GSMA

Smart Energy Systems

Connectivity for a zero-emissions future

The GSMA represents the interests of mobile operators worldwide, uniting more than 750 operators with almost 400 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces the industry- leading MWC events held annually in Barcelona, Los Angeles and Shanghai, as well as the Mobile 360 Series of regional conferences.

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Contents

Foreword

As we look toward COP26 and grapple with the economic recovery from the COVID-19 pandemic, there is an increased awareness that greater ambition is required if we are to meet the challenge of the climate crisis. As we set this ambition and design our recovery plans, it's the right time to consider the fundamental transformation required - to decarbonise we must digitise.

The mobile sector has a key role to play by increasing connectivity, improving efficiency and impacting behaviour change, mobile network enabled technologies help to avoid emissions. In 2018, the GSMA Enablement Effect report estimated these avoided emissions. Compared to the global carbon footprint of mobile networks themselves, the level of avoided emissions enabled by mobile communications technologies was 10 times greater – a tenfold positive impact.

This report, a follow up to the Enablement Effect report, takes an in-depth look into the most fundamental industry to decarbonise – energy systems. Until now, there has been a lot of focus on renewable technologies such as solar, wind, tidal and hydropower and less discussion on how they will work together. This is where Smart Energy Systems come in. Connectivity has a key role to play and in particular mobile connectivity. To reap the most benefit from mobile connectivity there needs to be greater evolution and cooperation between sectors such as energy, mobile network operators and ICT companies, and with energy regulators.

The case studies in this report represent fantastic innovation that could be rolled out to help achieve our decarbonisation targets quicker and easier. The implementation of Smart Energy Systems will prevent an overbuild of capacity worth 16,000TWh of annual generation, which based on today's electricity prices will save approximately $1.9 trillion per year. More importantly, compared to today's energy mix, it will save emissions of 7.7 billion tons of CO_2, making it responsible for over 23 per cent of global decarbonisation.

We hope this report starts a conversation about the low carbon future of our energy systems and the role mobile connectivity has to play.

Steven Moore
Head of Climate Action, GSMA

Foreword

The world around us is changing. Some people cannot help but fight these changes, nonetheless the changes are happening. In a short period of time, I have seen them everywhere. Small changes, such as washing your hands after a visit to a grocery store and bigger changes, like the 'new normal' of working from home. The COVID-19 pandemic has accelerated change in a lot of different ways. In 2020, digitalisation went into overdrive. Our quick adaptation to no longer being able to travel, to working from home, to delivering new services in a new way quickly showed us that we are able to achieve great things. Yet the experience of the past year has also made us more conscious of our own vulnerability. Not only personal and public health vulnerability, but also the vulnerability of our global supply system as well as our climate. Who doesn't remember the clear sky pictures of normally polluted areas? Of course, we can try to fight these changes. But we can also embrace the changes and turn them into opportunities.

With this paper, my colleagues and I from both KPN and the GSMA are choosing the second option. Due to climate change, our energy system has to change from a fossil-fuelled industry into a renewable energy based system. In order to make a successful energy transition, we need new and affordable technologies. We need inspired leaders that take action, and we need to be bold. Simultaneously, the world of wireless connectivity is also changing. In 2020 KPN launched its 5G-network, Wi-Fi has nearly become a necessity of life and it will not take long before the Internet of Things is as normal as the Internet of People.

This report describes how these two concurrent changes will result in a new revolution toward Smart Energy Systems. It shows how we will get one big step closer to being fossil-fuel free once we unite data with energy usage. In practice, the transition to Smart Energy Systems will mean weather forecasts and energy consumption patterns are combined. Our electric vehicles will be automatically charged when the wind is blowing, and the air-conditioning will turn on when it is sunny outside. This means, new business cases will emerge in both the energy sector as well as the connectivity sector. In this report they are described in five main areas: battery storage, distributed energy resources, microgrid trading, virtual power plants and vehicle-to-grid charging. Realising these business opportunities requires forward thinking and a collective strategy.

I truly believe that with this report we have created a good start for the changes we are facing. We know these changes are ahead of us and we know we can turn them into opportunities. Now let's get started!

Paul Slot
Executive Vice President KPN Infrastructure

Executive Summary

A Global Challenge Requiring Smart Solutions

Climate change has become the defining issue of our generation. For global warming to be kept below irreversible levels beyond 1.5°C, net global emissions will have to half by 2030, before reaching zero by 2050. Innovative approaches to manage supply and demand are needed to accelerate the transition from an energy system 84 per cent dependent on fossil fuels, to one that runs on renewable power. Interconnectivity between all elements is vital to achieve a Smart Energy System (SES).

The mobile sector will be essential to providing the backbone infrastructure for this. Using wireless connectivity, a broad network of diverse devices can be aggregated that both produce and consume energy. Harnessing the power of AI-based cloud computing, we can create platforms that control and optimise the use and storage of renewable energy resources, and retire fossil-fuels from the existing energy mix.

Through three key steps, wireless connectivity will prove to be a key component of a system that can guarantee energy demand is always satisfied by zero-carbon sources:

1. Maximising the lifetime power output of renewable generation assets
2. Minimising excessive energy consumption through end-use and transmission
3. Optimising load shifting and energy storage to align clean power supply and demand

These SES, with optimised end-to-end efficiency, can save 23 per cent of global carbon emissions, based on 2019 levels, by 2050 – more than would be achieved if 90 per cent of today's cars were retired overnight.

Influencing 86 per cent of energy between production and consumption by 2050, the prevented wastage in electricity will save an overbuild of power generation accounting for 16,000 TWh, saving $1.9 trillion per year based on today's energy prices.

As we enter a period of inevitable economic hardship following COVID-19, mobile networks will be key to optimising the transition to net zero emissions, despite not physically reducing emissions themselves. Considering the sector has a carbon footprint of 220 Mtonnes CO_2e, the level of avoided emissions it could enable through SES is 35-times greater through to 2050.

Smart Energy Systems can save 23 per cent of global carbon emissions, based on 2019 levels, by 2050 – more than would be achieved if 90 per cent of today's cars were retired overnight

A Multi-Pronged Approach to A Modern Power Sector

Achieving this huge impact on carbon emissions will not be achieved through one single application of wireless technologies within the energy sector, but through a wave of modernisation and digitalisation. Throughout the coming decades, this revolution will enable renewable energy to occupy the entirety of local energy mixes, facilitate the transition to electric alternatives for appliances like boilers or for vehicles, and ensure consumption on an economy-wide scale is as efficient as possible.

While the mobile sector itself becomes more reliant on low-carbon power for its decarbonisation, this report sets out five key areas where significant growth will be enabled by the development of wireless mobile technologies and cloud computing.

Within each of these five areas, wireless connectivity offers much greater simplicity in installation compared to fixed-line alternatives. It will also be put to work in a much more diverse range of applications including predictive and assisted maintenance, asset protection and control, and load shifting.

1 Battery Storage
- **Case study:** Allowing battery projects to be tailored to specific corporate needs (p24)
- **Case study:** Integrating fast-response batteries into high-profit markets (p26)

2 Distributed Energy Resources (DERs)
- **Case study:** Facilitating the adoption of modular and distributed hydrogen production (p20)
- **Case study:** Using drones to inspect widespread, critical energy infrastructure (p22)

3 Microgrid Trading
- **Case study:** Reducing need for grid upgrades by decentralising microgrids (p40)
- **Case study:** Providing energy democratisation using blockchain smart contracts (p43)

4 Virtual Power Plants (VPPs)
- **Case study:** Generating digital twins to simulate new energy scenarios (p29)
- **Case study:** Creating grids that rapidly self-heal during blackouts (p31)

5 Vehicle to Grid (V2G)
- **Case study:** Supporting vehicle-to-grid technology and smart chargers (p35)
- **Case study:** Tracking the dynamic nature of an electric vehicle battery swapping network (p38)

The use of 5G technologies will help to leverage beneficial characteristics of high volume, speed and reliability in communication between a huge number of devices to allow real-time analysis and optimised decisions to be made across the energy ecosystem.

A Clear Collaborative Route to Successful Deployment

Pilot tests and early developments have already demonstrated these technologies are ready to be deployed for global decarbonisation, but unlocking the benefits from wireless technologies is not guaranteed. There is currently a notable gap between the mobile and power industries, and few stakeholders understand the necessary evolution of both. A cohesive relationship is needed, both internationally and between industries.

For the energy sector, the overarching principle is decarbonisation. Mobile Network Operators (MNOs) will be key to the role of digitalisation within this. These MNOs will become mission critical service providers as their networks become entwined within SES and national grid infrastructure.

This business model expansion for the MNOs continues their ongoing pursuit within the Internet of Things (IoT), as they transition from being solely connectivity providers to firms that provide value-add services on top of their networks.

For the energy industry, these MNOs can provide systems integrations expertise, to connect the multitude of digital elements and services in the energy grid. They will serve as the essential link between other cloud-based applications, enabling the energy grid to interact with other businesses, governments, and consumer systems. They can also work to close the knowledge gap in the energy sector regarding wireless connectivity at massive scale.

Stakeholders in both sectors, as well as policymakers, will need to develop an optimised environment where the technology is made as accessible as possible for those attempting to implement climate change strategies.

1. First, distinct barriers must be removed to facilitate the widespread distribution of both mobile network coverage and clean power generation technologies.
2. Then, advanced computing infrastructure must be developed to aggregate the two on an international scale.

Realising the Benefits Requires Forward Thinking

The specific value wireless communication will bring to individual projects may not be immediately apparent upon installation. Most benefits will occur once they become part of a broader SES, covering a wide range of devices. To prevent this from impeding the early uptake of the technology, especially in markets where margins on electricity prices are being squeezed, it is the responsibility of governments and regulators to incentivise the interconnection between the two.

Introduction: Smart Energy Systems

Global societies have reached a tipping point. Addressing the climate crisis necessitates a rapid transition away from fossil fuel power generation, and towards decarbonised and sustainable alternatives. The technologies are ready. What is now needed is a collective strategy to deploy them at the required scale with minimal economic disruption. Wireless connectivity is a key component in this carbon-neutral transition through enabling new Smart Energy Systems (SES).

SES are a new solution, which combine energy generation and storage technologies with 'intelligent' applications, controlling and optimising their usage. They will be key to meeting targets from companies and governments increasingly aiming for net zero emissions by 2050 or sooner. In the total energy landscape, renewables (including biofuels and hydropower) currently account for just 11 per cent of global consumption, with an additional 5 per cent coming from nuclear power, leaving an 84 per cent fossil-fuel gap that needs to be filled by renewable technologies.[1]

The question of scale and speed is one of the most pressing as the new technologies being put to use in the energy sector need to become the bulk of the generation capacity. Thankfully, mobile networks and the new generation of AI-based cloud computing are well-placed to enable this rapid transition.

The combination of mobile networks and powerful cloud computing environments is vital because of their ability to aggregate emerging renewable energy systems into an asset to rival the gigawatt-scale of a nuclear power plant. By using wireless connectivity to combine several solar farms, or thousands of homes with small-scale renewables or storage systems, using cloud computing to manage them, new SES can be put to work in decarbonisation efforts.

This will be achieved through three key steps:

- First, the lifetime output of renewable power assets can be maximised through making real-time decisions to optimise performance based on technical characteristics and meteorological data.
- Second, the consumption of end-use devices can be minimised and shifted to periods when there is surplus renewable power generation.
- Finally, all components can be aggregated together, along with energy storage technologies, to create decentralised energy systems of maximum efficiency and minimum cost.

1 BP Statistical Review – 2019

How to build a Smart Energy System

The process of joining up lots of small components into an aggregated SES is not an easy feat. There are many moving parts to connect, as well as central business and government applications to configure. Mobile networks are a vital component, allowing these assets to connect in the field, with cloud-based computing environments acting as coordinators.

Examples of these SES devices might be a lithium-ion battery storage system designed to store energy from a nearby solar farm; a group of homes that have installed solar panels on their roofs; or a fleet of electric vehicles that will charge in a coordinated fashion when renewable power generation is high.

The stakeholders involved in SES need to know their responsibilities, and each participant needs to know which other partners to pay, or customers to bill. Ultimately, if SES are going to be commercial successes, all the partners need to know their roles and obligations in creating the optimum environment for their operation.

All of the different components need to be connected and then orchestrated, using wireless connectivity to link them to the internet where they can then be configured inside an application running in a cloud computing environment. New AI-based technologies will be especially useful in cloud applications, which will be put to work optimising the usage and revenue generation of SES deployments.

Solar Farm

Lithium-ion battery storage

Co-ordinated vehicle charging

Smart homes with solar panels

The foundations of Smart Energy Systems

No two SES will be identical, however there are three fundamental components nearly all of them will include. This section will explore these foundations, which are Wireless Connectivity, Cloud Computing, and Platforms.

Wireless Connectivity

Wireless Connectivity has always been an enabling technology; it helps create a foundation new businesses can be built upon. Sometimes, enablement means the creation of a completely new application, such as the app industry which has grown up around smartphones. Other times, it means improving existing applications – enabling new efficiencies or revenue streams.

The energy sector is one of the best examples of the latter, and there are some very convincing examples. Broadly, wireless connectivity has facilitated the deployment of new renewable energy generation systems. It has laid the groundwork for a new generation of electric vehicles and the required payment marketplace surrounding them, and is gearing up to connect all manner of buildings to a dynamic energy grid.

Data generated by smartphones, in-home appliances, business equipment, vehicles, cameras, and drones will power the next industrial revolution – or in this case, an environmental revolution. Managing tens or hundreds of thousands of devices is going to be immensely complicated if they are connected via dozens to hundreds of different physical networks carrying vast volumes of data.

If a utility or energy management firm needs to use meters to monitor live usage or wants to be able to control appliances at their customers' premises, relying on all those different networks is a significant operational risk. Using mobile networks can solve the problem, connecting these devices directly to a Mobile Network Operator (MNO) without needing to rely on customers, building owners, or governments as bottlenecks.

The advantage of wireless over wired

In many examples, the case can be made that wireless connections could be replaced by wired (fixed) connections. However, in the vast majority of these cases the cost of laying these cables and visiting every single installation would quickly undermine the business case.

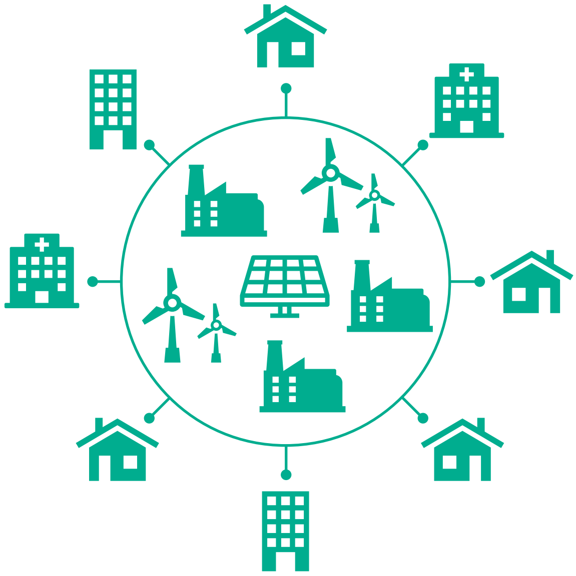
Also, using a wireless technology almost always translates to a simpler installation, where a technician can easily fit a new smart meter. This then relies on the wide-area wireless connectivity, rather than trying to rely on the WiFi connection in a customer home or hoping the end-user won't accidentally unplug it.

For mobile assets, wired connections are not a viable alternative. Electric vehicles (EVs) can be major assets to energy grids, as well as decarbonisation initiatives, but they also need to be managed at scale. Through the move towards being able to direct EVs to the best charging station based on travel data and usage patterns, these EVs can become mobile batteries to store surplus renewable energy.

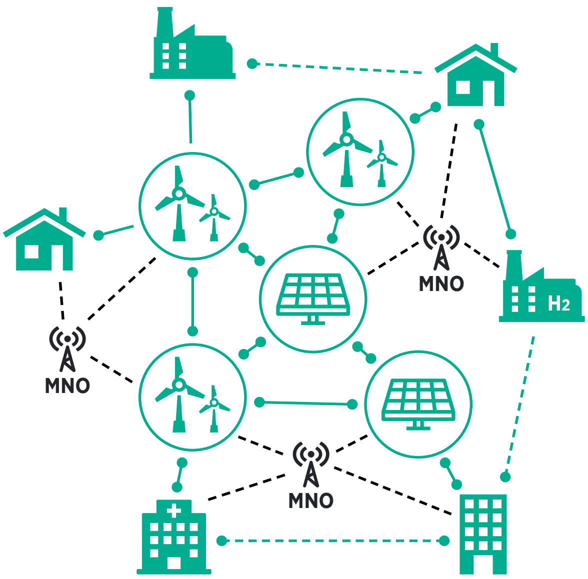
As most cars are parked for upwards of 95 per cent of their lifetime,[2] they can be seen as micro power stations, feeding electricity into the local grid when needed. These applications require connectivity that can travel with the asset, can be sufficiently ruggedised and will last the life of the asset.

2 RAC Foundation, Spaced Out: Perspectives on parking policy, 2012

Centralised generation



Distributed generation



Cloud Computing

Cloud Computing is the new normal for enterprises thanks to the flexibility of its pricing schemes. It allows a customer to only pay for exactly the amount of computing power and supporting software, without risking wasted investments.

