Executive Briefing

HOW 5G CAN CUT 1.7 BILLION TONNES OF CO2 EMISSIONS BY 2030

Based on extensive industry interviews and detailed modelling, 5G-enabled use cases can reduce carbon emissions in the energy industry by almost 1% by 2030. How - and what - should telcos, the energy sector and governments do to achieve this?

Dalia Adib, Principal Consultant | dalia.adib@stlpartners.com | October 2020
Matt Bamforth, Consultant | matt.bamforth@stlpartners.com
Preface

This document has been authored by STL Partners, an independent consulting and research firm. It is based on extensive research into the impact of 5G on the energy ecosystem and industry, 10 interviews with enterprises across the energy value chain (energy generation, distribution and supply), as well as telco executives. This also included an industry survey with more than 100 participants in both developed and developing markets. The research programme has kindly been supported by Huawei.

Mentions of companies in this document are intended as illustrations of market evolution and are not intended as endorsements or product/service recommendations.

If you find this report of interest and would like to discuss any aspects of the content further, please contact any of the following:

**STL Partners:**
- Dalia Adib: Principal Consultant and Lead Author, dalia.adib@stlpartners.com
- Matt Bamforth: Consultant, matt.bamforth@stlpartners.com

**Key contributors:**
- Ian Mash: Director - CTO Carrier Business Group, ian.mash@huawei.com
- Mark Easton: Principal Consultant - CTO Carrier Business Group, mark.easton@huawei.com

This report is part of a series of research on the role of 5G in accelerating digital transformation. Other reports within the portfolio include:

- 5G regulation: Ensuring successful industrial transformation
- $1.4tn of benefits in 2030: 5G's impact on industry verticals
- Curtailing carbon emissions – Can 5G help?
- Recovering from COVID: 5G to stimulate growth and drive productivity
- 5G’s impact on manufacturing: $740Bn of benefits in 2030
- 5G’s healthcare impact: 1 billion patients with improved access in 2030
- How mobile operators can build winning 5G business models
Executive summary

5G can contribute to solving the climate change challenge: Close to 1% reduction of total global emissions in 2030

Our forecast estimates that 5G could reduce carbon emissions by almost 1% in 2030 (over 250 million tonnes in that year), primarily by accelerating the use of wind and solar energy over fossil fuels. This impact over the period 2020-2030 is equivalent to almost 1.7 billion tonnes of emissions and approximately 64 coal-fired power plants’ emissions in one year, or half of all of Canada’s emissions in 2018.

Figure 1: Changes in global electricity consumption by fuel due to 5G (cumulative 2020–2030)

The assumptions and analysis were informed by interviews with energy and telecoms industry representatives, as well as a survey of more than 100 practitioners worldwide to validate the benefits of 5G. This research confirmed that 5G will be needed for use cases that leverage its key capabilities (low latency, high bandwidth, high device density and reliability) to ensure real-time decision-making at scale. One example being using 5G devices to allow wind turbines to automatically change blade direction based on external factors. These use cases will be an integral part of the future energy ecosystem, where everything will need to be connected — appliances, vehicles, energy networks, trading platforms, distributed generation sources, wholesale markets, renewable energy assets, etc. The scale of this is unprecedented and will be impossible to support across all scenarios using today’s network technologies.
Reducing carbon emissions is a key goal for governments and societies globally to mitigate the impact of climate change and limit the increase of global average temperatures. Global accords and initiatives, such as the Paris Agreement in 2015 or the European Commission’s 2030 climate and energy framework, are setting (binding) targets for nations to curb emissions and increase the use of renewable energy sources.

It is therefore in the interest of all parties to achieve this goal and for telcos to work closely with governments, technology companies, regulators and the energy industry to ensure 5G can contribute solutions to the climate change challenge as predicted.

**Ensuring progress: A call for telecoms, energy and government to cooperate**

Although 5G can provide real benefits to reducing carbon emissions, this impact is not guaranteed. It will require an optimal environment where technology is fit-for-purpose and accessible by the right stakeholders and key parties working together. The key actions for telcos, governments and energy ecosystem players can be summarised in seven principles below. The energy industry must recognise the potential that telecoms brings in advancing climate change strategies and cooperate by exploring new business models. **Governments and regulators** can support this by removing barriers which impede realisation and incorporate the role of technology in creating incentives for change.

![Figure 2: Seven principles for accelerating progress](source: STL Partners)

**Technology**
1. Ensure access to 5G in the right places
2. Leverage the unique benefits of network slicing

**Government & regulation**
3. Consider the role of technology in parallel with carbon emissions policy
4. Streamline infrastructure planning across telecoms and energy networks

**Telco business models**
5. Apply learnings from internal telco/networks transformation to the energy industry
6. Become active players in the decentralised energy ecosystem
7. Develop appropriate monetisation models

How 5G can impact carbon emissions: A result of many use cases, not one killer app

The forecasted impact of 5G is due to many use cases coming together to make a tangible difference. There is no one application that can substantially shift global carbon emissions, but a combination of
solutions that will help businesses reduce energy consumption, allow energy providers to balance their energy sources and produce renewable energy more effectively.

We found that the 5G-enabled use cases that will accelerate the move to lower carbon emissions will need to impact one or more of these mechanisms:

1. Green electricity generation: increasing the proportion of electricity coming from renewable energy sources;

2. Transition to electricity: moving away from energy that is directly delivered through combustion of fossil fuels (e.g. petrol cars, gas boilers) towards delivery through electricity;

3. Energy efficient consumption: reducing the amount of energy required to achieve the same outcomes, e.g. avoiding unnecessary energy consumption or using it more efficiently.

