depends on a complex set of questions and contextual factors. These include how the individual and collective value of automated control is communicated to and perceived by users, and the impact that it may have on them. These also include users' experiences of interacting with the automation technology at the micro scale and how their engagement is shaped by institutional configurations at the meso level or macro scale. Our cases show, however, evidence of a hierarchy according to impact on users, whereby the automation of loads with a greater potential impact on the everyday life of users - that is, loss of comfort or convenience - is generally less acceptable to them. Loads with greater potential impact include air conditioners and power boards, while loads with lower potential impact include batteries.

**Communications and interfaces with household participants must be designed according to the level of automation involved.** The role of these interactions with household participants of automated DSM is important in building a social license, and varies from one of 'helping' and 'reminding' to 'reassuring' and providing transparency about the scope of the automation.

**Automated DSM providers targeting residential energy users need to understand household energy activities.** Energy activities are different and valued differently within households. Valuation of load-shifting or other forms of automated control requires a careful consideration of how householders value the activities that involve different loads. As was found in the energy sociology analysis, some households are already changing when they use appliances for various reasons and looking to use automation and labour-saving technologies to help them do so. Energy industry should structure DSM to take these activities into account, working with logics that influence their timing**.**

The participants of the case studies have diverse and even competing motivations for participating in these trials and programs: interest in new technology, financial gains, environmental concern, personally improved energy security, contribution to grid stability and community orientation. **Energy users take up automated DSM solutions to the extent that they align with their motivations, interests and values**. For example, energy users who have purchased a home battery for environmental or financial reasons may be willing to participate in VPPs, while those who have purchased a battery to increase their energy independence and security may be less willing to.

**Several implications can be drawn for the governance of automated DSM programs:**

- Separation of energy (the focus of retailers and aggregators) and grid (the focus of DSOs) in the course of liberalisation contradicts holistic solutions in some areas, and most of the projects thus had a one-sided focus (either energy or grid) depending on the actor involved. Therefore, finding ways to bridge this gap and incorporate both aspects into program design is an important future task for businesses and regulators to consider

- It is currently unclear who determines how the flexibility will be governed - for example, how different goals be weighted or with which boundary conditions

- Business models that make their optimizations solely dependent on their optimisations on the energy market will not solve the problems in the local grids.

- DSOs must increasingly collaborate with other actors in order to realize smart grid innovations.

The ideal business models and their relationships to different forms of automated DSM are still to be determined. This is because **the value of automation and the demand flexibility that it might achieve remains profoundly contested:** there is no agreement between the energy sector, regulators, government agencies and energy users about the value of automated demand-side solutions.

**'Bundling' or 'stacking' energy services presents communication and potential acceptance issues.** Projects with well-defined and easily communicable goals and common benefits are more likely to see users engage with the project. 'Stacking' may overcomplicate this.

**Who benefits from automation projects will influence levels of acceptance and engagement by energy users.** The future may involve greater centralised control via digital

platforms owned by large multinational corporations, relocalisation of energy or some combination of the two. This will be a significant energy policy decision to come in the years ahead.

**The value for industry and users alike that is realised in the trials and demonstrations examined here will not necessarily be realised in ongoing or scaled up programs.** For example, careful consideration is required of the utility of data gathered in trials that often are characterized by one-off subsidies to attract typically enthusiastic early adopters. The data gathered in trials conducted to date, including those set out in this report, may therefore have limited relevance in understanding the household settings, demographics and values of later adopters in future automation projects. **Industry failure to grapple with the social diversity of settings where automation projects are being trialled is an existential threat to its ongoing viability. Social science expertise has an indispensable role in the development, ongoing operation and evaluation of automated DSM programs.**

## Directions for future research

- The **climate policy implications** of the policies and programs we have analysed are complex. In particular, the alignments between declared country-level policies in NDRCs and energy efficiency, demand response and associated programs requires further analysis. On one level, some key national policies are listed which have a clear and direct role with pilot programs; however there are clearly multiple forces governing how decisions are made across different scales which will require careful analysis. Our research shows that energy users in the countries analysed are likely to respond more positively to programs framed as explicit climate change policies; and that **the broader benefits of automated demand side management tend to be undersold.** Further research is needed into how to communicate such broader benefits in a comprehensible and tangible manner to users with different value-frames.
- **Relevance of household level trust to other energy users** could be probed - for example, where there are principal/agent issues in shared housing such as a tenancy arrangement or similar.
- The analysis revealed that automated DSM prioritizes certain **energy futures over** others, however. There is a need for more analysis to understand what futures these solutions construct, how these futures are being shaped and what their implications are. It would also be interesting to analyse in more detail what elements are *not* made part of the framing and what automated DSM narratives *exclude*.
- Further analysis is needed to understand the role of **cultural forces.** COVID-19 has obviously constrained our ability to conduct fieldwork *in situ* where the cases analysed have been conducted. This project initially envisaged visits to the sites of trials and programs by social scientists who are both trained in ethnography and sensitive to the institutional dilemmas driving the uptake of automated system, however this was made impossible due to COVID-19.
- The analysis of users of automated DSM solutions reminds us of the importance of considering **who is not being included in automated DSM pilots and who is excluded.** This is likely to have ramifications for how these technologies and

solutions will work. Currently, automated DSM solutions and services are being designed for and refined by participants of these trials and studies which predominantly are typical early adopters, many of whom are quite well-off with a special interest in technology. Some of the research methods employed in our case studies are also more inclusive of other participants. Research with broader samples of energy users are needed to get more robust results.

- **The diversity of actors that are important for mobilising support** for the implementation of automated DSM solutions and services is often overlooked. Particularly, typical middle actors or intermediaries (such as housing boards, electricians etc) have been ignored and should be given more attention in future research as they have proven important in the process of enrolling energy users in automated DSM.