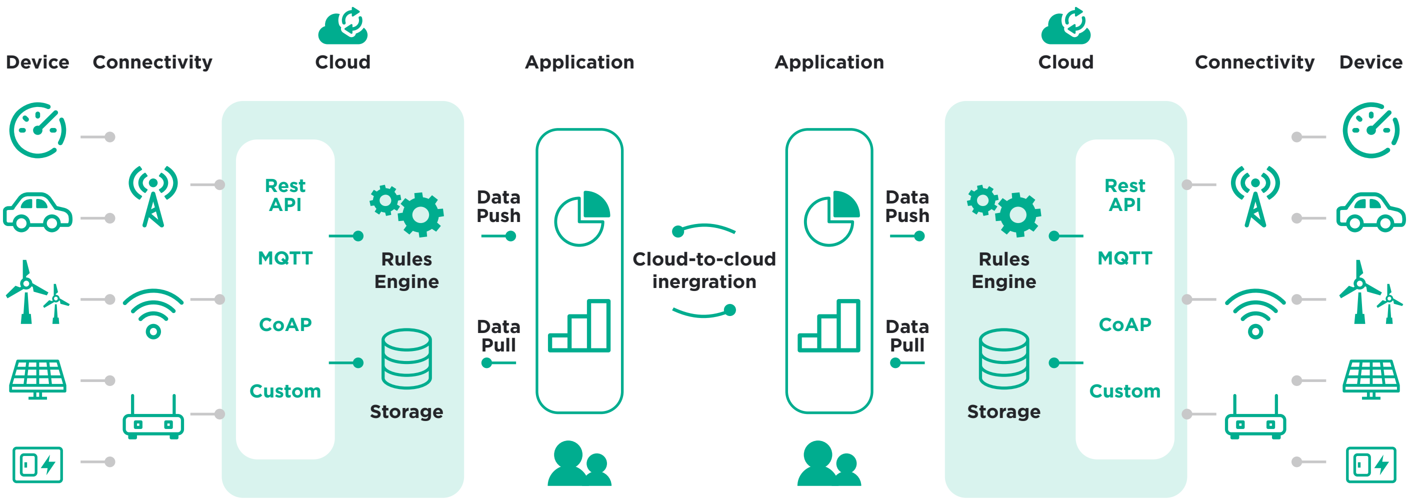
Instead of having to purchase, install, and support this computing power, the end-users can now pay for it as a service. Because of this flexibility, Cloud Computing enables customers to make use of new computing technologies, particularly AI-based data processing, leasing it on a very short-term basis.

This is a similar dynamic to offloading the 'cost' of running a private wireless network to an MNO and enjoying the easier operational load that comes with the decision. MNOs are already becoming Cloud Computing providers and are looking for new services to add to their offerings, leveraging the distributed networking facilities that form their communication networks.

The key benefit of this service-based approach is the limited capital requirement. As demonstrated through the likes of Tesla in the automotive market, new entrants are likely to be among the most innovative and influential in combating climate change. Facilitating the rapid development of these game-changers with access to low-cost, high-power computing is one of the primary roles of MNOs through the energy transition. →

MNOs are already becoming Cloud Computing providers and are looking for new services to add to their offerings

Data flow in a SES



Platforms

A Platform is the term used to describe the combination of technologies, usually from multiple vendors, that act as a foundation on which users can build new business applications. Unsurprisingly, Cloud Computing is a key part of this and acts as a central hub for data gathered from several different sources.

These Platforms can unite data from multiple different partners or stakeholders, processing it and then running the results through complex business applications and software in a collaborative fashion. This process enables new business applications that were not possible before Cloud Computing to become influential. In combination with the emergence of Platforms, MNOs have begun connecting a wide range of Internet of Things (IoT) devices, many of which play an important role in the energy sector.

A good example would be a platform that ingested data from smart meters, weather stations, and energy generation resources, and then compares this view of the system against historic consumer behaviour. Using this system, the energy sector could determine how customer demand will change throughout a day, based on current and historic patterns, and the effect weather will have on this particular day. This allows the energy mix to be optimised in near real-time.

This is the power of such a platform – one that could be run by a single business and filled with partners and customers, such as an MNO, Cloud Computing provider, or a government entity. The Platform is the glue that joins all the component parts together, creating a SES that acts as a unified whole and helps decarbonisation efforts.

Combined, Wireless Networks and Cloud Computing Platforms provide the foundations that help transform regular energy systems into SES. A new wave of startups is bringing these systems to the fore, but to become a transformational wave, these startups need to be able to integrate them into the world of business software. This is where the Platforms have an effect, with wireless connectivity able to connect all manner of new applications to this global ecosystem.

MNOs have begun connecting a wide range of Internet of Things devices, many of which play an important role in the energy sector

The role of the Mobile Network Operators

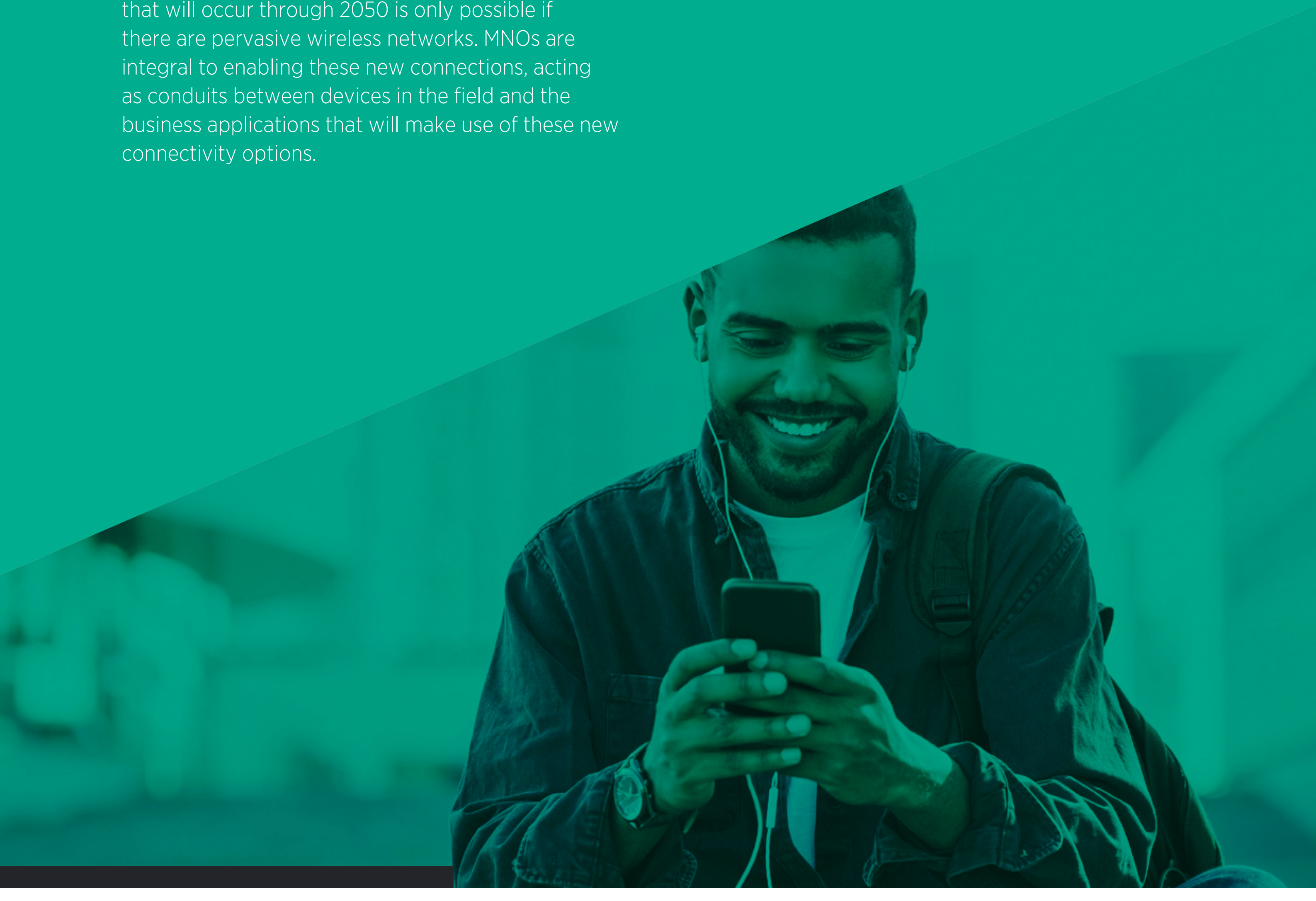
Put simply, SES require wireless connectivity to scale to connect the assets deployed in the field with the centralised coordinating applications. MNOs are becoming mission critical service providers as their networks connect the SES deployments with national energy grids.

Additionally, MNOs are already expanding their business models, looking to transition from being just connectivity providers to companies providing value-add services on top of their networks. This expansion is already well underway, with the IoT being a major cross-industry trend to pursue as every new device and connection is a sales opportunity for MNOs.

The aforementioned shift towards native connectivity that will occur through 2050 is only possible if there are pervasive wireless networks. MNOs are integral to enabling these new connections, acting as conduits between devices in the field and the business applications that will make use of these new connectivity options.

MNO networks will transport data from the network edge into the Cloud Computing ecosystem. Many MNOs have already created Cloud Computing divisions and, through the period, nearly all MNOs are going to move into this line of business. They will look to provide both the wireless connections and the supporting business software.

For the energy industry, MNOs can provide systems integrations expertise to connect the multitude of digital elements and services in the energy grid. They will serve as conduits between other cloud-based applications, enabling the energy grid to interact with other business, government, and consumer systems, and work to close the knowledge gap in the energy sector regarding wireless connectivity at massive scale.



The role of Smart Energy Systems in 1.5 degrees

To prevent climate change from causing irreversible damage to the planet, the Intergovernmental Panel on Climate Change has stated the world needs to reach net zero carbon emissions by 2050. This necessitates global collaboration between industry and policymakers, and without hesitation.

To achieve this goal, global energy demand needs to fall at a rate of at least 0.19 per cent per year from current levels, while the penetration of renewables is pushed above 85 per cent of production by 2050.

For many industries, including transport and heating, the best way to do this is through electrification, with electricity needing to account for at least 49 per cent of global energy demand by 2050 - hitting interim targets of 29 per cent and 38 per cent in 2030 and 2040 respectively.

This rise in electricity demand has to be satisfied through renewable technologies, with wind and solar power currently providing the lowest cost to decarbonisation and already undercutting fossil fuel generation in most parts of the world. These technologies depend on weather patterns, and once penetration of renewables surpasses 30 per cent in the electricity mix of different regions, starting in Europe, it will be essential to deploy SES to facilitate them.

This will serve the purpose of continuing the reduction in energy intensity in the power sector, which currently sits at 475 tons per TWh on average but is much higher in countries like India (700 tons per TWh). A large part of this reduction will come from preventing an overbuild of capacity and maximising the output of renewables assets.

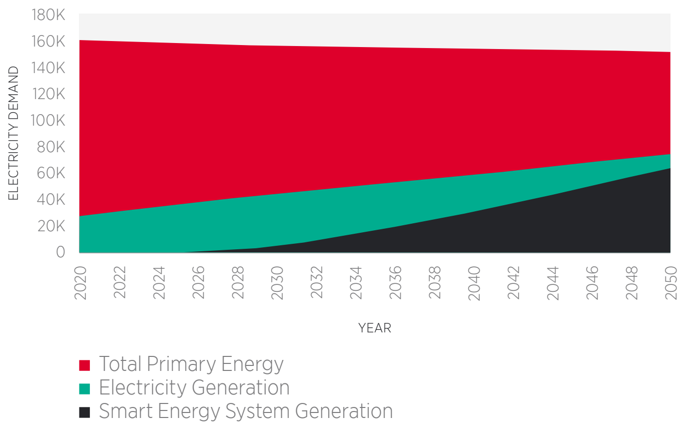
To maximise the benefits from SES, they must be deployed in parallel with renewable projects through an international electrification process. In an optimum scenario, all new renewables projects would be fitted with infrastructure that will allow them to participate in a globalised smart grid system.

Rather than the 67 per cent penetration in 2050 expected through market forces alone (see page 53), support from policymakers for SES and the wireless communication infrastructure required to facilitate it will need to drive penetration of SES to 13 per cent by 2030, 52 per cent by 2040 and then 86 per cent in 2050 as the system starts to mature.

By facilitating this, SES will prevent an overbuild of capacity worth 16,000TWh of annual generation, which based on today's electricity prices will save approximately $1.9 trillion per year. Perhaps more importantly, compared to today's energy mix, **it will save emissions of 7.7 billion tons of CO_2, making it responsible for over 23 per cent of global decarbonisation**.

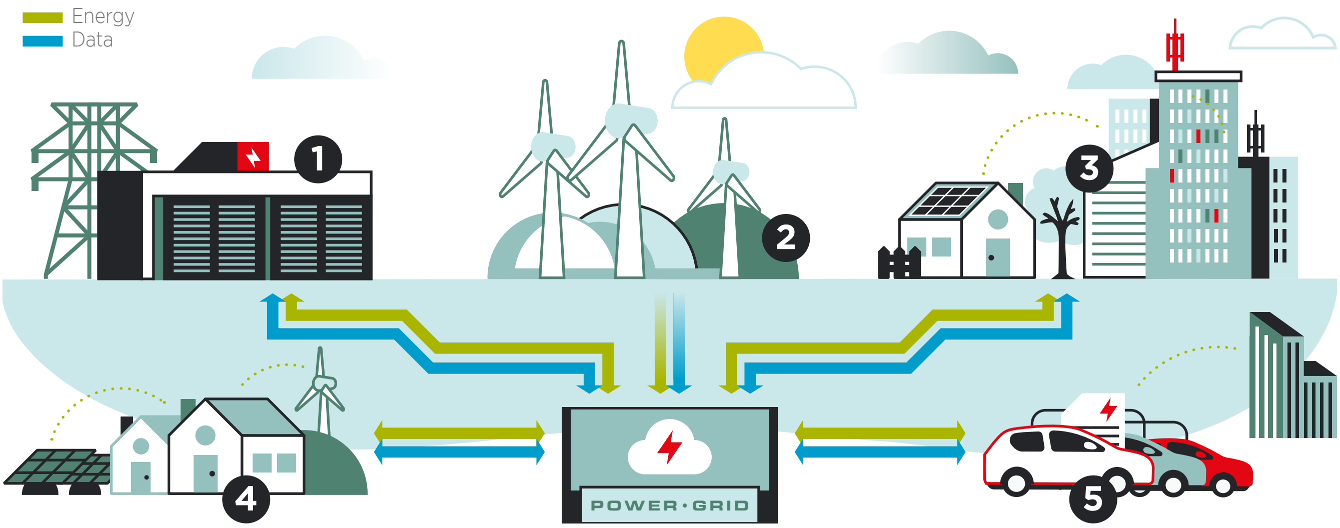
This will also see a rapid transformation from utilities into the digital age as they expand their operations from power to include electrified transport and the production and distribution of green hydrogen, which will be crucial in decarbonising the remaining portion of non-electrified primary energy demand.

Global Penetration of Smart Energy Systems: 1.5 degree C Scenario



Smart Energy Systems: an overview

Smart Energy Systems



There are immense environmental and societal benefits that will be realised through the adoption of SES, and while the process of deploying them can be complex, there are very clear business cases. This also means great investment opportunities in enabling and operating these new SES.

Realising the benefits of SES will not be achieved through one single application of wireless technologies within the energy sector but through a wave of modernisation and digitalisation.

There are five main areas that best illustrate the scope of these systems as shown above:

1 Battery Storage
2 Distributed Energy Resource
3 Microgrid Trading
4 Virtual Power Plants (VPPs)
5 Vehicle to Grid Charging (V2G)

Business opportunities for Mobile Network Operators and energy companies

This section will explore examples of these use cases that are already taking hold, illustrating the progress already being made and the role MNOs will play and how the benefits of wireless technologies can be leveraged to allow for real-time analysis and decision-making across the energy ecosystem.

Both utilities and network operators will be key partners for the startups which often drive the innovations behind these SES.

In terms of the business cases, MNOs will provide wireless connectivity for new appliances and devices deployed for SES. MNOs are also expanding into the services market, and for SES this will encompass Cloud Computing and business applications, including entire platform support too. Also, MNOs can leverage their engineering and integration teams to gain new business in the SES marketplace and become digital service providers. Any new installation is also an opportunity for network densification, which is a key objective for MNO's 5G deployment roadmaps.

For utilities, SES present major decarbonisation opportunities and enable the use of new, low-cost renewable electricity sources to improve profit margins. The utility can begin laying the groundwork for microgrids and Distributed Energy Resources, and then leverage new SES as part of an expansion into providing high-value ancillary services, such as frequency response and grid balancing. New SES will allow utilities to optimise their purchasing decisions to favour the cheapest and most environmentally-friendly options – maximising asset utilisation.

Distributed Energy Resources (DERs)

The first of the five areas is called Distributed Energy Resources (DERs), which are energy generating systems deployed in a non-centralised fashion.

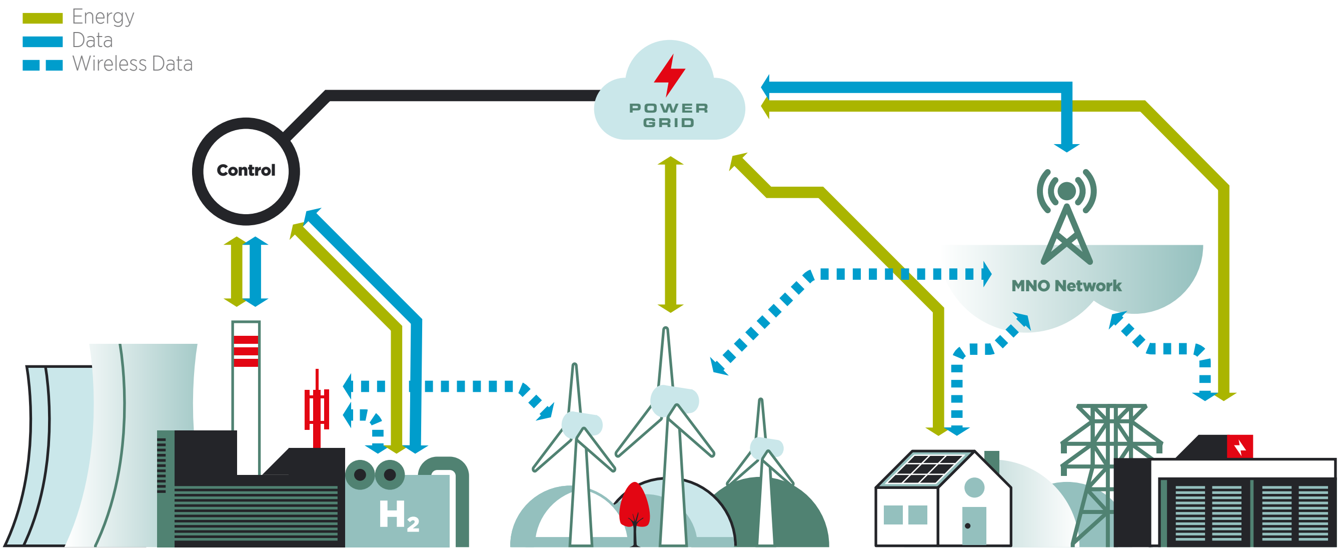
Historically, power stations have been built where most convenient, and the distribution networks that transported this electricity from the generation source to the end customer were unidirectional – flowing from the centre outwards towards the end-users.