The below framework demonstrates which 5G-enabled use cases can affect these mechanisms. This report explains the use cases in more detail: why they need 5G and how they can reduce carbon emissions, as well as what actions the telecoms industry, energy sector and wider stakeholders need to do to ensure these benefits are realised.
**Figure 3: Framework mapping 5G use cases to carbon emission reduction factors**

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<tr>
<td><strong>Increasing supply of electricity from renewable sources</strong></td>
<td><strong>Balancing the grid (given variable energy sources)</strong></td>
<td><strong>Accelerating adoption of electric alternatives</strong></td>
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<td><strong>Managing decentralised grids</strong></td>
<td><strong>Making direct energy consumption more efficient (networks)</strong></td>
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<th>5G use cases for the energy ecosystem</th>
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<td>Energy demand and supply management</td>
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<td>Smart grid load balancing</td>
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<td>Other factors (direct network efficiencies of 5G over 4G and general digitisation reducing need for transport)</td>
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<td>5G network efficiencies</td>
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<td>Digitisation &amp; automation</td>
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Source: STL Partners (an explanation for this framework can be found in [this section](#))
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Introduction: Transitioning towards a carbon-neutral world

Carbon reduction targets have been set at global, regional, and many national levels to tackle climate change. The Paris Agreement was the first universal, legally binding global climate change agreement. Adopted in December 2015, close to 190 countries agreed the long-term target to limit the increase in global average temperatures to 2 degrees Celsius above pre-industrial levels. The EU also has a binding target to cut emissions to at least 40% below 1990 levels by 2030, as well as achieving at least a 32% share for renewable energy and at least a 32.5% improvement in energy efficiency.

This report will focus on the way in which technology, in particular 5G, can enable individuals, businesses, the energy industry and governments to accelerate the transition to zero carbon emissions.

This analysis is based on desk research, an interview programme and survey with industry leaders, as well as detailed economic modelling to quantify the benefits that 5G can bring, and the contribution it can make to achieving carbon emissions targets.

A framework for thinking through the carbon emissions challenge

The main mechanisms through which technology (including 5G) can reduce carbon emissions arising from our consumption of energy, fall under one of three categories:

1. **Green electricity generation**: increasing the proportion of electricity generated from renewable energy sources

2. **Transition to electricity**: as electricity becomes greener, moving away from energy that is directly delivered through combustion of fossil fuels towards delivery through electricity

3. **Energy efficient consumption**: reducing the amount of energy required to achieve the same outcomes – either by not consuming energy when it is not needed or doing so more efficiently

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1 United Nations Framework Convention on Climate Change, 2015
2 European Commission - 2030 climate & energy framework, October 2014 (revised 2018)
Figure 4: A framework for outlining the key mechanisms for reducing carbon emissions

1. Green electricity generation
   - More renewable energy on the grid (solar, wind, etc.)
   - Increase renewable energy generation by smaller producers (businesses, consumers)
   - Balance capacity and frequency on the grid as we move towards more variable energy sources

2. Transition to electricity
   - Moving away from using fossil fuels to generate direct energy (e.g. gas for home heating, petrol for vehicles)
   - As electricity consumption increases, managing the strain on existing centralised electricity networks

3. Energy efficient consumption
   - Optimising electricity consumption, e.g. turning off applications when they are not needed or using more energy-efficient appliances / devices
   - Reducing losses in energy networks
   - Removing the need for high-energy consuming tasks (e.g. using virtual conferencing to avoid travel)

Greener electricity generation

Generating ‘greener’ electricity is a fundamental part of any carbon emissions reduction strategy. Energy analysts forecast that it will still take decades for a substantial amount of the grid to be powered by renewable energy sources. The chart below demonstrates the current prevalence of coal and gas in our electricity networks, with some contribution from nuclear and hydropower. By 2030, we will need rapid growth of wind and solar, but it only becomes a significant proportion of world supply by 2040.

Figure 5: Forecasts predict that future electricity generation will come from growth in solar and wind

<table>
<thead>
<tr>
<th>World electricity generation by power station type</th>
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<tbody>
<tr>
<td>Units: TWh/yr</td>
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Source: DNV

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Renewable energy generation must grow enough to meet three challenges:

- Replace current electricity generation from fossil fuels
- Provide electricity to power directly supplied by fossil fuels as these transition to electric power (see transition discussion below)
- Meet future demand arising from economic growth.

Moving from fossil fuels to wind and solar energy presents new challenges for balancing the electricity supply system. Due to the variable nature of these renewables (it’s not always sunny or windy) and our limited ability to store energy (with current battery technologies), the growing dependence on renewables means that supply cannot be controlled to meet demand. New business models enabled by millions of connected devices (washing machines, electric vehicle chargers) will allow us to reverse the market model such that demand meets supply.

Further in this report we describe in more detail how 5G networks will enable the acceleration of greener energy supply by:

- Improving the cost competitiveness of renewables (in particular, by reducing operating costs).
- Ensuring that renewables can contribute to the bulk of our energy needs, by supporting new business models ensuring energy demand across millions of appliances is managed in response to the fluctuating nature of renewables supply.

**Transition to electricity**

The second major mechanism to reduce carbon emissions is transitioning to using electricity as the primary source of energy for applications that currently rely on fossil fuel combustion. The two big transitions are the move from:

- fossil-fuelled cars and trucks to electric vehicles
- gas boilers to electric heat pumps.

Using electricity to power these appliances and processes is more energy efficient than burning fossil fuels and can therefore deliver an overall reduction in energy use and carbon emissions even if the grid is only partly ‘decarbonised’.

However, this will create a seismic change in energy consumption. Taking the UK as an example (Figure 6), the energy used for heating space and water is almost double that used for total electricity consumption in the country. Space and water heating is largely fuelled by gas today. Meanwhile, transport used over two exajoules of energy in 2018. Shifting these to electricity will put unprecedented burden on our electricity networks.
As well as the need to meet demand with supply discussed above, the other consequence of moving away from fossil fuels is that it may be more difficult to keep the electricity grid stable. Historically, turbines from traditional power generation stations have provided inertia, which has helped to maintain a buffer when demand for power changes over a short time. Power station turbines’ rotational inertia effectively absorbs and releases energy in response to fluctuating demand, resulting in grid frequency variations. To keep the grid stable and mitigate blackouts, frequency needs to avoid deviating by more than 1-2% from the target of 50 or 60 Hertz. Removing traditional thermal turbine generation means that solutions must be developed to provide highly-reliable sub-second responses – precisely the type of requirements for which 5G was developed.