This was very centralised production and distribution, involving large, gigawatt-scale power stations (mostly coal, gas and nuclear). It is most efficient to transport electricity over powerlines at very high alternating current (AC) voltages, which suited these giant generators as they produce sufficient power to warrant investment in large transmission projects. The electricity grid is then used to move this power over long distances before stepping the voltage down to a safe enough level near the consumer and delivering it as Direct Current (DC). The process of stepping electricity voltage up and down does have some wastage, as does the transport, and is generally agreed to be in the 5 per cent to 10 per cent range.

DERs differ greatly. As the name implies, they are deployed in a distributed fashion, meaning they can be located much closer to the end-users. Also, they have much smaller power generation capacity and are usually measured in kilowatts or megawatts. Because of their smaller scale, they often do not interact with the very high voltage transmission grids, and in many cases the DERs are only used to supply electricity to the building or campus on which they are deployed.

However, as these DERs are aggregated into SES, their impact will be realised on a much broader scale. This will open opportunities to include the smart distribution of all forms of energy including heat and gas – largely in the form of green hydrogen.

How to create an SES using DER



Use case: facilitating rapid cost reductions for green hydrogen production

Despite years of false starts, the global hydrogen energy market is finally starting to gain traction, with Europe vying to become a global leader. The European Union (EU) will want to avoid the dramatic 'boom and bust' it saw when it lost out to China in the early development of its solar supply chain.[3] Cutting the cost of hydrogen technology will hinge on a distributed approach, where unit costs are cut through economies of scale.

Green hydrogen, produced through the electrolysis of water using renewable electricity,[4] is being slated as one of the key routes to decarbonising industries which cannot simply replace fossil fuels with renewable electricity. Using hydrogen in sectors including heavy-duty transport, and steel and cement production could be responsible for as much as 34 per cent of anticipated global emissions reductions.[5]

For it to be used as a commercial fuel, green hydrogen from renewables will have to reach cost parity with grey hydrogen from steam methane reforming (using natural gas). Costs will need to fall from around €6 to €1.50 per kilogram, and the market where this happens first is likely to dominate the global supply chain.

Gains will be made through the cost of renewable electricity, product cycle and efficiency, but the majority of this price reduction will come through reaching economies of scale. It is estimated every time the number of units in operation doubles, costs could fall by at least 12 per cent.[6] Between November 2019 and August 2020, the announced project pipeline for green hydrogen grew from 3.5 GW to over 10 GW: nearly 40 times the amount of globally installed capacity today.[7]

To stay ahead of this cost-reduction curve, companies like Enapter in Germany are aiming to reach a point of serial fabrication much sooner than those manufacturing utility scale electrolysers by focusing on compact, modular units, which can reach a commodity status similar to what has been seen in solar panels or lithium-ion batteries. These both plummeted in cost in a short period, enabling their adoption. By doing this, Enapter believes a commercial price for green hydrogen could be reached before 2025.

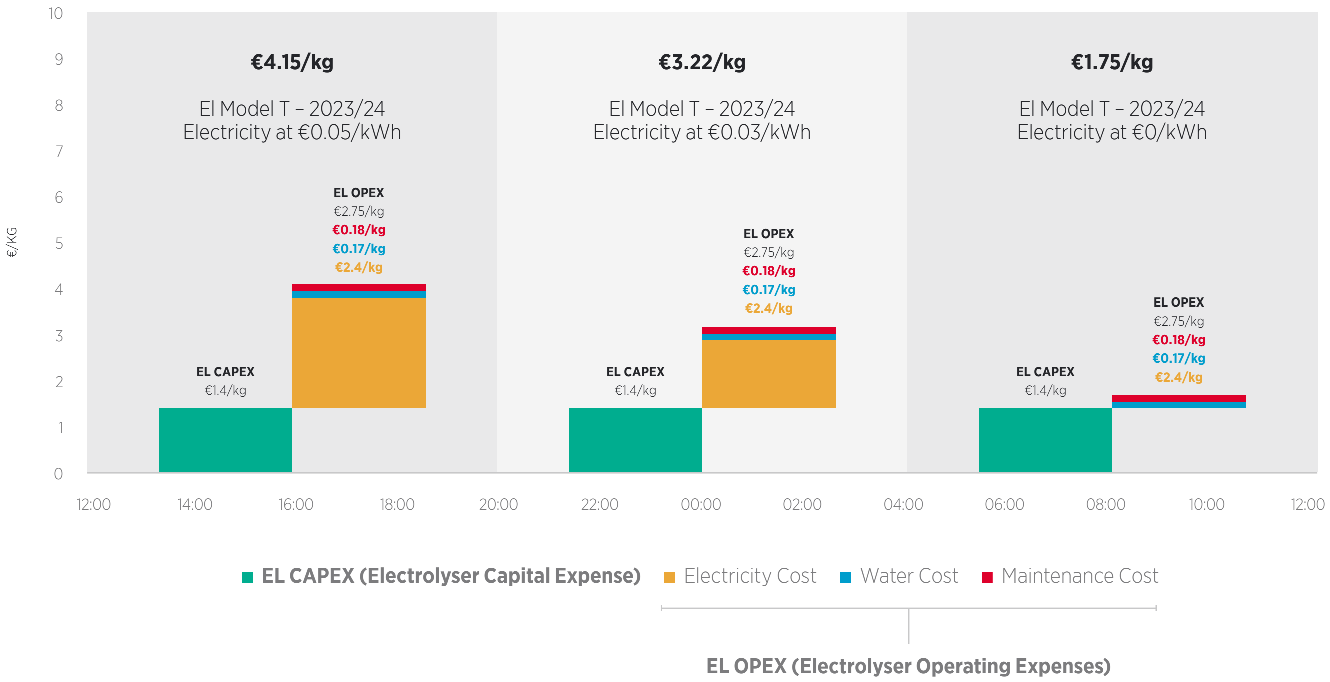
Achieving this status on a commercial level will require Enapter to make its modular electrolyser as flexible as possible. As with batteries, this relies on implementing a 'smart' management system to optimise the rate and time at which the device chooses to operate.

Enapter's Energy Management System uses Universal Communication Modules to communicate with local energy devices and grid electricity prices. By doing this, the decentralised device can be optimised to suit the customer's needs and offer the best rate of return by selecting the most profitable and necessary times to generate or store hydrogen from excess electricity. This also presents the opportunity for micro-energy trading similar to that seen with residential storage in the power sector, where distributed resources can be harnessed across a 'smart grid' system. With optimised trading, costs of both electricity and hydrogen will fall further.

Maximising the benefits and output from the device therefore relies on secure and consistently available connectivity and data transfer. Early applications for Enapter's devices have included microgrids on islands in the Indian Ocean, rural settlements in Uganda and in remote alpine cabins in Europe, where broadband connectivity is often weak or intermittent. The cost of installing fibre-based networks for these systems will be uneconomical, especially as devices are added one module at a time, and access to mobile networks will enable a distributed approach to electrolysis to proceed at maximum speed, and the cost of Europe's green hydrogen to fall faster than in other markets.

3 Reuters, German solar firms go from boom to bust, 2011
4 Enapter, Enapter White Paper, 2020
5 BloombergNEF, Hydrogen Economy Outlook, 2020
6 EU Horizon 2020, Report on experience curves and economies of scale D7.5
7 WoodMackenzie, Green hydrogen costs to fall by up to 64 per cent by 2040

Total cost of green hydrogen[8]



When most people talk about DERs, they are referring to renewable sources of energy, and the most familiar examples are rooftop solar panel arrays and wind farms. Solar can be installed in small-scale arrays on top of homes, or at larger scales in solar farms. Wind turbines can vary considerably in size, but you generally will not find a wind turbine in an urban environment. Smart management is, however, becoming increasingly applicable for offshore wind applications, providing communications for vessels having to spend longer amounts of time further from shore and allowing for remote inspection and predictive maintenance. Projects that have deployed private 4G networks so far include Norther and Mermaid in Belgium, deployed by nCentric and Nokia.

Of course, many non-renewable energy sources also fall under the DERs umbrella, including gas peaker plants, backup diesel generators, and even small modular nuclear reactors (SMR). The nuclear example is still in development, but gas peakers and diesel generators tend to be used in emergencies. They are fired up when the main electricity supply has suffered an outage, or when there is an imbalance on the main energy grid that needs to be corrected. However, renewables are proving very capable alternatives to these fossil fuel-based methods when paired with storage in a SES and will replace them in time.

As the energy system transforms to incorporate these DERs, alterations will need to be made through construction and operation, and greater quantities of data will be required to monitor a larger number of generational and transmission resources.

8 Enapter - https://www.enapter.com/media-coverage/h2-view-exclusive-calculating-the-cost-of-green-hydrogen

Use case: allowing drones to inspect widespread critical infrastructure

While the bulk of the future of SES will lie in the digitalisation and automation of utilities to optimise the efficiency of DERs, mobile networks will also be essential in facilitating the transition by improving the performance and reducing the operating costs of existing energy assets.

The easiest way to achieve this is to make sure generating assets are generating for as much of the time as possible and ensuring broken components in a plant are accurately identified and repaired with minimal downtime.

While traditional generating assets, like coal-fired or nuclear power stations, are highly centralised and easy to inspect on site, renewables projects take up considerably more room. Solar installations, for instance, take up 5 acres per MW of capacity, meaning it is not cost-effective to perform physical inspection on a regular basis.[9]

For solar farms, in particular, a more cost-effective solution to minimising downtime is to perform remote inspection using drone technology. Powered by low latency networks, these drones can be controlled to collect and send live data to project operators to give the operational status of components and panels within a project.

One of the most important inspections to be made is thermal imaging to identify hotspots within solar panels. These 'hotspots' occur when there is a defect within a solar cell, and as local temperature increases, the efficiency of the solar panel itself decreases. The hotspot itself indicates excess energy is being wasted as heat, rather than being converted to electricity. Hotspots are generally unstable and usually intensify until the overall performance of the panel is eventually nullified.

Studies have indicated that at any one time, a typical solar farm can have 1.5 per cent of panels hosting a hotspot between 10°C and 20°C above operating temperature and another 2.5 per cent had hotspots more than 20°C above operating temperature.[10]

Rather than using a team of professionals to manually inspect each panel, drone operators can use a two-person team with minimum disruption, reducing time on site and lowering maintenance costs. Software like Raptor Maps can be used to collate facility-scale data to give a comprehensive overview of a plant's performance and can often use AI and machine learning to perform predictive maintenance and prevent future failures.

Similarly, for wind farms, an inspection of components like the blades can be performed during brief, planned shutdowns, and inside the turbine tower of the turbine while operating. Drones may also be used for the inspection of power lines to identify any failures or risks within electricity transmission.

With all of these projects operating over a significant geographical footprint, beyond visual line of sight operation is a common requirement, and radio-controlled drones, with ranges topping out at around 2 kilometres, can often be insufficient.

Mobile networks, including those using 5G for large data applications, can be deployed to deliver low-latency drone control for inspection over the full project area. These 5G-based networks will enable real-time transfer of data from equipment the drones carry, such as thermal imaging and machine-vision cameras and sensor suites, which can be seamlessly integrated into cloud-based applications.

While sensors are being developed to allow for devices to identify their faults, this full-level digitalisation is a long way down the line, and in the years before utilities go fully digital, smart maintenance solutions will be critical to optimising utilities' infrastructure. Drones, enabled by mobile networks, will be key to this transition.

9 Solar Trade Association – Explainer: Solar Farms
10 Sunfields Europe, Key Points to avoid solar panel hot spots [https://www.sfe-solar.com/en/noticias/solar-modules/solar-panels-hot-spots-temperature-key-points/]

Battery Storage

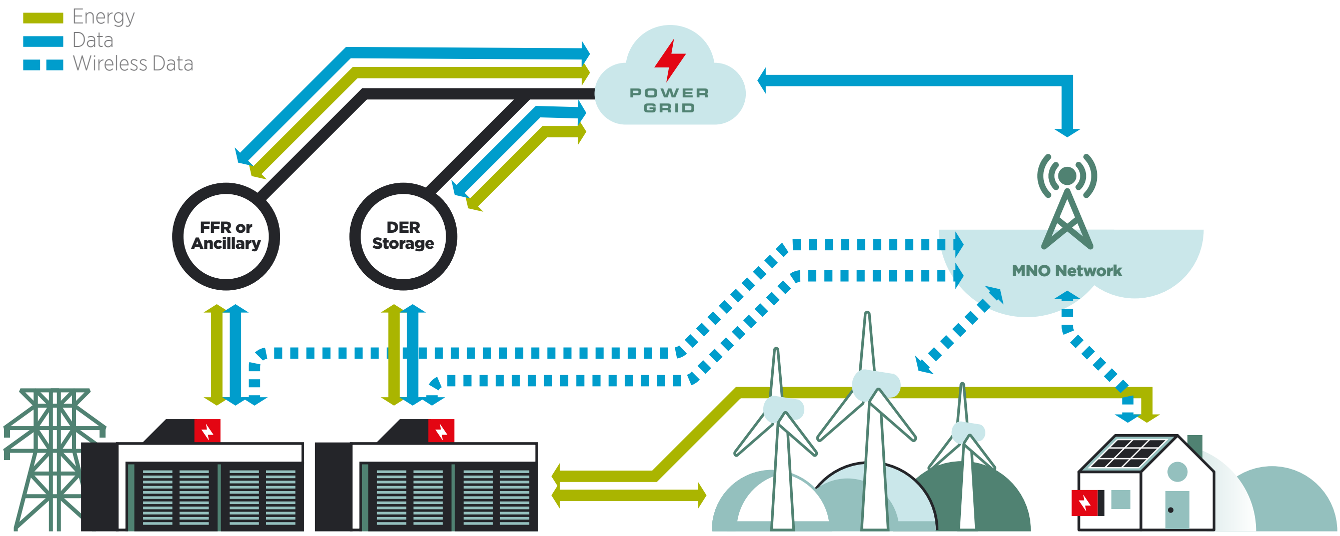
The second main trend is Battery Storage. As the penetration of renewables in the energy mix increases, the intermittent nature of the sun shining or the wind blowing mandates energy must be stored and then released when generational output is low to ensure a consistent supply of renewable electricity to consumers.

Most examples concern large lithium-ion battery storage arrays, which can store surplus energy from renewables when there is greater supply than demand, and then discharge their batteries when demand exceeds supply.

Battery Storage helps ensure grid-scale DERs can be deployed more easily as they smooth out the variability in generation output found in wind and solar farms. There are also Battery Storage arrays more focused on the Ancillary Services use case, which is used to correct imbalances in the electricity grid.

For example, Fast Frequency Response (FFR) is an application that lets a battery act as an emergency asset, ready to respond to a change in grid frequency at an incredibly fast speed. If that frequency imbalance is left uninhibited, there is a risk of a power outage. In FFR applications, the batteries are ready to respond to a change in the transmission frequency, and the battery owner or operator is paid for this service.

How battery storage enables DER and other grid services



Use case: accelerating the deployment of tailored corporation battery projects

One of the significant challenges for a system-wide shift to clean energy is the specific requirements of each energy consumer. With vastly contrasting energy demands, businesses across the world are starting to find value in accelerating their transition, many by signing power purchase agreements with renewables developers, and many developing their in-house projects.

In collaboration with various companies across the energy sector, Dutch telecommunications company KPN is one of those exploring options for its decarbonisation, indicating an early cohesion between the energy and communications sectors in the shift to smart energy systems.

As part of its Energy Innovation Lab, KPN has started a pilot project to assess how backup batteries in telephone exchanges can increase the company's adoption of green energy while reducing its spend on electricity.

The pilot will assess how backup batteries in KPN's telephone exchanges can store green energy during periods of the day when output from wind and solar is high, and discharging when the supply from renewables is low, while also providing a fail-safe mechanism to prevent loss of connection through local power outages in the system.

Using mission critical batteries to prevent power cuts is not a new application for the telecommunications industry, but in countries like the Netherlands failures occur very rarely, and very little value can be prescribed to the batteries.

Increasing this value through KPN's method hinges on a smart approach to power purchasing decisions when deciding to store electricity in the battery system. While KPN will partially fill its batteries with its solar panels, the battery will aim to purchase the rest of the energy from the grid at optimum times. These will be defined as when the price of energy is low or even negative to prevent wind power being curtailed, or when the penetration of renewables in the electricity mix achieves a high 'Green Score' – which often occurs overnight.

This shift will allow cost savings within KPN's electricity purchasing, while also facilitating its shift to net zero emissions. Through its connection, the battery management system – provided by EnergyNXT – can be configured to optimise both the Green Score and energy prices, with sufficient access to data in decision making.

KPN's initial study is currently underway using a 230kWh Nickel Metal Hybrid battery installed at a single telephone exchange to support fixed-line operations in Amersfoort. Rather than installing a fixed-line network to allow network access to the battery, which will allow operations to be managed and findings to be assessed, KPN has adopted a wireless network due to increased simplicity and minimal disruption through deployment.

The data collected will also be used as a minimum viable product for KPN's data service hub, which aims to provide more accurate modelling and forecasting of consumer energy characteristics. The project will run through 2021, with any success likely to propagate throughout many of the company's server locations across the country.

For KPN, the energy demand for its telephone exchanges is fairly consistent and only varies slightly on a seasonal basis as cooling required to prevent data centres from overheating. But for other companies with different requirements, the flexibility that such battery projects can provide can allow the value of battery projects to be tailored to specific operations and maximised in all cases. With KPN preferring the use of wireless networks for deployment, it has demonstrated that such networks can be crucial to allowing organisations of various sizes to deploy clean energy pilot projects as part of their internal decarbonisation efforts.

However, there are many examples of Battery Storage units that can be installed in a home to serve the same purpose the larger grid-scale units perform on the main electricity grid. Here, they store energy during quiet periods of demand and can release this in an optimised manner, either to the grid or to the battery owner. For utilities, these batteries enable them to make the best use of renewables, including rooftop solar installed at the home and larger grid-scale resources.

For example, while the household sleeps, the battery can be charged using available wind power. The morning rush, when the occupants get ready for the day, can be powered solely by the energy in the battery. Once the occupants have left, this battery can be replenished using solar and wind to serve the evening demand once the occupants return home.

This requires a great deal of coordination between the utility's main power generation assets, the batteries in these homes, and devices like smart thermostats and household heating, ventilation and air conditioning (HVAC) systems. Connected at scale, many thousands of homes can be controlled by a utility system to make sure it can use a far higher amount of low-cost renewable electricity in its energy mix, which will have enormous environmental benefits.