5G networks can enable the acceleration of this transition from direct fossil fuels to increasingly renewable electricity by:

- Improving the performance and cost-effectiveness of electric-powered alternatives (for example, by making electric vehicles much cheaper to buy and as convenient to refuel as fossil fuel vehicles through optimised battery lease-and-swap networks)

- Providing high-reliability, low latency connectivity to the energy suppliers and users committed to maintaining stable frequency across the electricity grid

- Ensuring that renewables can contribute to the bulk of our energy needs, by supporting new business models ensuring energy demand across millions of appliances is managed in response to the fluctuating nature of renewables supply (for example, by charging electric vehicles or heating domestic hot water when renewable supply is at its peak).
Energy efficiency

The final key mechanism in reducing carbon emissions from energy use is through greater energy efficiency: reducing the energy required to achieve increasing social and economic outcomes. Projections from energy analysts show that we will need to de-couple energy consumption from economic growth by dramatically improving productivity, optimising use and reducing waste.

Figure 7: Estimates and predictions of world energy consumption by source (1980 – 2050)

This will be partly achieved through measures specifically intended to reduce energy use such as advanced energy controls (e.g. heating or lighting turned off if no activity detected). However reduced energy use will also occur indirectly as a consequence of widescale automation and optimisation of processes in manufacturing, transport, field services, retail, healthcare and other sectors. STL has characterised this as the Coordination Age and set out in recent research how 5G will enable these transformations. These indirect, 5G-enabled impacts on energy use and carbon emissions are not possible to estimate with any confidence but could well exceed the projected impacts we have modelled in this study.

5G networks can enable wider improvements in energy efficiency across the economy in two ways:

- Enabling measures specifically aimed at improving energy efficiency, for example by connecting smart airbricks that optimise ventilation in domestic properties and reduce the energy needed to heat homes.
- By enabling widescale automation and optimisation of processes across the economy with the indirect consequence of reducing the net energy inputs needed to achieve the same level of outcomes in sectors such as manufacturing, transport, field services, retail and healthcare.

These are discussed in more detail in the following sections.
Towards a smart grid: The changing energy ecosystem

The changes outlined above require a fundamental change to how energy is produced, delivered and consumed. We are moving away from a linear value chain model, where supply is generated as needed and distributed through centralised networks, to a connected ecosystem of energy producers and consumers, all of whom may play multiple roles.

This concept of the "smart grid" revolves around using data, combined with analytics and machine learning, to connect disparate ecosystems and enable real-time decision making. These ecosystems will increasingly exist at a local level; domestic consumers, businesses and local governments will generate energy (e.g. through solar panels, batteries, local wind farms, etc.), as well as consume it. Decisions on who provides energy to whom may happen at this scale, but they may also need to interact with other ecosystems. For example, using data on the price of electricity on the wholesale market to determine if and when it makes sense for a prosumer (a consumer who also produces energy) to buy and sell energy.

Figure 8: Transitioning from centralised to decentralised networks

A deep-dive into the role of 5G

Key benefits of 5G in the energy sector

As the latest generation of mobile communication technology, 5G is different from previous generations since it offers more than just an improvement in speed compared to 4G. It is more flexible than previous generations due to its software-based nature and has been designed to consolidate the requirements from multiple use cases, whether this be for ultra-low latency or high bandwidth.
Customers can therefore use its different characteristics to meet different and new application’s needs. 5G’s key capabilities are summarised below:

**Figure 9: 5G’s technological capabilities and their implications for users**

- **Latency**: Roundtrip latency under 10 milliseconds
- **Bandwidth**: Data rates of 100MB/s on average (peak at 20GB/s)
- **Capacity**: Up to 1 million devices per square kilometre
- **Reliability**: 99.999% network reliability
- **Mobility**: Seamless transfer between radio nodes up to 500km/h
- **Battery Life**: Up to 10 years battery life for low power (IoT) devices

Near instant delivery of data to/from sensors enables real-time capture and process automation. Stream high-definition and ultra high-definition video. Carry data from many more sensors enabling a more accurate picture of an asset to be captured. Use 5G for mission-critical applications where failure is not tolerated. Data availability on fast-moving mobile assets – e.g. electric vehicles - without being dropped. Reduce the cost of maintaining devices and improve energy efficiency.

In the energy sector, communications will be a critical foundation to enable decentralised grids and ensure a flexible system of variable demand and supply. This layer acts as a platform on top of legacy infrastructure that has already been built to support the distribution of energy. It is analogous to telecoms networks transitioning to software and virtualisation to create more value on top of the existing physical infrastructure, as well as be more agile and responsive to demand. In energy, the communications layer will create new ways of pooling and managing the underlying energy networks, ensuring both demand and supply can respond to one another.

However, there are still challenges for the energy industry to make use of data:

- **Coverage and access to connectivity**: it is still difficult to collect data, especially given where relevant assets and devices currently “live”; smart meters are stored in cupboards or basements, energy generation plants (e.g. wind farms) are often located in places with limited access to connectivity, those who own the connectivity are not the same as the users (e.g. maintenance companies vs. plant owners, or appliance manufacturers vs. home owners).

- **Data fragmentation**: even where data can be gathered, the diversity in end-devices, connectivity protocols, systems and users without a common way to provision and analyse the data means that the ability to create value from information is limited.

5G will be one of the tools for enabling this foundational technology layer. In some cases, 5G may help to overcome the existing challenges related to data and connectivity. Although it cannot be the answer to IT challenges related to data fragmentation, it can help with coverage. For example offshore wind farms are exploring the ability to set up a 5G network to allow vessels to access broadband out at sea.
More importantly though, 5G has specific characteristics that will be critical for ensuring real-time decision-making at scale, which will help to overcome future challenges:

- **Real-time decision-making**: AI-driven automation will underpin the future energy ecosystem, as different parts interact and information is used to determine when to consume energy, how much to consume, how to provide the energy, which source of energy to use, etc. 5G’s attributes that make it particularly well-positioned to address this need include:
  - Latency: Reducing the time to collect data, share it with relevant parties and send instructions to trigger an automated response;
  - Bandwidth: AI-based decisions need to be informed by copious amounts of data, for example the ability to predict when an asset will break down requires tracking dozens of parameters constantly – wind turbines are today generating data on 10,000 measurements on a yearly basis and this will only increase as the data is used for new use cases;
  - Reliability: For automated decisions that need to be implemented in real-time, 5G will provide the most reliable connection to ensure the decision is transmitted without fail and to continuously monitor that it is implemented as expected.