While the bulk of energy storage will continue to be in the form of 'front-of-the-meter' utility-scale plants, residential storage offerings like the Tesla Powerwall are set for a dramatic 500 per cent growth in adoption between 2018 and 2024, with 6.6GWh set to be distributed across Europe.[11]

This will be partially driven by the cost reductions being seen in lithium-ion battery manufacture, but the uptake in the installation will depend on the rate of return available for customers when feeding electricity back into the grid. This depends on three things:

1. Purchase price: the time and price of purchased electricity for charging.
2. Feed-in volume: how much electricity is sold back to the grid over a given time.
3. Payback tariffs: the price grid operators pay for batteries to absorb or release energy.

11 Wood Mackenzie, Europe Residential Energy Storage Outlook, 2019

Use case: integrating fast-response batteries into grid services markets

While the purchase price depends on how 'smart' the battery is in optimising purchase decisions based on live electricity prices, feed-in volume and payback tariffs depend on which market the battery system can compete in. Because of their reduced scale, residential storage is unable to compete in markets like the grid-scale capacity market, where premiums are available for guaranteeing a large amount of available battery storage at any given time.

The markets where residential batteries are currently competing are the day-ahead and intraday markets (with Norway's Nord Pool being an example, operating in 18 European countries including the Nordics and the Baltics), where electricity is bought or sold ahead of time based on inexact forecasts for supply and demand. The closer one gets to the time of use, the more accurate the forecast is, the more frequent the charge/discharge cycles of the battery, and the more revenue available to the system. For any batteries competing in these markets, their ability to do so is more to do with regulation and network capability than the technology itself.

Taking this one step further, however, there is the Balancing or Frequency Response Market, which must keep the frequency of the grid's electricity within an acceptable range to prevent blackouts due to sudden and unexpected changes in demand/supply.

This market accounts for smaller variations in electricity. Electricity systems are designed to withstand small fluctuations but, to keep within safe limits ancillary services are needed to keep a reasonable equilibrium. For instance, the European grid operates on an alternating current (AC), with a frequency of 50Hz. If supply drops below demand, this frequency falls, with the opposite happening if supply rises compared to demand. The system itself can typically withstand a +/- variation of around 2Hz before a blackout occurs.

To stay within this range, a frequency response is needed. Balancing markets are split into 1st, 2nd and 3rd Control, based on the speed of response, although only 1st Control is appropriate for batteries, with the capability to both absorb excess generation and supply power in times of shortage.

Electricity systems are designed to withstand small fluctuations, but to keep within safe limits ancillary services are needed

For Frequency 1st response, high prices are paid to suppliers for the amount of available ancillary capacity they can provide or absorb, nearly instantly, at any time of day, similar to the capacity market, while they are also paid for the amount of electricity they end up feeding into the grid.

Systems of large 'inertia' are often slow to ramp up/down their generation for this market, which is why agile batteries are becoming such a popular choice in bridging that gap as they fire up. There is a big market for these service providers, as they help the grid operators to keep the grid load balanced. Batteries are beginning to replace older technologies, such as gas-fired 'peaker' turbines, and these batteries are enabling quicker adoption of renewable energy.

Ireland's 'DS3' market[12] is a good example of the revenues available for enhanced fast frequency response (FRR) providers, where revenues for electricity provided are multiplied by 3 if a system can respond within 0.15 seconds.

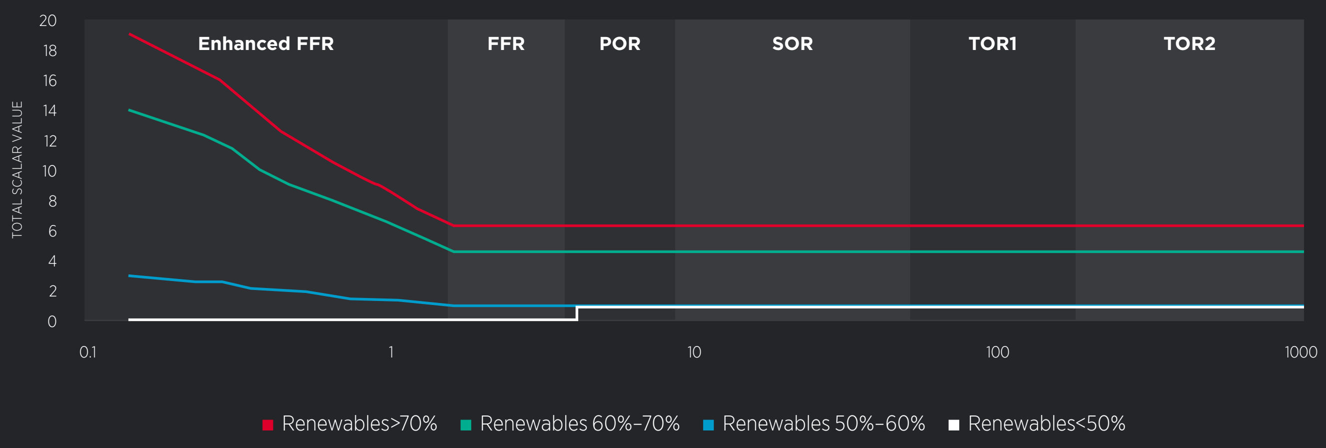
This 0.15-second response time is dependent on the sequence of events, from the over/undersupply in the grid to the point of response from the battery.

Naturally, this speed relies on rapid communication and decision making from each storage system, creating a need for fast and guaranteed connectivity between devices, which may be more feasibly achieved using mobile networks than by relying on household internet. Low latency 5G technologies will prove to be a crucial enabler.

This is compounded by the fact that several of these market places have requirements for devices to be available for use nearly all the time – DS3, for example, states a service availability of 97 per cent for battery owners to get the full remuneration rate.

While incorporating residential batteries on an individual basis is relatively impractical for these markets, if aggregated into virtual power plants (VPPs) then the greater amount of capacity in a diversified portfolio will be attractive for system balancing. As resources are pooled together, the amount of data transfer required increases in tandem, while the need for low-latency remains high.

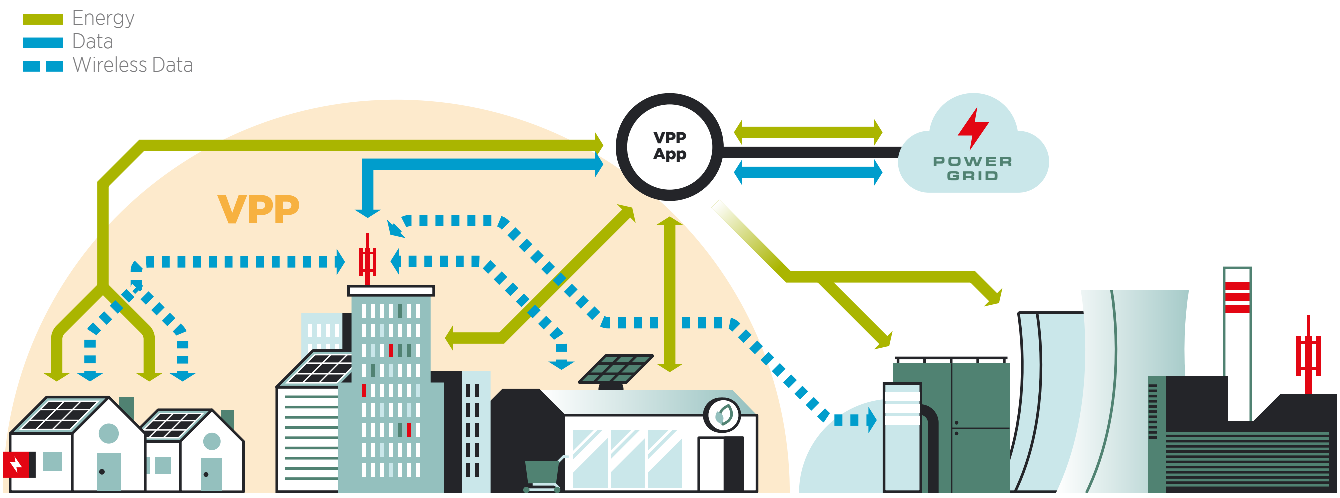
Revenue multiples for fast response storage in Eirgrid's DS3 Programme, Ireland.



12 Eirgrid, DS3 Programme, 2020

Virtual Power Plants (VPPs)

Virtual Power Plants



This is the point where the third main trend comes into play. Virtual Power Plants (VPPs) are the next evolution from the traditional centralised power station model. Using cloud-based orchestration technologies connected via mobile networks and the internet, several different DERs can be aggregated into a single VPP and treated as if it were a single 'virtual' unit – which can collectively rival the largest fossil fuel generation assets.

Pooling resources into a single supply system also provides access to a more diverse range of resources. As more energy consumers shift to become 'prosumers,' who also generate or store their own power through residential solar panels, batteries or even electric vehicles, the number of 'nodes' available for such VPPs increases.

Any collection of DERs can be aggregated in this fashion, but most current examples focus on using Demand Response (DR) technologies as the basis. Put simply, DR requires a two-way communication between the energy supplier and the consumer.

The largest challenge here is in the transmission of data and electricity. In early VPPs, efforts have been focused on AI, with Neural Networks running optimisation problems to calculate the cheapest way of supplying 100 per cent of electricity demand while using as much of all the available resources as possible – whether that is a few solar panels on a home's roof or an entire solar farm.

In this case, the utility will also use many cloud-based tools to forecast its future demand, and if it sees it might face an energy shortage – due to cloudy weather affecting solar production, for instance – it can incentivise its customers to change their demand. This means the utility does not have to make use of expensive, fossil fuel-based emergency capacity – like gas peaker plants.

In commercial settings, this might mean installing meters and controllers on large industrial appliances, so their operation can be remotely synchronised to suit the incentive program the utility offers. For consumer homes, this might mean a smart thermostat being triggered to heat or cool a home at the most cost efficient or environmentally friendly time – all without the end-user being inconvenienced.

Use case: digital twinning using larger data to simulate new energy scenarios

One of the key features of SES, often overlooked, is that the wealth of data processing can be used in hypothetical virtualised scenarios to trial different ways of distributing low-cost, decarbonised energy across networks of various scale.

As a model can be built with more and more elements, systems can be modelled more accurately, and informed decisions can be made that maximise the efficiency of energy distribution. For both virtual and practical systems, a wealth of connected sensors allows more data to be collected and forecasts to fall more accurately in line with supply and demand characteristics in a certain region. Wireless connectivity is essential to this data collection.

The key example is smart meters. In their current iteration, rather than controlling smart devices, the bulk of these primarily operate as monitors of consumption. Nonetheless, their implementation can allow more tailored data about an individual's consumption habits, rather than grouping them in with grid-level data.

But smart meters are far from the only sensor that could be used to monitor consumer habits in real-time. Use of weather monitors to predict the output of renewables, consumer proximity to homes, as well as traffic data are among sources that can be collected to minimise the wastage in energy consumption and optimise grid conditions to match real-time and future demand.

Through aggregating all such data in large service hubs, real-time information can be compiled to generate a 'Digital Twin' of an area, where the system can be analysed in a granular approach, rather than as an entire entity. Live three-dimensional models are currently being developed to feature components such as electric vehicles, domestic batteries and generators and turbines.

With requirements for low-latency and large quantities of data to reliably connect devices that are often not stationary, developers of these systems are currently trialling 5G mobile networks for interconnection of devices. Virtual dashboards are therefore able to show the energy network's main features and model a live 5G data connection to key assets.

With this Digital Twin simulator system generated, virtual tests can be run with greater accuracy, allowing project developers to learn by simulation and build up more advanced business cases for investors. In terms of infrastructure, renewable energy projects are relatively capital intensive, and demonstrating that generation output can all be satisfied locally means that there is less risk of redundant infrastructure or wasted finance.

One such project, where a 5G-powered Digital Twin has been developed is the Orkney 5G Centre in Scotland, which entered operation in April 2020, led by Heriot-Watt University's Grid facility and supported by the Scotland 5G Centre. The project aims to capture the supply and demand characteristics of Orkney as the islands reduce their carbon emissions and ramp up renewable power generation, as well as other decentralised infrastructure.

With the islands generating 120 per cent of their own electricity needs, largely through clean technologies, this testing model "is the ideal testing ground for principles that could be applied on a larger scale elsewhere," according to Gordon Ross, innovation strategist at Heriot-Watt University, who identified that "the future of energy is going to be defined by smart, distributed networks, and micro-grids."

In reference to the project, Heriot-Watt chief entrepreneurial executive David Richardson said: "Our digital twinning system will demonstrate how Orkney's new energy network will operate, what the different component parts are, how people can interact with it and collaborate to create a genuinely democratised energy system."

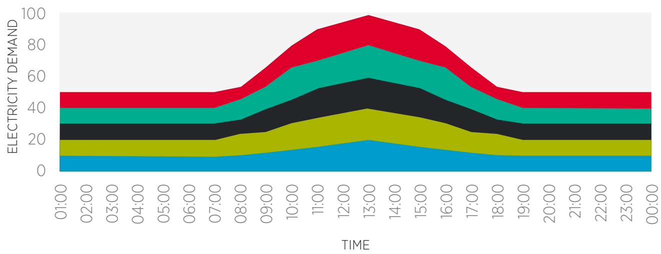
While one side of this solution is maximising the availability of renewable power, the other is about shifting demand peaks to minimise the instances where demand for renewables outweighs supply. In commercial hubs like ports, for example, where multiple businesses may ramp up demand at a given time, complementary peak shifting throughout the ecosystem of the area means the overall area will be serviced by clean energy for a greater proportion of the time.

Within a VPP, risk is defined by the ability of the system to maintain a constant energy supply to its customers. Data must be transferred to assess the systems operational characteristics and to maximise the returns from any available capacity across the VPP's network of resources.

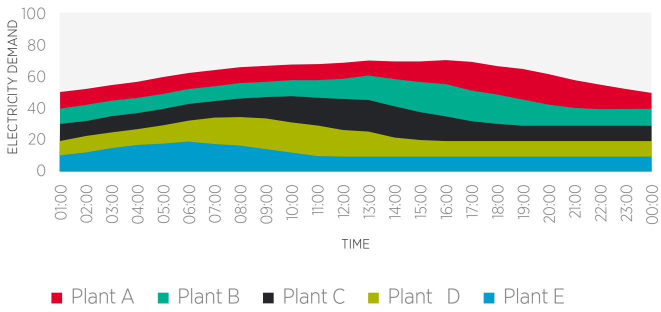
Early examples of this, including those seen in California and China, have focused on using fixed-line communication. However, as utilities look to improve the capability of their VPPs, using wireless and mobile communication will allow access to a wider range of generation assets to places where fixed-line installation is not practical. Machine-to-machine communication can allow wider access to these VPPs by providing the automatic collection of generation data, communicating the capacity and pricing, and enabling payment.

This has two primary benefits. Firstly, it will mean access to more types of energy market. More generation assets mean more power and a larger amount of capacity which can be harnessed at any given time – meaning rapid response markets can be accessed, as VPPs surpass barriers for minimum capacity requirement.

Demand surge without smart load shifting



Suppressed peak power demand with collaborative load shifting



Secondly, it can provide access to locations poorly served by fixed-line communications, widening the geographic distribution of the energy system. This, in turn, means the system becomes more resilient to local weather patterns, with a diverse portfolio of generation assets also limiting exposure to extreme climate-related events damaging individual assets. In terms of market access, this can allow VPP operators to provide electricity capacity with a higher percentage of availability, although the transmission system needs careful management.

Use case: decentralised, self-healing grids to keep blackouts small, safe and short

To reach climate targets rapidly, a wealth of new electricity transmission infrastructure will have to be developed. With this, the safety and security of the system cannot be overlooked. As technologies become electrified through the energy transition, the risk and consequence of electrical outages increase in parallel. It is of paramount importance these faults are prevented where possible and identified rapidly when they occur to minimise disruption.

Unpredictable events that disrupt transmission are often unavoidable; the electrical grid will always be at some risk of outage due to weather, equipment failure, wildlife, human error, or even sabotage. The frequency of these events is also increasing as a result of climate change. The UK has seen a 320 per cent increase in major storms over the past 5 years, while wildfires in California are substantially increasing in both scale and frequency over recent decades.[13,14]

Consequences depend on the magnitude, cause, location and duration of the fault. In places like Texas in the US, for example, electrical failures from powerlines (often caused by weather storms) have caused 4,000 wildfires in the past three and a half years, while downed lines, if not disconnected, pose a significant threat to human life.[15]

In high risk residential areas and dry woodlands, it is essential that faults are detected and that circuits are opened to disconnect powerlines almost instantaneously to keep the fault and any consequences localised.

While these systems aim to limit any immediate damage from the fault, accurate identification of the location is necessary to minimise the response time for emergency services and maintenance crews in the repair process. Knowing where to precisely find the fault, instead of having to check the entirety of a line from point to point, means repairs can begin much quicker.

Smart protection systems are being developed by companies like Efacec using both ‘selective blocking’ or ‘synchrophasor’ technologies to coordinate different nodes throughout the system, which measure the voltage properties of distribution.

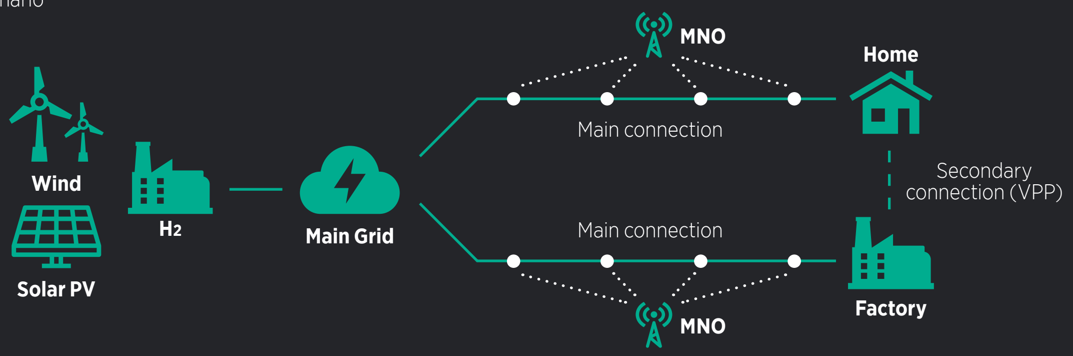
These approaches compare values between incremental points within the network. If values vary significantly from those expected over time or between locations, then precautionary shutdowns can be imposed to prevent catastrophic failure.

Communication speed is paramount to reduce the time of fault identification, and current radio skimming methods cannot provide in-depth analysis of system performance. With synchrophasor approaches, in particular, a continuous stream of data being sent to operators is likely necessary with low latency requirements that are currently only available with 5G technologies.

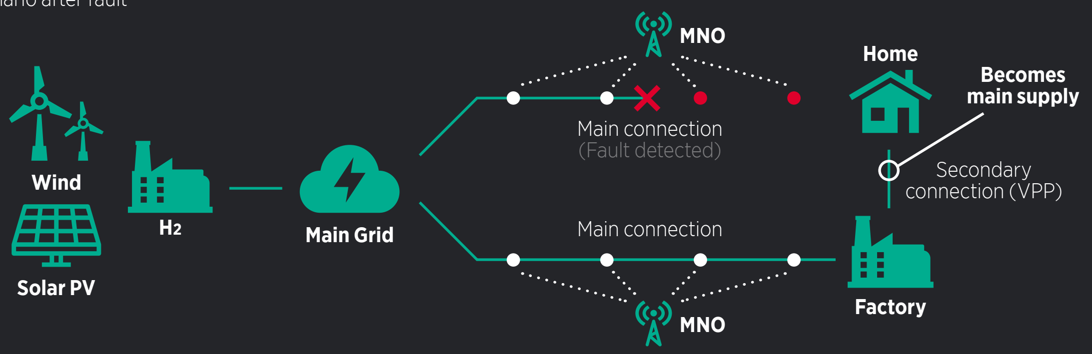
As technologies become electrified through the energy transition, the risk and consequence of electrical outages increase

13 Swinton Insurance, 320 per cent INCREASE IN Major UK STORMS FROM (2010 -2014) TO (2015-2020)
14 NASA’s Earth Observatory, Six trends to know about fire season in the western U.S.
15 Texas Wildfire Mitigation Project, How do power lines cause wildfires? [Online]. 2014 https://bit.ly/3b1kT7b

Ordinary scenario



'Healed' scenario after fault



With access to high speed, wireless networks, which can be powered through outages using battery energy storage, these mechanisms can operate through rapid device-to-device communication between the nodes in the system.

In a decentralised system using distributed energy resources, transmission can also be operated more flexibly and rerouted so transmission 'self-heals' when faults occur, minimising the extent and length of any disruption in the area. Projects like SliceNet in Portugal, Efacec, EFA and Altice Labs are hoping to prove 5G technology can be deployed in a system that can identify faults more rapidly and 'self-healing' will allow for minimal homes to be disrupted.

Through current iterations of fault location, isolation and service restoration (FLISR) technology, the minutes of customer interruption have been reduced by as much as 51 per cent, with the number of customers interrupted falling by up to 45 per cent. The frequency of interruption events also fell by up to 58 per cent, while the number of miles travelled by service trucks was significantly reduced, as grid operators deployed maintenance teams more effectively.[16]

While this offers utilities an option to employ a private, low-latency network to ensure communication, the use of public mobile networks presents the opportunity for such grid management to be used at any point in the network, also covered by an MNO.

16 U.S. Department of Energy, Distribution Automation, September 2016

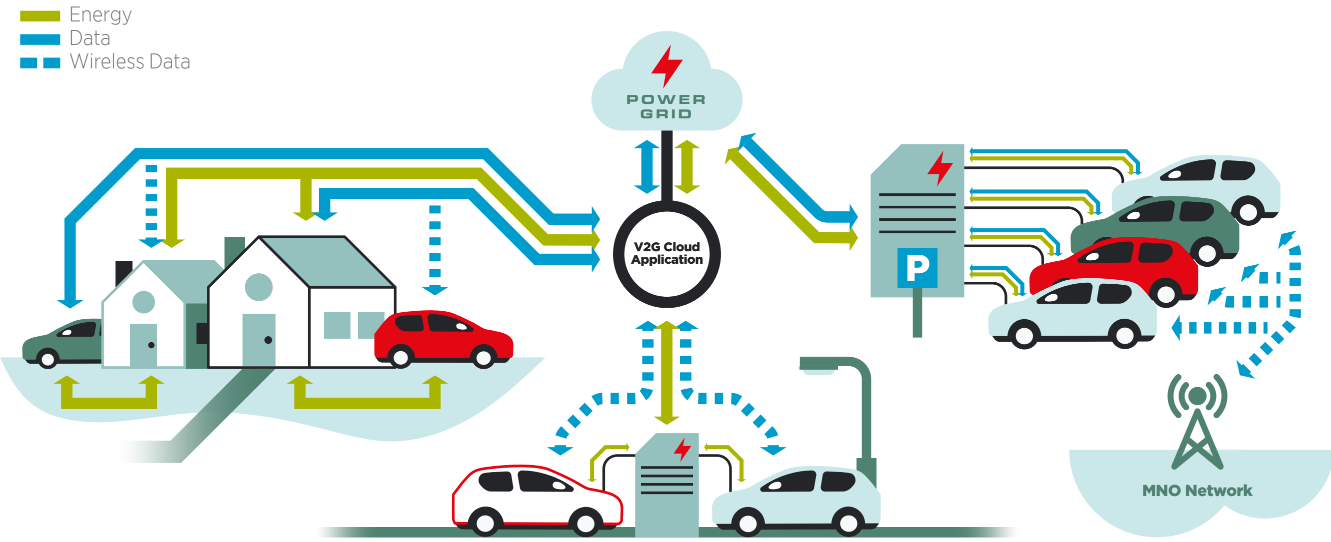
Vehicle to Grid (V2G)

Currently, most people understand VPPs to consist of more commercial DERs than consumer ones, but this is changing. The shift of consumers to 'prosumers' that both generate and consume energy is seeing more homes equipped with DERs like rooftop solar, battery storage, and DR capable appliances. With a rapid acceleration in EV adoption, the inclusion of these mobile batteries brings the opportunity for Smart Charging (which falls under both DER and DR classifications) as well as the fourth main trend – Vehicle to Grid (V2G).

The shift towards EVs is one of the most achievable decarbonisation goals. The number of EVs on the roads is forecast to rise 14-fold in just 10 years, with 116 million expected to be in global operation in 2030, bringing a combined battery capacity of over 7TWh.[17] When plugged in and sufficiently charged, these EVs can be aggregated as part of a dynamic VPP to serve as a battery that balances the electricity grid.

Some anticipate the annual electricity to charge EVs could exceed 1,100TWh by 2030 – roughly the same as from Europe's entire industrial sector.[18] To ensure a mass of consumers arriving home and plugging in their cars does not cause rolling power outages, charging infrastructure needs to be implemented to control and optimise EV charging times based on local grid conditions. Brownouts or restrictions would be extremely detrimental to EV adoption, so it's important to ensure these vehicles can be charged in an optimised fashion. Mobile networks will be vital for the secure connectivity required for V2G to be adopted at scale.

The role of vehicles in a SES



17 BloombergNEF, Electric Vehicle Outlook, 2019 - https://about.bnef.com/electric-vehicle-outlook/
18 IEA, Global EV Outlook, 2019

Early uptake has focused on pushing the technology to market with 'dumb charging' infrastructure, where a car is essentially charged in the same way as a mobile phone. But both cost of ownership and grid-wide electricity demand will be slashed significantly by the emergence of smart charging technologies, where charging is managed based on live electricity grid data. The only way this can be managed is through a secure and increased level of connectivity.

To increase smart EV adoption, this charging infrastructure must also be developed to allow for home charging. Tesla's Supercharger network is the best example of this market power but remains exclusive to Tesla owners due to the required smartphone applications, as well as the proprietary plug that connects the car to the charger.

Smart charging aims to track consumer energy habits, and then manage the charging of their vehicle to optimise energy consumption against renewable supply. For example, rather than charging a vehicle at 8pm when electricity usage is typically high, the system can make use of hours in the early morning when renewable electricity can account for a larger share in the energy mix.

From the consumers' point of view, this also has benefits in terms of cost. Electricity prices, like with any other commodity, follow supply and demand dynamics, and by capturing lower prices, users are able to save up to €80 per year in charging costs.[19] With the installation of smart chargers being approximately €550, a payback time of around 8 years is similar to what has been deemed as acceptable within the residential solar market.

19 Indra, Indra Smart Charger Data Sheet

Use case: supporting the exponential growth of smart EV charging

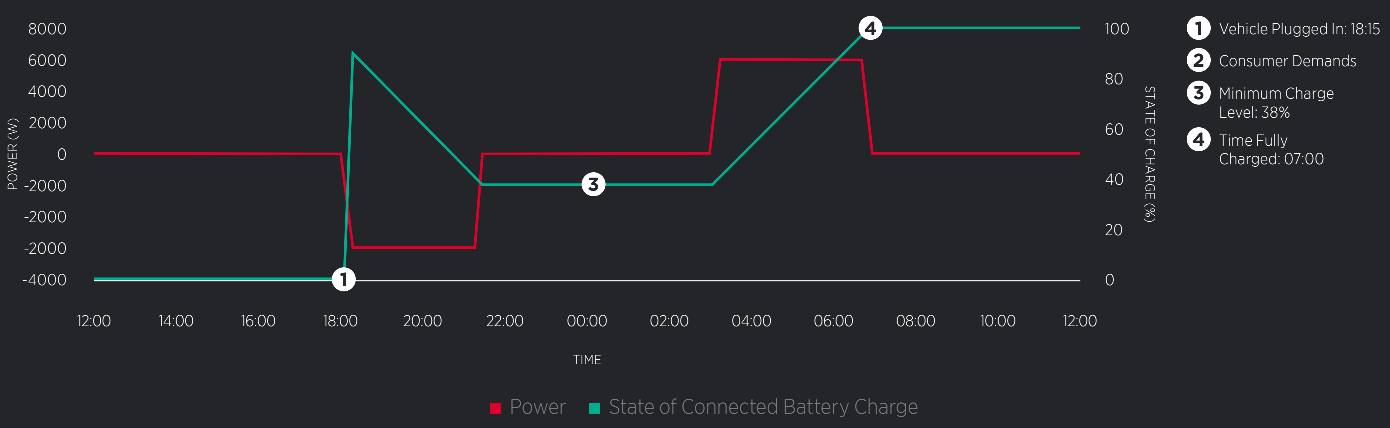
Cloud connectivity is required to manage purchasing decisions and the flow in and out of the vehicle's battery, based on real-time electricity statistics. Currently, V2G and smart chargers usually rely on a consumer's home broadband network, which makes sense when users are on fixed rates tariffs. In this case, the connectivity incurs no additional cost compared to the data cost through a 4G connection, which would likely exceed €1 per month.

However, as the market scales, charge points will become pieces of critical national infrastructure. If V2G applications are to be used to help balance the electricity grid or to replace the need for fast-response fossil-fuel generators, they need to be reliable. Home broadband connections can't be relied upon for this, and MNOs will be called upon to provide mission-critical mobile networks.

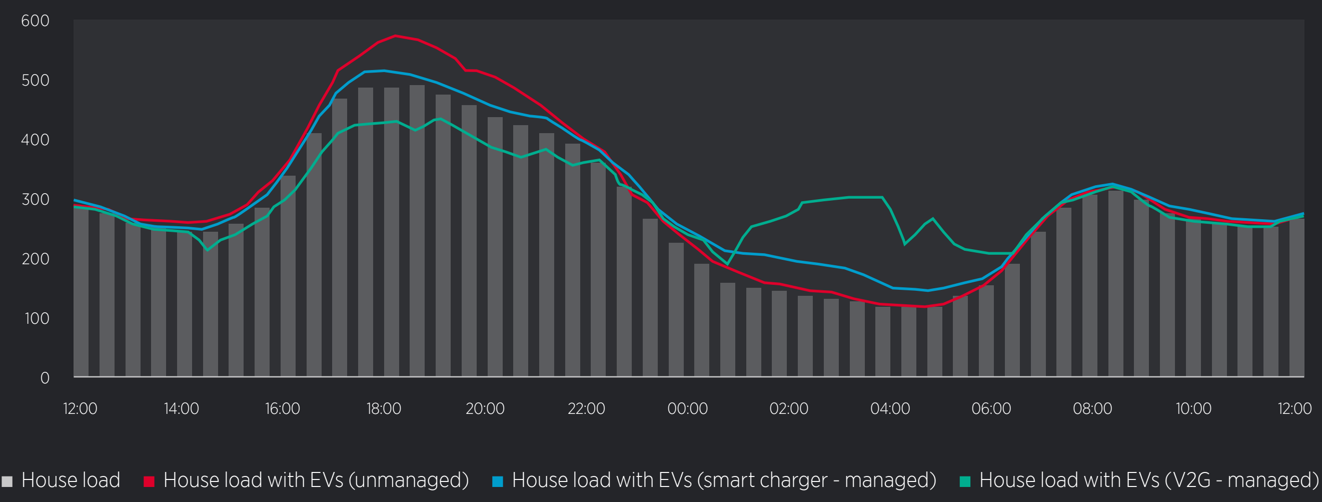
Significant security protocols will have to be put in place to ensure close to 100 per cent availability if V2G is to be part of the first response to events like power outages. The speed at which the EV's battery can respond to these events, by rapidly absorbing or supplying electricity, also determines how much revenue is awarded to the EV owners by grid operators.

To compete within this market and provide guaranteed availability, companies like Indra in the UK have identified it will be necessary for smart charging operators to physically harden their connectivity through local 4G or 5G networks to allow a form of foolproof backup network access to the increasing number of devices installed across the electricity grid.

Vehicle-to-grid example charge/discharge schedule



Impact of V2G on household electricity demand



For MNOs, the inclusion of 4G and 5G small cells in charging units also opens up opportunities to use the new V2G infrastructure as repeaters to extend the reach of their mobile networks. There is arguably no better place for such a device than on the outside of someone's house to help expand 5G coverage.

One of the key opportunities in this market is within the emerging market for car sharing, with companies like Car2Go offering flexible vehicle renting schemes. If the ownership of the battery shifts to a company, then the cars' batteries can be aggregated into a dedicated VPP. Early trials of such schemes have used AI to forecast the demand for rental cars and used the batterie's capacity to feed into the grid when not in use. By doing this, research has shown sharing companies can access an additional 7 per cent of net profit, which could rise to 12 per cent if battery technology continues to advance as expected.[20]

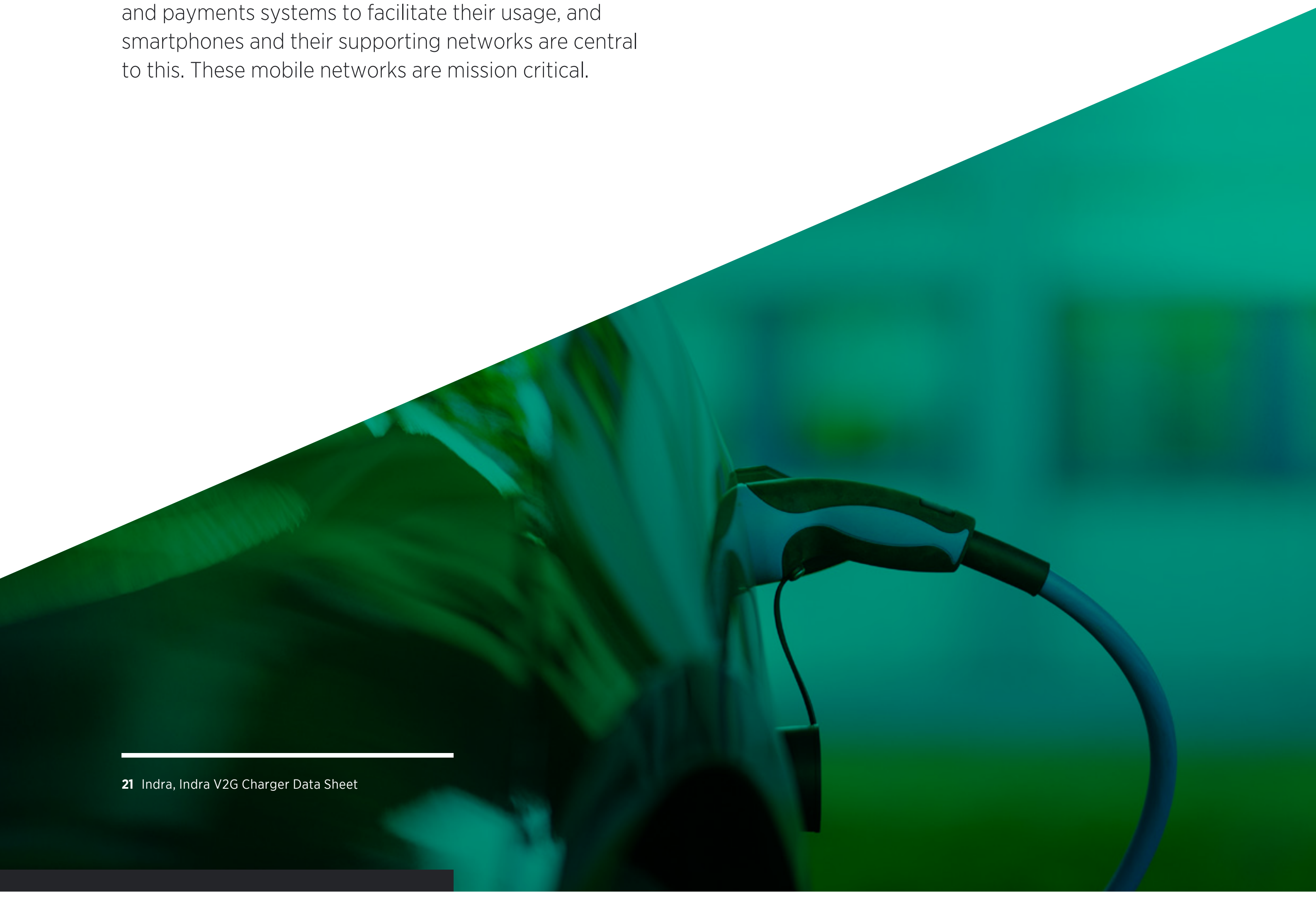
If the ownership of the battery shifts to a company, then the cars' batteries can be aggregated into a dedicated VPP

20 Powertac, Smart Charging and Virtual Power Plants, 2015

Research also suggests the increased flow of electricity in and out of a car's battery may be less damaging than keeping the battery stored at full capacity for long periods, inferring smart charging will lower the maintenance costs of EV ownership.

In addition to smart charging, V2G charging is also starting to become increasingly attractive to consumers, with the possibility to sell the stored electricity in the car's battery back to the grid at times of high demand. Because of the increased complexity in the equipment, V2G installation costs are currently close to €6,000, but these are falling. With the average payment to the consumer often exceeding €400 per year, attractive returns for consumers could be achieved by 2023 if appropriate support is seen for early infrastructure development.[21]

There is a huge nascent market surrounding the adoption of V2G charging infrastructure, particularly in the home, as well the public networks at workplaces or parking complexes. As these V2G-powered VPPs emerge, they require business applications and payments systems to facilitate their usage, and smartphones and their supporting networks are central to this. These mobile networks are mission critical.