- **Scale**: The future energy ecosystem will need everything to be connected end-to-end – devices, users, energy networks, trading platforms, distributed generation sources, wholesale markets, large assets, etc. The scale of this is unprecedented and will be difficult to support in all scenarios by only using today’s network technologies. 5G brings the following capabilities to support with this:
  - Capacity: Not only will the number of things connected grow in the future, but the number of sensors associated with each “thing” multiplies; new wind turbines today already have approximately 200 sensors attached to each one;
  - Battery life: Devices in remote areas are difficult to manage and replace, whether across transmission networks or a large solar panel farm, yet this will become even challenging given the exponential growth in the number of devices, therefore it is beneficial to extend battery life for as long as possible to avoid these costs.

**New use cases and enhanced applications**

The capabilities 5G brings unlock new use cases that will contribute to the energy industry and wider ecosystem, ultimately supporting the goals of reducing carbon emissions. Figure 10 highlights some of the potential use cases and the relative importance of the 5G characteristics. These use cases will need to be evaluated at an aggregate level to demonstrate tangible impact on carbon emissions (see next section), rather than as single “killer use cases”.
Figure 10: Energy use cases mapped to 5G characteristics

Figure 11 demonstrates the benefits these use cases can bring – from both an economic perspective (for the relevant enterprise customers) and/or for the environment. We will deep dive on five of the use cases:

- Smart grid load balancing
- Energy demand and supply management
- Drone maintenance and repair
- Automated asset control
- Location-based battery supply
**Figure 11: 5G use cases in energy**

<table>
<thead>
<tr>
<th>Use case</th>
<th>Benefits</th>
<th>Why 5G?</th>
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<tbody>
<tr>
<td>Predictive maintenance</td>
<td>Reduce downtime</td>
<td>Capacity</td>
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<td></td>
<td>Maintain constant supply of energy</td>
<td>Reliability</td>
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<td></td>
<td>Reduce operational costs</td>
<td>Device costs</td>
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<td>Automated asset control</td>
<td>Increase output (supply of energy)</td>
<td>Capacity</td>
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<td>Improve valuation</td>
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<td>Reduce damage and associated financial costs</td>
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<td>Digitally-assisted field engineer</td>
<td>Reduce maintenance costs</td>
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<td>Reduce downtime</td>
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<td>Location-based battery supply</td>
<td>Improve accessibility to and adoption of electric vehicles</td>
<td>Mobility</td>
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<td>Reduce energy consumption</td>
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<td>Avoid overloading electric grid</td>
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<td>Smart grid load balancing</td>
<td>Reduce energy costs</td>
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<td>Avoid overloading electric grid</td>
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<td></td>
<td>Ensure stable grid</td>
<td>Low latency</td>
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Source: STL Partners
Smart grid load balancing

Decentralised grids will need smart grid load balancing to balance energy supply and demand. This involves connecting sources of energy supply and generation as well as end-users to dynamically turn things off and on when needed.

The sub-use cases for smart grid load balancing include:

- **Balancing capacity**: Predicting supply and demand of energy and automatically scaling generation or (large user) consumption up or down. Today this is done in minute intervals, national electricity grids have mechanisms that work in 240-minute intervals (e.g. Balancing Mechanism Start-up in the UK), 89-minute intervals (Short-Term Operating Reserve) and 2-15 minute intervals (“Turn up”). However, there is demand from industry to move to real-time decision making in the future.

- **Virtual power plants**: In order to allow micro-generators (consumers, smaller enterprises, local communities) to participate in balancing capacity, there need to be aggregators who combine end users and small suppliers to build up a block with big enough demand and supply capacity for an aggregator to sell into the national grid. Companies such as SmartKlub (engaged in a 5G testbed) do this by consolidating energy from smaller businesses, commercial offices, schools and individual households. Another method is to create virtual power plants, such as Upside Energy and Limejump, which connect assets to the market and conduct transactions on their behalf. These require highly reliable, low latency connections to monitor the assets in real-time and ensure they can take part in balancing capacity or frequency response. Virtual power plants prefer to retrofit assets with a cellular connection to ensure a reliable connection, regardless of
where the asset is. 5G will again help to scale such solutions as the number of connected assets rises exponentially in the future.

- **Frequency response**: As thermal plants play less of a role in energy systems, system inertia is reduced and deviations in the target frequency of the grid are happening more often and more drastically. This makes it critical to be able to connect alternative rotational stabilisers to boost frequency and manage short-term balancing demand and supply to avoid damaging frequency fluctuations. It will be critical to predict fluctuations, using data on energy demand/supply, and trigger mitigating actions instantaneously. This is a key use case for 5G, since low latency connectivity is critical.

### Energy demand and supply management

Energy demand and supply management is a use case that encompasses many different applications to help consumers, businesses and municipalities to use energy more efficiently and reduce their carbon emissions. To do so effectively, real-time data needs to be collected and fed into analytics platforms to automatically determine how much energy should be used, the best time to consume energy for certain appliances, when prosumers should sell energy back to the grid, etc.

5G will be particularly useful when managing energy at a wide scale (high device capacity needs) and in business critical operations, for example for large industrial customers. Businesses that have set stringent energy targets will need reliable connections that monitor consumption and contribute to automated control systems.

There are also synergies with private 5G networks. Large manufacturers, for example, are deploying private cellular networks to run their remote operations. These same networks could be used to manage energy consumption, thus improving the business case for 5G.

Below are a few innovative solutions that illustrate the role connectivity is playing in energy demand and supply management. These could be enhanced by 5G in the future as they scale and extend to other types of devices and uses:

**AirEx smart ventilation solutions**

- **AirEx** is a system that can be retrofitted into existing housing to reduce heat-loss and maintain healthy living spaces by ensuring that the right levels of ventilation are provided to home.

- The AirEx vents are connected securely for compliance, energy consumption monitoring and use external data (e.g. weather forecasts).

- A more reliable and secure approach would be through a wide area connection, ideally a specifically optimised 5G slice. This would be particularly beneficial when AirEx is retrofitted to multi-tenancy dwellings by the landlord (e.g. housing association).
Octopus Energy smart tariffs

- Supply electricity through variable tariffs, including “Agile Octopus” – a 100% green electricity tariff that grants consumer access to lower prices depending on when they consume electricity (example pricing comparison below).

**Figure 13: Daily energy price fluctuations (Octopus Agile vs. flat rate)**

- This means consumer will use electricity when it there is more supply (with high contributions on the grid from renewable energy sources) and helps to keep the grid stable

- Octopus is starting to partner with device manufacturers to avoid relying on manual behavioural changes by consumers – e.g. with Tesla, combining Tesla’s EV battery with a smart charging cable and their tariff to automatically charge vehicles at times in the day when prices are lowest, publishing rates via an API

- This is only done on a piecemeal scale currently; in the future, it needs to scale outside of just “green enthusiasts” and be completely automated, without relying on human intervention

- 5G can help support the growth in the number of devices and ensure reliability, particularly if devices need to be managed by a third party or in a wide area urban environment – e.g. electric vehicle charging points across a city.

**Drone maintenance and repair**

Drones use ultra-high quality video analytics, combined with other sensors data, to detect issues and even carry out repairs. Solar farms are beginning to use thermal imaging software to detect faulty/underperforming solar panels, whereas wind turbines use high-resolution photography and LiDAR to inspect erosion on the blades.
Companies, such as Skyward (a Verizon company) offer drone management services today to energy companies, and highlight the role of 5G in changing how drones are used: reducing the end-to-end maintenance and repair process on large energy assets from taking days (or even months) to real-time. 5G will enable autonomous drone navigation and Beyond Visual Line of Sight (BVLOS) journeys, although regulation on drone use is fragmented across different countries. Moreover, ultra HD video footage needs to be streamed back and forth from the drone to an AI platform – a bandwidth requirement that only 5G can support. The more accurate this data is, the more likely drones can be used to conduct deeper inspections and carry out micro-level external repairs.

This saves costly engineer trips for both maintenance and repair and can reduce planned and unplanned downtime. In survey data collected by STL Partners, 79% of solar power generators and 77% of wind power generators said that being able to complete operations and maintenance (O&M) repairs in a single annual trip would reduce maintenance costs by up to 10%\(^3\). Operations and maintenance costs are hugely significant in renewable energy generation and can make up an estimated 80% of annual costs for both wind and solar\(^4\). For solar farms, O&M costs make up roughly 15% of LCOE (lifetime costs divided by total energy production)\(^5\), and for offshore wind this figure is approximately 30%\(^6\).

**Figure 14: O&M costs as a proportion of LCOE are significant for wind and solar power**

Wind turbines and solar panels (at scale) are expensive assets, which means small gains in productivity can make a significant difference to the overall value of the generation facility. When

\(^3\) STL Partners, survey data collected June 2020  
\(^4\) STL Partners, survey data collected June 2020  
\(^5\) European Commission: EU-wide Solar PV business models: guidelines for implementation, September 2016  
\(^6\) CATAPULT, see: link
surveyed, 75% of solar power generators and 62% of wind power generators reported that automatically controlling assets could increase their annual output by up to 10%\(^7\).

To be able to do this in wind energy generation, turbines need to be equipped with dozens of sensors monitoring all parts of the turbine. The data can then be used to optimise the generation process. For example, the ideal pitch of the blades and direction of the turbine could be forecasted for each turbine uniquely and applied to increase productivity.

5G’s ability to support thousands of devices provides advantages here. Automated asset control will only be made possible if latency is minimal and can leverage hundreds of connected sensors. Today, turbines have a maximum of 8-10 sensors attached. Mobile connectivity is particularly useful given that many of these sensors need to be connected directly to the cloud wirelessly, e.g. on a blade, to reduce latency to a minimum.

The other benefit of this use case is that it can support wind turbine services companies to change their business models. Using the data generated, they could provide a service that manages farm output based on real-time prices of the market to maximise their customer’s revenue: higher performance at peak prices and (asset-preserving) gentler performance when prices are lower. This is akin to how Formula 1 drivers choose to push or to preserve fuel/tyres/engine over the course of a race to minimise pit-stops.

**Location-based battery supply**

The location-based battery supply use case involves highly connected vehicle and road infrastructure to allow drivers to change their car batteries when they need to. This avoids long waiting times from charging mechanisms and helps to overcome battery limitations (see Figure 15). At present, a typical EV (60KWh battery) takes just under eight hours to charge from empty-to-full with a 7kW charging point\(^8\), which makes battery swapping schemes an attractive alternative.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Barriers to adopting electric vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cost of electric vehicle</td>
</tr>
<tr>
<td>2</td>
<td>Ability to access EV charging points</td>
</tr>
<tr>
<td>3</td>
<td>Battery limitations</td>
</tr>
<tr>
<td>4</td>
<td>Fuel costs</td>
</tr>
<tr>
<td>5</td>
<td>The time it takes to charge an electric vehicle</td>
</tr>
<tr>
<td>6</td>
<td>Lack of choice (vehicles)</td>
</tr>
<tr>
<td>7</td>
<td>Lack of education</td>
</tr>
<tr>
<td>8</td>
<td>Government incentives</td>
</tr>
</tbody>
</table>

**Figure 15: Main barriers hindering adoption of electric vehicles**

Source: STL Partners’ survey with 100+ energy experts

\(^7\) STL Partners, survey data collected June 2020

\(^8\) https://pod-point.com/guides/driver/how-long-to-charge-an-electric-car#:~:text=Summary,with%20a%207kW%20charging%20point.
A 5G-enhanced version of this service would use AI-based predictions on expected demand (based on data on cars, planned routes, traffic flow, battery capacity, etc.) to ensure battery supply can be planned for and sufficient across a distributed network of stations. Not only would it be able to connect to handle the network, but it would be able to simultaneously handle massive numbers of vehicles.