21 Indra, Indra V2G Charger Data Sheet

Use case: tracking the dynamic nature of an EV battery-swapping network

As vehicles transition from gasoline and diesel to electricity, passenger cars are becoming an increasing part of the utility business model. While the batteries within these vehicles have largely been explored for use by the consumer in V2G charging, if mindsets are changed around battery ownership then battery swapping could present a wealth of challenges and opportunities for both the automotive and smart energy industries.

The concept of battery swapping alleviates one of the largest barriers to the uptake in electric vehicles – charging time. Currently, even the most rapid EV charging station takes at least 20 minutes.[22] With modern EVs being designed on 'skateboard' style platforms, vendors such as Canoo, Rivian, Nio and Williams are exploring the idea of swapping stations, where batteries can be replaced regularly, in as little as 3 minutes.

There are some significant barriers to this approach when it comes to defining who is accountable in the eyes of insurers if a battery fails and causes a car collision, or when a warranty claim is made. For this idea to take off, it will require a huge change in mentality from car owners. Imagine if you had to swap out your engine for one of unknown age every time you went to refuel a petrol or diesel-powered vehicle.

One of the key possibilities, however, is for battery swapping to be included within "lease-and-swap" networks. Fisker and Canoo are among manufacturers that have both recently launched plans to distribute vehicles through "flexible leases" in a subscription format, which could bundle things like road tax and insurance into one package which takes into account the risk of battery failure.

This could similarly be incorporated through Tesla's scheme of selling insurance alongside vehicle ownership. Chinese companies like Nio and BAIC are similarly aiming to sell batteries and vehicles separately to accelerate the EV penetration in China – and then expand into the rest of the global market.

BAIC already has 187 battery-swap stations across the country and plans to expand this to 3,000 by 2022. The company offers an all-you-can-swap deal to owners of its BJEV model for $60 a month. Nio offers a similar deal where users can rent additional batteries for $10 per day to swap in themselves.

Even if these technologies only account for a small percentage of the vehicle market, through fleet leases for instance, as the global electric vehicle market scales to reach 140 million units sold by 2030 then monitoring the movement and stock of each battery at different swapping locations will be essential, and will require mobile data solutions for operators to manage.

If combined with V2G technology, for example, the batteries at each swapping location could be used as a form of energy storage for the electricity grid, but the location and availability of capacity will need to be accurately monitored and reported to system operators via wireless connectivity and Cloud Computing environments. Research has shown car sharing companies can access an additional 7 per cent of net profit from electricity sales on top of their existing rental revenues, which could rise to 12 per cent if battery technology continues to advance as expected.[23]

22 Podpoint, How long does it take to charge an electric car? [Online] https://pod-point.com/guides/driver/how-long-to-charge-an-electric-car
23 Powertac, Smart Charging and Virtual Power Plants, 2015

Microgrid Trading

On the subject of supporting infrastructure is the fifth main area central to decarbonisation. Microgrid Trading concerns energy trading among members of a microgrid, which is a small and often independent energy grid that has a focus on resilience and self-sufficiency.

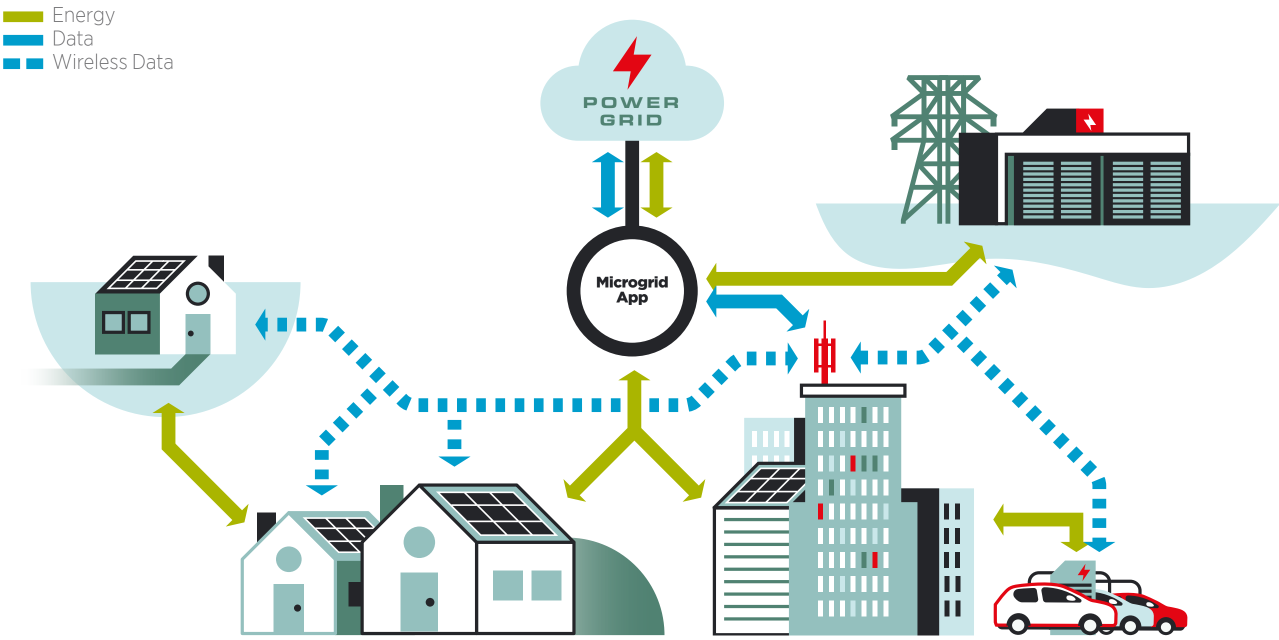
Currently, transmission systems are blind to where producers or consumers are physically located. All electricity fed into the grid is pooled into a centralised system and then redistributed, meaning producers of solar power in the south of the country could be powering a factory in the north.

Decentralised microgrids using DERs can be deployed to minimise the distance between electricity generation and consumption, reducing both the cost and losses associated with transmission. Through a smart energy system, where the output of distributed energy resources can be tracked alongside live consumer demand within a microgrid's domain, locally sourced renewable power can be guaranteed.

Microgrids are more commonly found in commercial settings, where a single customer requires emergency backup capabilities for mission-critical business applications. Production lines and data centres are good examples of microgrid candidates, but large enterprise parks and hospitals, where a lot of real estate footprint can provide a lot of rooftop solar capacity, are also ideal.

Neighbourhoods are also excellent candidates for microgrid adoption, but these will differ from today's microgrids by having multiple customers or users. Collectively, the homes in a street or the houses in a village could be pooled together using rooftop solar panels to generate electricity, battery units in the home to store it, and other decarbonisation initiatives such as ground-source heat pumps and insulation.

How energy is traded between microgrid participants and central power grid



Use case: reducing need for grid upgrades by decentralising microgrids

One of the key challenges facing the entire energy sector is the rate at which electricity demand will increase. With continued economic development as well as the penetration of technologies like electric vehicles and electric heaters, global demand for electricity will nearly double between now and 2050.[24] With the share of renewables rising from 27 per cent to 85 per cent in this time, with resources that generate electricity in patterns that don't follow demand, there will be significant periods where generation levels are more than triple those of today.[25]

Anticipating this rise in production, grid operators are having to address the fact transmission lines will need to be significantly upgraded to handle a surge of capacity installations. However, decentralised smart grids may provide savings in both cost and efficiency, using mobile networks to manage a household-to-household energy trading system, preventing the need for long-distance transmission.

Transmission options generally trade off lifetime cost against the losses through wasted electricity between production and consumption. In the UK, electricity distribution losses account for 8 per cent of electricity generated, varying between 3.1 per cent to 10 per cent for the individual District Network Operators. While this naturally accounts for a similar per cent in lost revenue, losses on the power networks are also responsible for approximately 1.5 per cent of the UK's greenhouse gas emissions.

Historically, reducing this figure has relied on using more powerful transmission, such as high voltage direct current (HVDC), which has losses of around 3 per cent per 1,000 kilometres, compared to overground cables with a figure closer to 7 per cent. However, the increase in cost between the two is a substantial drawback for grid operators: overhead lines cost between £2.2 million and £4.4 million per kilometre through their lifetime, while HVDC connections cost between £10.2 million and £24.1 million per kilometre.[26]

Decentralised smart grids may provide savings in both cost and efficiency

24 IRENA, Global Energy Transformation: A Roadmap to 2050
25 IEA, Fuels & Technologies, 2020
26 IEA ETSAP, Electricity Transmission and Distribution, 2014

Either way, it is either relatively expensive or inefficient to transport electricity over long distances. However, if electricity can be consumed close to the source of production, gains are made in upgrade cost and efficiency simultaneously.

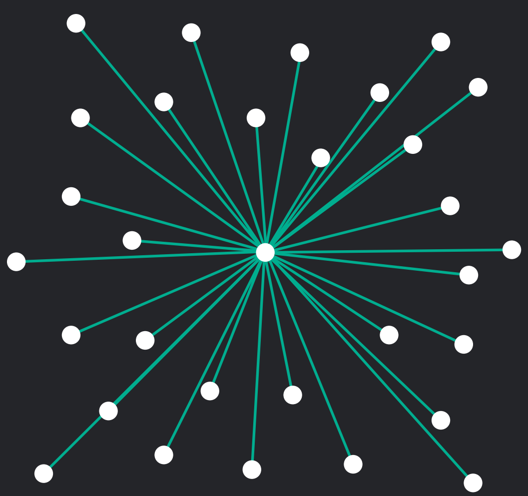
Part of this will include minimising the use of battery storage, which, while necessary to account for the intermittency of renewable production, still incurs energy conversion losses of around 20 per cent due to the process of converting from AC voltage to DC for storage in the battery, and then back to AC for use in the home.[27]

By using a system where nearby homes share energy with each other to balance local energy harvesting and demand in microgrids, energy losses within local Alternative Current (AC) lines can be reduced by 64 per cent, while the necessity to implement expensive nationwide grid upgrades is significantly reduced.

This will involve a household-to-household trading system, which is likely to use blockchain-based ‘smart contracts’ where the point of generation and consumption of each unit of electricity can be tracked and directed – and then the bill between households and the utilities can be settled.

For such microgrids to be as inclusive as possible, this will demand significant volumes of real-time data transmission across areas that may not always be reliably served by fixed-line broadband. Wireless networks such as LTE and 5G provide a key opportunity to optimise the deployment of such smart microgrids and facilitate cost and efficiency savings on a national level.

Centralised



Decentralised

27 Huang et. Al., Minimizing transmission losses in smart microgrids by sharing renewable energy, 2016

This microgrid would have a connection to the main electricity grid both to import and export energy, for example if the home's batteries were full and the sun was still shining. The external connection to this 'islanded' microgrid is always helpful in emergencies or periods of unusual weather, but the goal is to try and create as self-sufficient a microgrid neighbourhood as possible.

But because the usage of each home differs, there needs to be a way to share electricity between the households. This is where the trading technologies take effect. One home can 'sell' surplus solar output to another home with a current need for electricity, or top up a depleted battery or EV.

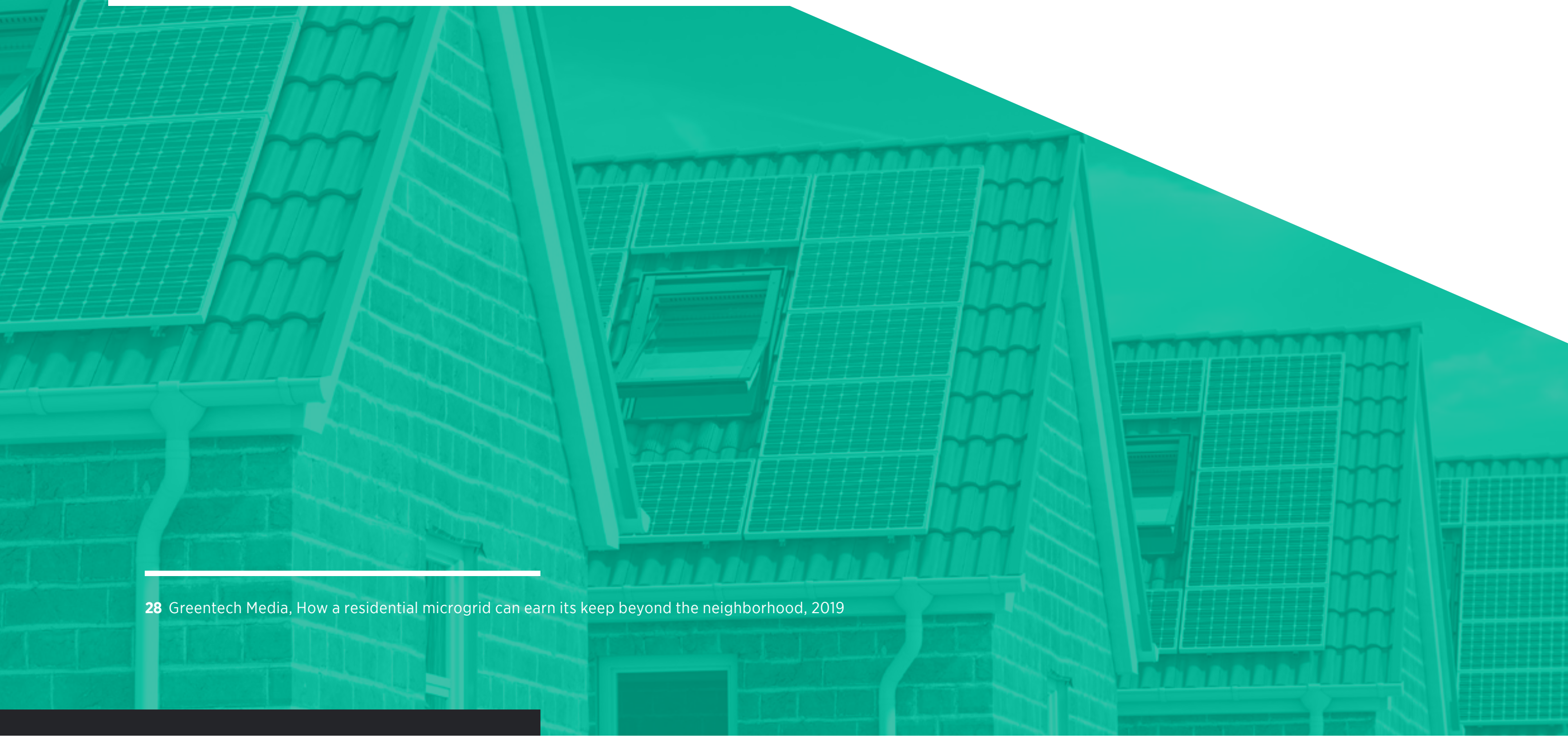
A list of these transactions needs to be kept so each home can be credited for the energy it produces and billed for the energy it takes in from its neighbours or the national electricity grid. Similarly, each home needs to be able to tell its neighbours its available capacity and expected needs, as a microgrid such as this can only work if all participants are working in unison.

This requires smart meters in each home, as well as a Home Energy Management System (HEMS) that can coordinate the battery and solar panels, and likely control the HVAC system and EV charging too. These will require a robust wireless connection, linking them to an orchestration system hosted in a cloud platform, which can connect the utility business systems with the technology vendors that supply the equipment in play.

These microgrids can be incredibly complex systems, but the computing technology to operate them is available today. Similarly, utilities can begin viewing their customers as assets – it is clear certain microgrids could be configured as VPPs. These assets could then support other nearby microgrids too.

If the point is reached where enough self-sufficient microgrids have been installed, decarbonisation can turn its focus to solving the high-capacity needs of the industrial sector, where sectors such as steelmaking and aviation are among the most challenging. There have been very promising tests using blockchain-based technologies to track the trading between members within these microgrids, and between the microgrids and the national electricity grids.

Currently, microgrids have been installed in industrial, military, and commercial environments, but residential deployments are now being explored. Several research and development microgrids are active, with Alabama Power's Smart Neighborhood of 62 homes being one of the best documented examples.[28] Partners include the US Department of Energy, and the Electric Power Research Institute (EPRI). In Europe, residential microgrids have centred around the energy trading application, whereas in the US, the nature of many rural communities has prioritised energy islanding and redundancy.



28 Greentech Media, How a residential microgrid can earn its keep beyond the neighborhood, 2019

Use case: allowing energy democratisation using blockchain smart contracts

While smart and renewable energy systems are a huge part of decarbonisation, there is a growing school of thought that technology alone cannot be the silver bullet to fix climate change. Societal change is needed. One of the most promising signs comes from a shift of consumers, who simply buy and use electricity from the grid, to prosumers, where the user also generates some level of their demand themselves. Enabling such behaviour is key to changing larger consumer habits surrounding both energy usage and production and a shift towards an 'energy democracy'.

One of the key arguments in support of allowing the development of small-scale assets is that of computing. Personal Computer (PC) technology advanced so quickly that mainframe computers were made largely redundant, and if Google had just focused on large-scale computing then there would not be cloud networks today.

For clean technology, this necessitates the growth of technologies such as rooftop solar power, home battery storage, and even hydrogen production through small-scale modular electrolysers. While the EU has no specific legislation to promote prosumers, feed-in tariff schemes have meant over one million households in both Germany and the UK now have installed solar panels.

By collating these resources into virtual power plants (VPPs), local purchasing of electricity and household-to-household trading can be enabled by the use of blockchain and smart contracts between prosumers and consumers.

In such a system, excess electricity produced by a household will be sold locally, with prices defined based on supply and demand to match that available from the grid. Beyond this, excess production on a community level can be sold to the centralised grid.

Such schemes have been piloted in countries like Switzerland by Quartierstrom and the Water and Electricity Works Walenstadt (WEW), which tested a blockchain project that created a local energy market between 37 homes for a year. The goal was to see how homes that produced rooftop solar electricity could trade with other participants and the role the central grid would play in the process, using a blockchain system to keep track of these transactions acting as a digital ledger.

Through the project, most solar power was consumed locally. Within the winter months of December and January, around 90 per cent of the solar was used by the generating home itself, or its neighbours. In the summer months, over half the generated solar was sold off to WEW.