For example, in India we are starting to see early examples of the location-based (electric vehicle) battery supply use case. Indian Oil recently announced plans in collaboration with SUN Mobility to set up battery-swapping stations at their petrol pumps. Chinese electric vehicle maker Nio Inc launched a battery leasing service earlier this year, leveraging its 143 battery-swapping stations already operating in China and adding 300 stations next year. This scheme will expand to Europe in 2021.

**Figure 16: SUN Mobility’s battery swapping stations**

![SUN Mobility's battery swapping stations](source: SUN Mobility)

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9 https://www.livemint.com/industry/energy/indian-oil-battery-swapping-station-for-evs-how-it-works-11593322918297.html
10 https://uk-mobile-reuters-com.cdn.ampproject.org/c/s/uk.mobile.reuters.com/article/amp/idUKKCN25G00E
5G’s impact on carbon emissions: 1.7 billion tonnes less global carbon emissions by 2030

The use cases above cannot dramatically change the future trajectory of global warming on their own, but, when aggregated, all have a role to play in reducing carbon emissions. If we use our previous framework, we can map the relationship between the use cases and the key drivers for helping to solve the global warming challenge, as seen in Figure 17. This also includes two additional ways in which 5G can impact emissions outside of the energy industry: 5G network efficiencies and general digitisation and automation. Both of these will be exemplified in the Energy efficient consumption section.

Figure 17: 5G use cases mapped to the carbon emissions reduction framework
STL Partners modelled the first two mechanisms in detail (green electricity generation and transition to electricity) and projected that global carbon emissions would be 0.8% lower in 2030, compared to a base case where 5G-enabled use cases were not adopted.

**Figure 18: Global divergence in annual carbon emissions between the base case and the 5G case (GTCO2)**

The findings further highlight the need to make many small changes to be able to shift the curve. Here, we are referring to an annual difference of 254 megatonnes of carbon dioxide globally (MTCO2) between the 5G case and the base case in 2030, equivalent to approximately 64 coal-fired power plants’ energy in one year, or half of all of Canada’s emissions in 2018. This impact would multiply in the years after 2030 and the saving will only continue to grow as more countries reach a level of technological advancement sufficient to support 5G-enabled technology. Even by 2030, some countries will still be developing their 5G networks, and it will take time for the energy ecosystem and its key stakeholders to adopt new business models.

We have also broken down the reduction in global carbon emissions by the mechanism through which they are achieved. The figure below shows the relative impact of 5G’s role in accelerating “green electricity generation” compared to the “transition to electricity”. We forecast a reduction in carbon emissions from direct combustion of fossil fuels (due to “transition to electricity”) in the period 2020-2030 to be a cumulative 550 MTCO2 of savings in the 5G case, although this will be gradual. The more significant reduction will come from “green electricity generation”. In other words, 5G use cases have

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11 Model was based on a sample of countries which represent approximately 99.5% of total global emissions.
a relatively bigger impact on making electricity cleaner, even though they also enable the switch away from fossil fuel combustion (e.g. vehicles) with electric alternatives. By 2030, it is projected that, in the 5G case, we can have reduced a cumulative 1.1 billion tonnes of CO$_2$ emissions from electricity consumption.

**Figure 19: 5G’s impact in reducing annual carbon emissions from direct combustion (of fossil fuels) and electricity (MTCO2)**

![Change in annual carbon emissions enabled by 5G use cases (MTCO2)](image)

**Green electricity generation**

Use cases that are particularly relevant to the energy generation sector (predictive maintenance, automated asset control, drone maintenance and repair and digitally-assisted engineer) support the ambition to accelerate adoption of renewable energy on the electricity grid by making them more competitive. Hence, green electricity generation.

Both solar and wind are relatively early stage technologies, which are still on their learning curves. This means that any way to improve renewables’ economics will accelerate their adoption. Governments have historically tried to do this through subsidies and other financial incentives to encourage investments into wind/solar farms. However, many countries are now reducing those subsidies and other countries have never done so. In order to incentivise investments in renewable energy, it must be more compelling to build renewable energy plants than alternatives (fossil fuel, nuclear and hydroelectric), and governments still have a key role to play in creating those incentives.

Our forecast demonstrates the aggregate impact of these use cases in changing the mix of energy sources on the electricity grid between 2020-2030. Figure 20 shows the difference between electricity consumption from each fuel in the 5G case, compared to the base case. By gradually making wind
and solar more competitive, solar and wind will take up a larger proportion of energy on the grid (+0.6% and +0.3% respectively).

**Figure 20: Changes in global electricity consumption by fuel due to 5G (cumulative 2020–2030)**

Transition to electricity

5G-enabled use cases can accelerate the replacement of applications that use direct fossil-fuel energy (e.g. petrol cars, gas boilers) with electricity and therefore have a tangible impact on reducing carbon emissions. This is because the electric grid has a lower carbon intensity and will continue to become greener as more of it is powered by zero-carbon sources.

The two main ways in which 5G-enabled technology can help shift adoption of electricity is by making them **more cost effective** and **more accessible** than their hydrocarbon-powered alternatives. For example, the location-based battery supply use case helps make EVs more accessible, while better energy demand and supply management mechanisms can make electric alternatives more cost effective. Mobile smart charging systems connected by 5G can reduce the cost of electricity used to fuel the car. Drivers could leave their vehicles and allow the smart charging machine to automatically charge at the optimal time – i.e. when electricity supply is adequate (and from renewable sources) to stabilise the grid. This would be an extension of Octopus Energy’s variable tariffs today.

Our survey across energy professionals in the industry estimated that 5G-enabled solutions could help increase adoption in electric alternatives by the following amounts in 2030 across the main domains of opportunity:
Figure 21: Increase in adoption of electric alternatives due to 5G

<table>
<thead>
<tr>
<th></th>
<th>Consumer space heating</th>
<th>Consumer water heating</th>
<th>Industrial space heating</th>
<th>Commercial space heating</th>
<th>Transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change (%)</td>
<td>+3%</td>
<td>+12%</td>
<td>+4%</td>
<td>+8%</td>
<td>+6%</td>
</tr>
</tbody>
</table>

The aggregate impact of this differs across countries. In Canada (Figure 22), there is huge potential from transitioning to electricity for heating in particular, given that it is a cold country that is still mainly using natural gas across space and water heating. The area which 5G enabled use cases are predicted to make the biggest difference is in commercial space heating, but net savings across all areas resulting in 5.23 MTCO2 lower carbon emissions in 2030.