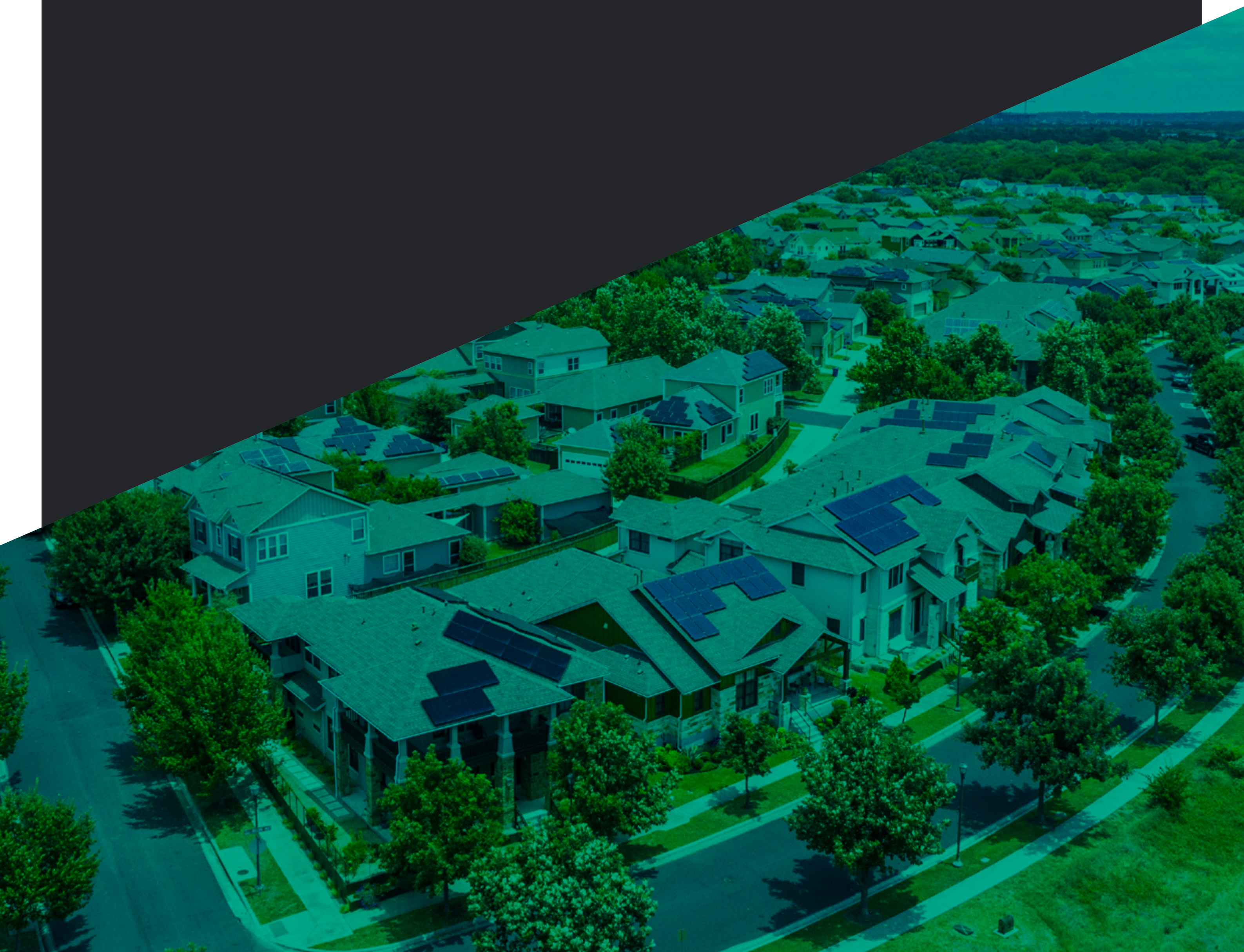
Technology alone cannot be the silver bullet to fix climate change. Societal change is needed

One of the most interesting aspects of the project was the impact it had on consumer habits. With access to their production and consumption data on a community level, there was an uptick in residents scheduling their appliances to run when the sun was brightest. To this end, they became very aware of how the energy market functions, which is a promising indicator for utilities wanting to deploy such projects at national scale. It suggests consumers would understand how such a system would operate, and could change their behaviour accordingly due to price sensitivity.

This increased engagement in the local energy system can be essential to promoting a democratised energy transition. In a more efficient system, smart contract trading between households will reduce bills as well as boost the uptake of residential energy products and community renewables projects – chiefly community solar.

Such information provision, along with production of accurate price forecasts within the VPP, depends largely on the transfer of large amounts of data. With a data platform active on top of the 'microgrid' system, full characteristics can be viewed at a granular level, with the potential to further include things like the location of EVs and other mobile forms of energy storage and demand.

Alongside this, while the system aims to decrease total energy consumption, the infrastructure needed for the project consumed 4 per cent of the total produced energy. As systems start to scale, this efficiency becomes increasingly important, and the need for wireless communication with low energy intensity becomes essential – something 4G LPWA and emerging 5G technologies are well-placed to do.



Introduction: Regulatory Landscape

For the first time in history, EU member states are pulling in the same direction for renewable energy legislation. In November 2019, the Clean Energy Package[29] (CEP) directive was finalised giving the region a top-down set of guidelines that should enable the transition to decarbonised energy grids.

SES have two main areas to address in terms of regulations. The first are those regarding the wireless networking technologies that connect these systems to the internet and their supporting applications. The second is the specific energy network regulations that govern how they can be connected to energy grids, and these are the bigger concern.

On the MNO side of things, the roadmap for future regulation is clear, and many MNOs are already deploying 5G networks for testing and evaluation. Some MNOs have launched commercial 5G networks too, and the industry is confident it fully understands the regulatory environment.

For those developing SES technologies, the regulatory roadmap is significantly more complex, and this lack of clarity is a major barrier to adoption for SES deployments. The CEP directive should significantly change this for the better.

Currently, the DERs outlined in the second chapter already encounter these problems. As SES are going to be more complex, they are more likely to be hindered by a lack of regulatory clarity because of their two-way communication and position in mission-critical applications.

Similarly, in nascent stages of commercial development, global stakeholders have continuously struggled to define regulations for battery storage and decide whether or not it should be treated as a generation asset (like solar or wind power) or given a standalone classification.

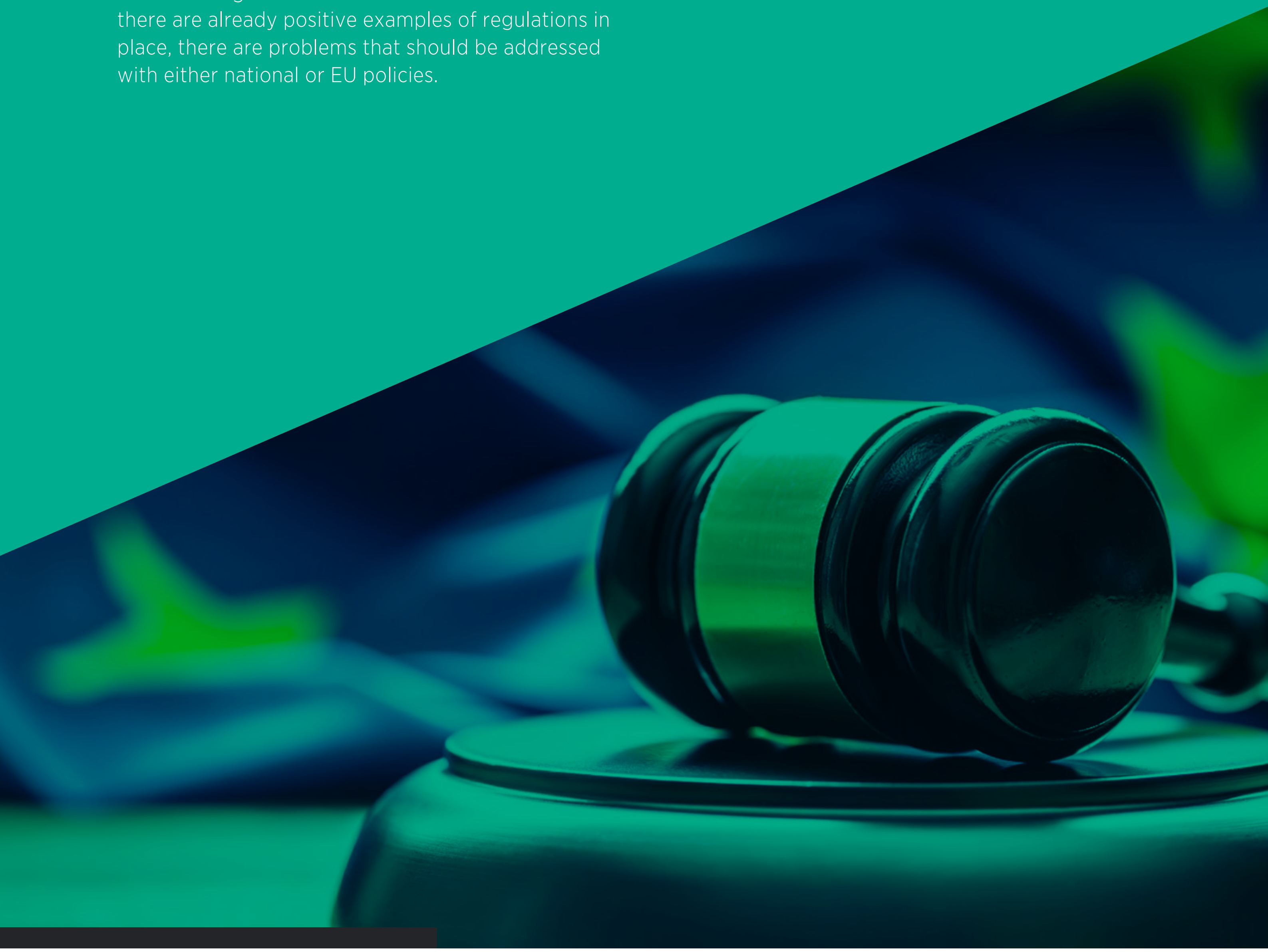
29 European Commission, Clean Energy for All Europeans Package, 2019

Overview

This section aims to identify examples of current regulations or national policy benefiting SES. Technical standards do not drive adoption. Government regulation, industry advocates, and influential vendors do. To this end, there will be no discussion of the standards themselves.

There are already many examples of national regulations that help lay the groundwork for SES adoption. However, the different approaches of each of the EU member states should be harmonised at the EU level, to create a better business environment. This would accelerate the implementation of SES technologies and the environmental benefits that SES enable.

The following sections aim to demonstrate that while there are already positive examples of regulations in place, there are problems that should be addressed with either national or EU policies.



The switch to Electric Vehicles

There are purchasing incentives for EVs in 12 EU countries, which usually take the form of a tax credit or bonus payment. In the UK, a discount of up to £3,500 is available,[30] which could rise to £6,000 in coming months,[31] and in Germany there is a €4,000 bonus for battery and fuel-cell vehicles.[32]

Also looming are proposed bans on internal combustion engines (ICE) inside major cities and countries. Norway plans to ban the sale of new ICE vehicles in 2025, as does Sweden by 2030,[33] while the UK hopes to do the same in 2035, and France plans to do so in 2040.[34] The Netherlands is proposing an ICE ban in 2030,[35] while Athens, Madrid, and Paris all plan to ban diesel vehicles from their roads in 2025.

Several schemes aim to restrict areas of cities to ICE vehicles within certain hours of the day as a means of reducing air pollution. EVs are exempt from these 'clean air zones', which serves to create another purchasing incentive for consumers. These zones are common among capital cities in Europe but have been slower to be rolled out to other municipalities.

30 Gov.uk, Low emission vehicles eligble for a plug in grant, 2020
31 Electrek, UK drivers may get £6k taxpayer-funded incentive to switch to electric cars, 2020
32 BMWI.de, Government policy for Electric Mobility, 2016
33 NY Teknik, New government – now a ban on petrol cars awaits, 2019
34 Quartz, Nine countries say they'll ban internal combustion engines. So far, its just words., 2018
35 Bloomberg, Electric car subsidies have rendered Renaults free in Germany, 2020

Charging hardware standardisation

Many of the proposed sales restrictions are not yet active legislation, meaning there is room for them to slip or be ignored by future political regimes. Enshrining these proposals as law would be a welcome first step, which could then be expanded upon. SES like V2G would benefit greatly from any increase in EV adoption.

Another example is the different types of plugs for EVs. In Europe, the two main approaches are CHAdeMO, which is generally favoured by the Japanese automakers, and CCS, which is used by most European and American manufacturers. Tesla has its own plug design too, and there are two different generations of both CHAdeMO and CCS to contend with.[36]

In its current iteration, the CHAdeMO protocol is far better suited for V2G charging, and with regulations steering companies like Nissan towards CCS for its Ariya EV model, growth in vehicles available for V2G over the next few years could be stunted.

Something as seemingly trivial as the type of plug could have significant knock-on effects for years to come. Any consumer confusion here is detrimental to their purchasing decision to switch from ICE vehicles to EVs. Given the long lifetime of vehicles, the impact of confusion here is going to be compounded over time.

Standardisation at the regional level could enable faster and smoother adoption of EV charging stations and V2G, as well as remove one of the persistent barriers to purchasing – the concern over where consumers will be able to charge their EVs. Carrying around an adapter cable is a short-term solution, but automakers could be compelled to standardise and agree upon a universal design.

Just as the EU addressed the waste incurred by the different ways of charging mobile phones, it could also address the problem of differing types of EV plugs and charging technologies.

Harmonisation would improve the consumer experience and reduce waste, but most importantly it would accelerate the adoption of EVs and hasten decarbonisation, as well as reducing urban air pollution. Each potential barrier to consumer adoption that can be removed through a top-down regulatory or incentive-based approach is a win for climate change and carbon emission reduction.

36 Rethink Research, Google Maps EV filter highlights just how fractured charging is, 2019

How consumers profit from green decisions

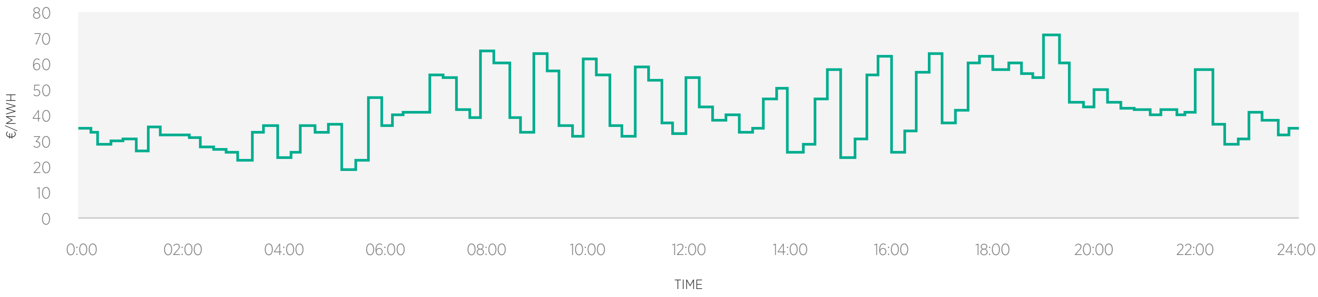
The various feed-in tariffs and net metering initiatives are good examples of current successful approaches, but again are ones that could be considerably expanded. These schemes track the amount of electricity generated by a home's rooftop solar panels and then fed back into the main grid. They require smart meters to track the electricity imported and exported by the home, but also upgrades from the utilities and electricity distributors to accommodate this two-way traffic.

Utility efficiency schemes have proven popular, where local or national governments provided tax incentives or financing schemes designed to improve the energy efficiency of consumer homes. Adding new insulation, installing solar panels, and upgrading to more efficient appliances were the most popular examples, but now EV chargers and associated tariff schemes are emerging too.

Consumer awareness campaigns have had some success too, and smart meters play an important role here. The in-home display shows live and historic usage, which influences consumers to reduce their consumption, turning off lights and appliances, and seeking out 'vampire loads' on their energy usage. In time, these displays will evolve, with the help of smartphone apps, to enable DR applications, which can be used to balance the energy grid according to the available renewable generation capacity.

Why price fluctuations should be kept

Typical price pattern intraday market



The cost of new technologies is still too high and poses a significant barrier to entry. Maximising the uptake of small-scale systems like residential solar or home battery storage depends on the number of consumers who are willing to take on the initial capital cost. Increasing this uptake can be done by either subsidising the purchase cost for the buyer or by decreasing the pay-back time through increasing the revenue generated by the system.

This is especially prevalent for systems that can both buy and sell electricity from the grid, including V2G chargers and home electricity storage. The margins made are dependent on fluctuations in electricity prices. If a system can buy electricity at €20 per MWh on the German Intraday market at 5.45am when power supply is high and demand is low, then can sell it at 8.30am when demand ramps up, it may be able to sell it for over €60 per MWh making a 200 per cent gross profit.

As the penetration of renewables increases, the extent of this price fluctuation, and thus the business case for smart storage systems, increases in tandem. With wind power providing excess electricity overnight, negative electricity prices are becoming increasingly common in Europe. Through a slump in demand through COVID-19, European countries on average saw negative day-ahead power prices around 0.8 per cent of the time during the first nine months of 2020 – a rate nearly 4 times higher than seen between 2015 and 2018.[37]

While these negative prices need to be managed carefully and not used to penalise developers of renewable power systems, the variation in electricity prices is essential for smart energy systems.

Regulatory approaches that must be avoided in relation to this include the UK's Targeted Charging review, which aims to reduce uncertainties in forward-looking charges by keeping electricity prices in a narrower band. Providers of V2G charging like Indra Renewable Technologies have identified that such rulings could reduce consumer revenues by as much as 70 per cent.

While the revenues from load-shifting and selling electricity to the grid could have potentially brought £500 to the customer each year in the previous system, the figure is now below £200. The cost of installation of a V2G charger is normally in the range of £4,000 to £5,000, and the resulting pay-back periods of over 20 years will dramatically reduce the number of interested consumers.

37 EnAppSys, Negative UK spot power also dampens Dutch, Belgian prices, 2020

Removing market barriers for small-scale generators

One of the key opportunities presented by new mobile technologies is the ability to aggregate energy storage systems to provide ancillary services to the grid. These services help balance any variation in power generated from renewable power sources like solar and wind. As these variations are not entirely predictable and can occur suddenly, regulation can incentivise a fast response within these systems. In Ireland's DS3 energy market, for example, revenues for electricity provided are multiplied by 3 if a system can respond within 0.15 seconds.

The benefit of connected systems in these markets is also compounded by high availability requirements. For instance, the DS3 requires a system providing first frequency response to be available to the grid for at least 97 per cent of the time, otherwise the rate of revenue is reduced.

Data hubs have proven to be important first steps towards embracing SES. In Estonia, Elering launched its Estfeed platform,[38] which acts as a hub, collating data from smart meters, energy market prices, weather station data, and the electricity grid, and then acting as an interchange with third-party applications.