Figure 22: Canada shift in energy demand to electricity (2030)

On the other hand, the addressable opportunity for further improvements in transitioning to electric heating in a country like Norway is slightly smaller given that 99% of residential energy is already supplied by either electricity (86%) or direct renewable energy consumption (13%). The contribution of 5G-enabled use cases is particularly substantial in aiding the transition to electric vehicles, resulting in 1.4 MTCO2 lower carbon emissions from transport in the 5G case compared to the base case.
Energy efficient consumption

Within the mechanism of making energy consumption more efficient, there are two categories whereby 5G can make a difference:

1. Making **direct energy consumption** of telecoms networks more efficient by implementing 5G technology

2. Making **indirect energy consumption** more efficient – i.e. the use of 5G-enabled technology to reduce consumption for the same output in other industries

The impact of transitioning to 5G to improve energy efficiencies in the mobile network was explored in a previous report by STL Partners, *Curtailing carbon emissions – Can 5G help?*. We found that a fast roll-out of 5G could reduce cumulative carbon emissions by 0.5 billion tonnes of CO₂ globally by 2030\(^\text{12}\). This is due to the **direct curtailment of energy consumption** in both mobile access networks and the 5G core network, due to more efficient network equipment and operational practices than 4G. The energy load – the average amount of energy required to transmit data (e.g. kWh/GB, GWh/EB, Joule/bit) – of a 5G cell site is 8-15% that of a like-for-like 4G cell site. With mmWave, this has the potential to fall to 1-2% of a 4G macro site.

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\(^{12}\) STL Partners: "Curtailing carbon emissions – can 5G help?", October 2019
5G can also support with optimising **indirect energy efficiency** across the entire economy – optimising energy consumption of all 5G-connected appliances, reducing travel, reducing waste, improving productivity, improving yields (e.g. farming output for the same inputs) and other indirect energy efficiency effects across all sectors. This includes use cases that help individuals and business to monitor and improve the way they use energy (e.g. "energy supply and demand management" or the AirEx smart ventilation control) or any other carbon-embedded inputs (transport, metals, plastics, chemicals, concrete).

But it also includes 5G’s role in digitising the way in which we work and conduct our everyday lives. More recently, the result of COVID-19 is that it has highlighted how much of our daily interactions can be conducted without being face-to-face. It is notable that during the lockdown period in the UK, the record for most consecutive days with no coal-fired power generation\(^\text{13}\) was broken, as well as the record for peak solar generation, supplying almost 30% of total electricity demand. 5G is intrinsically a connectivity technology, which will allow us to conduct more and more formerly face-to-face interactions online, helping to reduce carbon emissions from travel.

An example is shown in our supplementary report, *5G’s impact on transport and logistics: $280bn of benefits in 2030*, which analyses the role of 5G in connected traffic infrastructure. By improving traffic systems, decreasing the distance that vehicles drive and minimising the amount of time they spend in traffic, the amount of fuel consumed is decreased. Connected traffic infrastructure alone could save

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\(^{13}\)https://www.theguardian.com/business/2020/apr/28/britain-breaks-record-for-coal-free-power-generation#:~:text=Britain%20has%20gone%20without%20coal,18%20consecutive%20days%20this%20morning.

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67 million tonnes of oil equivalent in 2030 globally. This is the same amount of fuel that Thailand consumes in an entire year.

Figure 25: Decrease in fuel required (million tonnes of oil equivalent)
Next steps for accelerating progress

The results of the analysis emphasise the need to make big changes to nudge progress in the right direction. However, simply relying on 5G technology being rolled out in a ‘business as usual’ fashion and hedging bets on a ‘build it and they will come’ strategy will not work. For these outcomes to materialise in the way we have envisioned, telcos, governments and other key stakeholders in the industry should follow these seven principles across three main categories: technology, government and regulation, and telco business models.

**Figure 26: 7 principles for accelerating progress**

- **Technology**
  1. Ensure access to 5G in the right places
  2. Leverage the unique benefits of network slicing

- **Government & regulation**
  3. Consider the role of technology in parallel with carbon emissions policy
  4. Streamline infrastructure planning across telecoms and energy networks

- **Telco business models**
  5. Apply learnings from internal telco/networks transformation to the energy industry
  6. Become active players in the decentralised energy ecosystem
  7. Develop appropriate monetisation models

Source: STL Partners

**Technology: 5G accessibility and taking advantage of network slicing**

1. **Ensure access to 5G in the right places**

The analysis in this report assumes that, by at least 2030, use cases can leverage 5G and it is easily accessible. This means that telecoms operators should:

- **Avoid delaying 5G roll-out**, which is becoming more difficult as revenue from connectivity services remain stagnant, or in decline, and the COVID-19 pandemic changes the market environment.

- **Build 5G in areas where there is industrial demand**, since many use cases will exist outside of operators’ initial targets for 5G coverage (urban centres), i.e. remote wind farms, industrial batteries, solar farms. This may require private cellular networks to justify building out 5G for areas with 1-2 industrial customers.

A comparison between the location of wind farms across the UK and UK operators’ initial plans for 5G deployments accentuate the discrepancy, using Three UK as an example. While the mobile operators
focus on rolling out 5G to areas of high population density in large cities, wind farms are instead located in remote areas, often near the coastline. Telcos should be encouraged in deploying 5G to support these types of customers and/or work with governments to help scale access quickly.