This data can then be accessed by companies and organisations, with the best example being WePower's use of the data platform to model Estonia's energy market and demonstrate how transactions could be made using the Ethereum blockchain to record who produced what power, and then who bought it and then settle payments accordingly.

Denmark's Energinet launched a platform called DataHub in 2013, which had similar goals, while Dutch MNO KPN is currently establishing its own Data Service Hub. As blockchain technologies were not yet mature, that element is absent from Energinet's operations, but the system still collated smart meter and grid data so that consumers were able to sell energy produced by the solar panels back to the Danish grid.

38 Rethink Research, Google Maps EV filter highlights just how fractured charging is, 2019

Regulation standardisation across Europe

The grid-services markets, specifically Fast Frequency Response (FFR) and Intraday, would benefit from regulatory clarity. Currently, the rules and rates vary greatly between EU member states, meaning the renewables and storage vendors competing at a European scale face an overly complicated regulatory environment.

Standardised regulation across Europe will hugely simplify any collaborative approach to the EU's decarbonisation and adoption of renewable resources. With a fixed and clear route to market, a foundation will be laid for Europe's clean technology vendors to reach economies of scale more rapidly and become more competitive in other global markets. As seen through the dramatic 'boom and bust' of the solar sector, fractured regulatory guidance in the current environment makes it increasingly difficult for European majors to emerge in this sector, ceding ground to Chinese and American vendors.

Creating regulations that allow solar, wind, and storage to compete in the same capacity markets and energy auctions would open the door for faster decarbonisation. Similarly, laying the legal groundwork to enable VPPs to compete in the same markets as fossil fuel-based power plants should help exert pressure on those high-carbon resources, leading to their earlier retirement.

Reforms to Europe's carbon pricing market, the EU Emissions Trading System (ETS), to account for more ambitious decarbonisation targets will provide negative pressure on fossil-fuel power generation by increasing prices and accelerating the uptake of clean technologies and SES. Adjusting the energy capacity markets to allow renewables and SES to compete with carbon-heavy approaches is also imperative.

Continent-wide grid participation rules

Harmonised grid participation rules would speed the adoption of new SES, as well as application specific technologies like FFR battery storage. If a set of industry standards could be agreed upon, it would help smaller firms compete in multiple national markets within Europe, as well as enable the largest vendors to target Europe-wide deployments.

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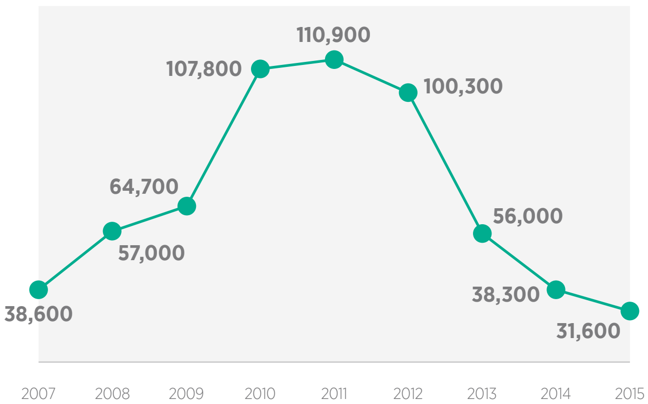
Solar Jobs in Germany



Consistent buyer-side subsidies

While buyer-side subsidies will be needed to increase consumer adoption of smart energy systems, available revenues from these systems also need to be protected. This needs to happen without penalising the revenue available to power producers, and Contract for Difference (CfD) auctions can allow project owners to receive stable revenue, while intraday variations in electricity prices are not reduced. If governments are insistent on protecting consumers from these variations, then the revenue for fast responding energy storage systems must be boosted through generous feed-in tariffs and compensation for high levels of availability to the grid.

Access to open source data

There are a few specific problems that could be addressed with gentle regulation and industry consensus. Perhaps the best candidate is the need for open source data platforms, which should foster cooperation between businesses and governments, as well as enable citizens to engage with the data generated by these SES.

The trend of 'Open Data'[39] has focused on the democratic power that free access to public data can bring, and in the context of nationally important energy networks there is considerable anticipated overlap between the push for Open Data and the adoption of the cloud-computing data platforms that are going to enable SES.

To this end, open source data platforms like Powertac[40] appear to be fundamental parts of the transition to a decarbonised energy mix, which in turn is enabled by the collective power of these data platforms and the resources they control. Every energy asset deployed needs to be connected to such platforms, and wireless mobile connectivity is key to this transition.

39 European Commission, European Data Portal
40 Powertac, www.powertac.org

Smart Energy Systems and decarbonisation

SES will allow us to provide the global population with low-cost, zero-carbon electricity. Each SES installation helps reduce the amount of conventional energy generation capacity that needs to be created by getting more out of the existing capacity through usage and load optimisation.

Once solar and wind power reaches a combined 20 per cent in a country's electricity generation mix, as they have in many countries, technologies such as smart grids and energy storage become mandatory to prevent wastage. Smart grids alone can help push the penetration of renewables from 20 per cent to 70 per cent,[41] and become noticeably effective once renewables penetration surpasses 15 per cent.[42] Otherwise, utilities are required to have gas-fired peaker plants on standby in case of a sudden shortfall in renewable generation or surge in demand.

On a microgrid level, by maximising generation from renewables and optimising demand patterns to create a balanced grid, the efficiency of the power sector can be improved by as much as 35 per cent. Using today's best available technologies and projections for future energy mixes, SES enable an additional 25 per cent of the renewable energy generated to be used in the grid-load.[43,44]

Without SES, there would be a need to build more generation capacity to achieve the same results. By shifting renewable power supply and energy demand through a SES, an overbuild of power generation capacity can be prevented, starting with the abolishment of fossil fuels, before providing cost savings to a renewable-driven power sector.

While the early penetration of SES supported renewable deployments will involve advanced metering infrastructure (AMI), advances in Cloud Computing and AI will result in optimised electricity distribution – reducing renewable oversupply, and forcing carbon-intensive methods of generation into early redundancy.

Smart grids alone can help push the penetration of renewables from 20 per cent to 70 per cent

41 European Commission, Horizon 2020: Testing and Evaluating Sophisticated information and communication Technologies for enabling a smarter grid, 2020
42 Irena, Smart Grids and Renewables: A Guide for Effective Deployment, 2013
43 ITU, Boosting energy efficiency through smart energy grids, 2012
44 i-Scoop, Smart grids: what is a smart electrical grid – electricity networks in distribution, 2019

The primary benefit of this enabling technology comes into play as renewables become a larger part of the global energy mix. The risk of a disparity between supply and demand increases significantly as economies become more reliant on weather patterns for their electricity instead of on traditional coal or gas plants.

Despite the increased need for SES, global investment in electricity grids has fallen for 3 consecutive years, falling 7 per cent between 2018 and 2019 to just under $275 billion per year. Digital technologies accounted for around 15 per cent of this. Transmission grids remain almost entirely centralised and nearly all SES projects are still in the pilot phase while countries continue to evaluate how different technologies can maximise energy utilisation. However, by 2023 it is expected 65 per cent of power, gas and water companies will have invested in edge analytics and Cloud Computing to optimise their assets as SES start to materialise.[45]

A wide range of technology companies and startups claim to have developed products that can provide significant material savings for utilities. Advances in Cloud Computing will continue to drive the evolution of devices from 'connected' to 'intelligent,' and 5G technologies will eventually be included as standard in many designs. Governments, regulators and utilities must help facilitate the adoption of novel assets for grid operators, including non-wired alternatives to machine-to-machine communication within the system.

While bodies like the EU set out directives for a continent-wide target to reach net zero emissions by 2050, the success of SES implementation will naturally fall to national policy. Countries like the Netherlands highlight how considerations must be made for a tailored approach based on national objectives.

45 ITC, Top 10 Worldwide Utilities Predictions, 2019

Case study: the Netherlands

As part of the EU, the Netherlands is aligned in terms of its ambitions to reach net zero emissions. Independent of the EU's net zero directives, the country has published its 2019 Climate Agreement, which sets targets to achieve a 49 per cent reduction in its 1990 emissions levels by 2030, before a 95 per cent reduction by 2050.

Through a drive to improve energy efficiency, the country is on track to decouple its energy demand from its economic growth. Between 2010 and 2019, the country's GDP has grown at an average of 1.34 per cent per year compared to its energy demand, which has shrunk by 1.53 per cent each year over the same period.

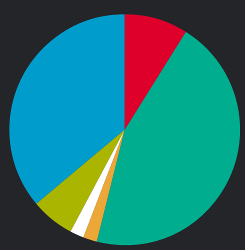
Through this time, electricity consumption in the country has stayed fairly constant, rising from 116.4TWh in 2010 to 116.9TWh in 2019, accounting for between 14 per cent and 16 per cent of total energy consumption. Renewable sources accounted for approximately 8.6 per cent of this. In the context of Europe, the Netherlands' sizeable petrochemicals and natural gas industry remain hard to decarbonise, meaning its electricity consumption per capita is 14 per cent above the EU average.

Moving forwards, however, the Netherlands has been one of the clearest in publishing its strategy to decarbonisation. Reducing emissions in these 'hard to decarbonise' sectors will focus on the country's new Government Strategy on Hydrogen,[46] while the country is set to introduce a ban on the sales of new petrol and diesel vehicles from 2025, which will create a surge in orders for EVs and activity in V2G technology.

The country's grid operator, Enexis Netbeheer, is currently building an IoT-based smart grid, pooling the data from 900,000 connected smart meters. The Intelligent Grids Innovation Program, run by the Dutch Government, is also funding 94 pilot projects aiming to improve grid technology and smart metering.

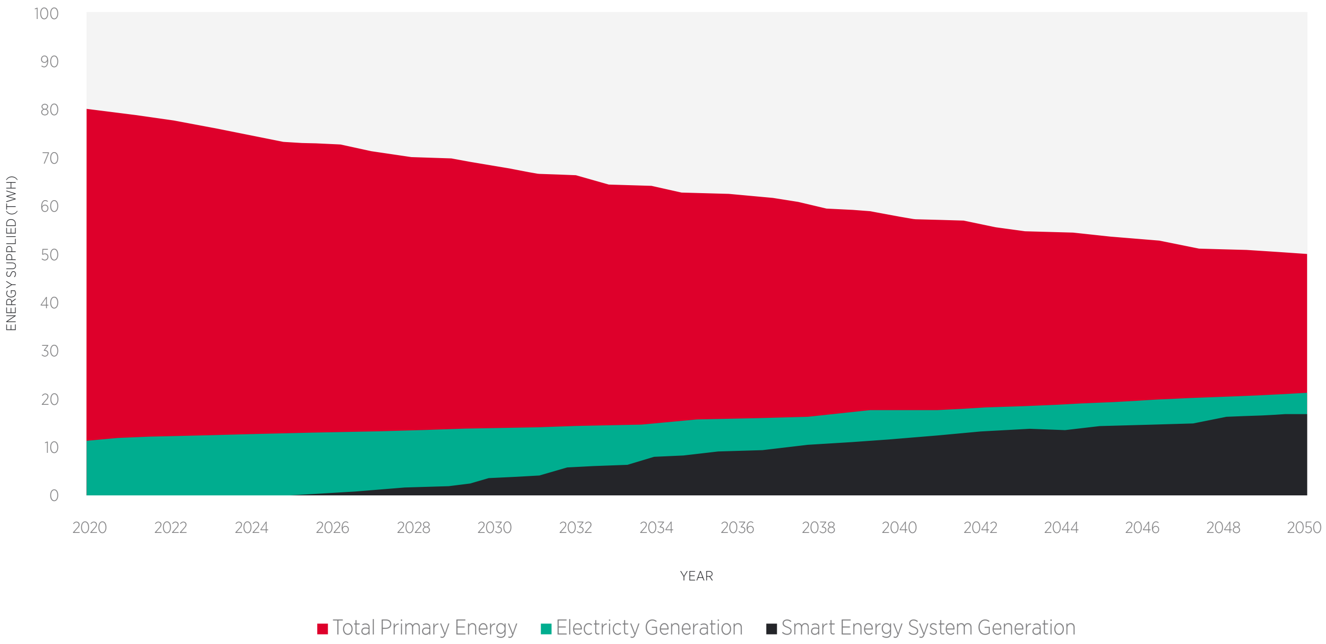
The Netherlands Energy Mix (2019)

Population:	17.28 million
Annual CO_2 Emissions:	150 Million Metric Tons (MTons)
Primary Energy Supply:	824 Terawatt Hours (TWh)
Electricity Generation:	117 Terawatt Hours (TWh)



46 Government Strategy on Hydrogen – Government NL 2020

Penetration of Smart Energy Systems (The Netherlands)



While the Netherlands has placed itself at the leading edge of this market, active SES still account for less than 1 per cent of the electricity grid. Accelerated by a rise in connected EVs and an expansion of 20GW of wind power, electricity generation will account for approximately 21 per cent of the country's energy demand by 2030, up from 15 per cent today. This will then rise to 30 per cent by 2040 and 43 per cent by 2050, following a similar growth curve to solar and wind power in the energy mix.

The share of renewables in this electricity mix will rise from 18 per cent to between 27 per cent and 35 per cent by 2030, according to the country's plan, before it pushes towards full decarbonisation over the following decades. This early penetration will see the share of SES in transmission rise from nearly nothing to 26 per cent of electricity supply, before a huge rise to 70 per cent in 2040 and 82 per cent in 2050 as utilities look to digitalise and maximise returns through the energy transition.

With this level of penetration, SES will handle 176.3TWh of the Netherlands' annual electricity supply in 2050, with efficiency improvements savings 44TWh per year compared to 2019. This level of generation is comparable to that which could be expected from over 9GW of offshore wind capacity at a capital cost of over $25 billion – a massive saving for the country, which can be spent on other decarbonisation efforts.

The other way to look at this is that it prevents the need to generate electricity from fossil fuels. At the Netherlands' current carbon intensity of electricity of 450 Tons per TWh, SES could reduce today's emissions from the power sector by 20.4 per cent and the Netherlands' total carbon footprint by 13.2 per cent by 2050. This equates to 17 million tons of CO_2 each year, the same reduction that could be achieved by removing nearly half of the country's passenger cars.[47]

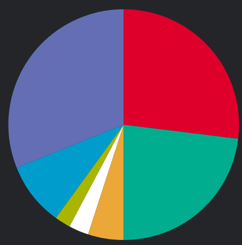
47 EPA, Greenhouse gas emissions from a typical passenger vehicle, 2018

Scaling Smart Energy Systems for global impact

In terms of market development and smart grid penetration, the Netherlands is roughly 3 years ahead of the global average. Using the same approach to development across the global energy landscape, SES can be deployed to significantly reduce global emissions from current levels of 33,100 MTons per year.

Global Energy Mix (2019)

Population: 7.7 billion
Annual CO_2 Emissions: 33,100 Million Metric Tons (MTons)
Primary Energy Supply: 162,194 Terawatt Hours (TWh)
Electricity Generation: 27,004 Terawatt Hours (TWh)



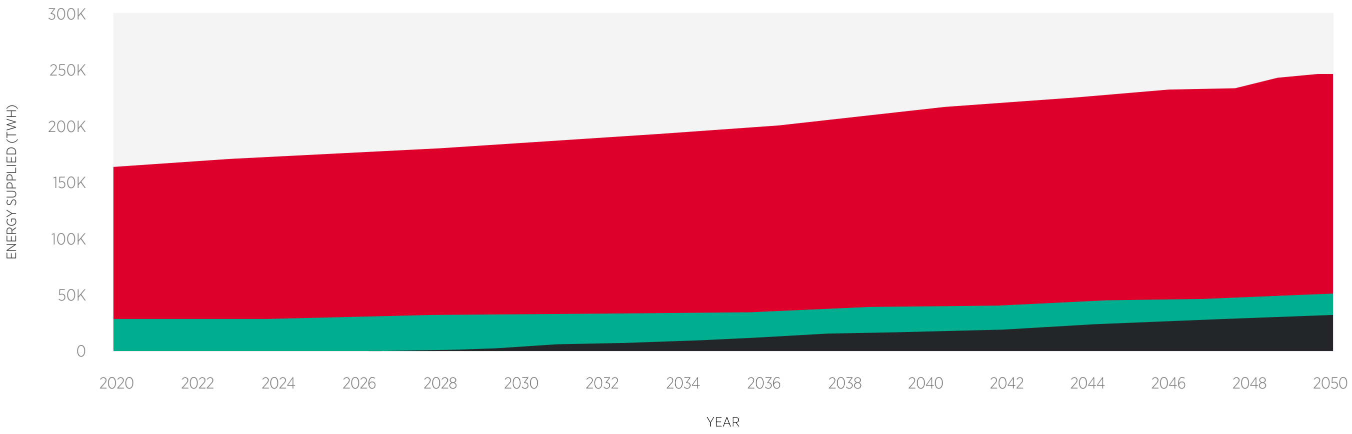
- **27%** Coal
- **23%** Gas
- **5%** Nuclear
- **3%** Hydropower
- **2%** Wind & Solar
- **9%** Biofuels
- **31%** Oil

Unlike in the Netherlands, the current trajectory will see global energy demand increase by approximately 50 per cent by 2050, driven by population growth and urbanisation in developing economies. Electricity demand will nearly double in this timeframe and the share of the power sector in global demand is set to rise to around 21 per cent. With renewable technologies accounting for the bulk of this growth, the penetration of SESwill rise from 0.1 per cent today to approximately two-thirds of electricity transmission.

With the global average for emission intensity from electricity sitting around 475 tons per TWh, this penetration would save 8,500TWh of electricity, which would otherwise be wasted, and over 4.0 million tons of CO_2 every year – more than that released by the whole of Europe.

This approach, however, is conservative and does not align itself with the global ambition to limit climate change to 1.5°C.

Penetration of Smart Energy Systems (Global) - business-as-usual scenario



■ Total Primary Energy ■ Electricty Generation ■ Smart Energy System Generation

Conclusion

The technologies needed for Smart Energy Systems already exist and are being deployed in electricity grids around the world. This report has provided case studies in each of the five main areas of SES and how they can work together.

A new generation of power stations will be created by harnessing abundant renewable resources through decentralised energy generation, along with fast wide-ranging mobile networks, together with powerful cloud computing and low-cost battery storage.

There are already many examples of regulations beneficial for the adoption of SES. However, there should be further concerted efforts to harmonise the approaches different countries and local governments are taking.

If technology uptake and regulatory reform happen swiftly in the coming years, then SES will be a major contributor to efforts to decarbonise not only our electricity systems, but also the global economy as we move away from a reliance on fossil fuels.

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