**Figure 27: 5G coverage is not aligned with hotspots of demand from the energy industry**

![Wind farms in the UK and Three UK’s initial target towns and cities for 5G deployments](image)

2. Leverage the unique benefits of network slicing
One of the fundamental capabilities of 5G that is going to set it apart from previous generations of mobile networks is network slicing. Network slicing is a form of virtual network architecture which allows multiple, differentiated virtual networks to use the same shared physical infrastructure, end-to-end.
For customers, this means providing flavours of 5G networks that are customised to the need or application. By segmenting use cases or applications enabled by 5G slices, telcos can tailor services to meet specific performance characteristics (e.g. battery life, latency, resilience). Importantly, this also means not including expensive functionality that is not required (e.g. mobility support for devices that are not moving between cell sites).

Examples for the energy industry include:

- A 5G slice for mission critical connections used to manage frequency response, including batteries and large assets connected to the grid. This requires highly available and reliable links, plus the ability for the slice to be prioritised during periods when there is high frequency variability on the grid.

- A slice for electric vehicles, which would need different 5G functions such as mobility (ensuring connections are maintained as devices move through cells).

Initially, 5G network slices are likely to serve groups of use cases with similar characteristics; in the long run, this may evolve to become more targeted for certain applications. In order for energy customers to take advantage of network slicing, telcos will need to ensure they have the technology ready. This emphasises the importance of rolling out a 5G core that is cloud-native, flexible and has the ability to allow enterprises to configure networks to satisfy their quality of service (QoS) needs. More on this topic can be found in a previous report 5G network slicing: How to secure the opportunity.
Government and regulation: Bringing energy and telecoms closer together

3. Consider the role of technology in parallel with carbon emissions policy
Governments have historically used regulation and financial incentives to accelerate renewable energy and encourage behaviour to reduce carbon emissions, however technology plays an important role too. A clear example already discussed in this paper is using 5G-enabled solutions to reduce the cost of operating wind and solar farms, thus improving their cost competitiveness. This is particularly important in the absence of governmental support (e.g. through subsidies) for such projects. From a government perspective, this should encourage taking a more holistic view when setting policy. For instance, including 5G network coverage for key industries, including low-carbon energy generation, rather than solely meeting population-driven coverage targets.

As shown in Curtailing carbon emissions – Can 5G help?, the speed of 5G roll-out impacts how significant changes in carbon emissions from the mobile network itself will be. The difference in cumulative carbon emissions (2020-2030) across the mobile industry between a fast roll-out scenario and the medium base case was estimated to be 0.5 billion tonnes of CO₂. The role of 5G in enabling emissions reductions in other industries, demonstrates a multiplier effect from slowing down roll-out; not only will it slow down the ability for the network to improve its own performance and efficiencies, but it could delay investments by others in more efficient use of energy.

4. Streamline infrastructure planning across telecoms and energy networks
Another parallel between telecoms and energy is the fact that both require vast physical network infrastructure, which is becoming more distributed. And both are having to do this to meet local demands. In telecoms, this is about providing network services that are customised to the end-user and ensuring a quality of service (e.g. using small cells and edge computing to deliver low latency content). Within the energy context, it will help to bring demand closer to supply and vice versa.

Both of these networks are critical to our future society, yet it is not always easy to deploy them quickly. Part of the challenge relates to existing processes (e.g. government planning permission) and the physical effort of building out the network infrastructure, particularly in populated urban environments. Government authorities may want to consider planning for infrastructure across these in a more streamlined way. This avoids multiplying the level of disruption from having fragmented construction projects, as well as making it easier to take advantage of economies of scope and scale – e.g. using sites which are already well connected to power supply for building 5G (small cell) infrastructure. The reverse is also true; Deutsche Telekom converted 12,000 street cabinets into EV charging points in 2018, Virgin Media is also planning to do so in the UK.
Telco business models: Creating new 5G-enabled services for the energy ecosystem

5. Apply learnings from internal telecoms and networks transformation to the energy industry

Telcos’ chances of success in a key role in the energy ecosystem will be improved if they can make the most of existing skills and assets. Although the telecoms industry itself is undergoing a transformation, it is often perceived as an advanced sector compared to other markets. Some of the learnings and skills that will be applicable to the energy industry include:

- **Data analytics:** One of the biggest challenges for future energy will be creating a data platform to integrate real-time information from millions of devices and ensure this is shared securely with the relevant parties. Telcos’ experience in data analytics, from managing customer data to using real-time data to optimise network performance, provide a strong foundation for creating platforms and services for the energy industry.

- **Software-defined networking:** Telcos have transformed their network infrastructure to be operated in a more programmable and agile way through NFV and SDN. Energy networks will similarly need to move towards these models and make use of digital technologies to manage decentralised networks, as well as avoid any possibility of downtime across network and energy generation assets.

- **Distributed cloud and networking:** As telcos seek to adopt cloud themselves across IT and networking and continue to provide cloud and edge cloud services, they will build skills required to develop solutions where tight coupling of compute/cloud and connectivity are key.

Elisa (a telecoms operator based in Finland) is a leading example of a telco building on a platform originally implemented to improve internal operations to another industry – in this case manufacturing. As explored in *Elisa’s Smart Factory: How to win over industry leaders in two years,*
Elisa managed to use the IP developed for its network operations centre (NOC) to create Elisa Smart Factory.

6. Become active players in the decentralised energy ecosystem

A decentralised energy ecosystem requires multiple stakeholders to participate and co-innovate. To translate use cases into services, telcos will have to define value propositions that work for all parties across the fragmented energy value chain. Examples of telcos that have done this well (and some less well) in other ecosystems are outlined in a previous STL Partners report *Telco ecosystems: How to make them work.*

Consider Octopus Energy’s Vehicle-To-Grid solution, Powerloop, which allows customers to automatically charge EVs at optimal times of the day (when the rate is low) and sell electricity back to the grid. All these stakeholders shown in Figure 30 play a different role; telcos will need to appreciate this value ecosystem to position themselves within it effectively.

**Figure 30: Powerloop ecosystem and key components**

![Powerloop ecosystem diagram]

Telcos are in a strong position to drive the ecosystem, because of the move towards local management of energy networks for decentralised systems. This manifests itself in community-level projects, some of which are being funded at local government levels. For example, communities owning renewable energy generation installations, driving energy efficiency projects, implementing automated systems to collectively scale up/down energy demand and creating direct partnerships with local distribution network operators and off-grid suppliers. Telcos are arguably well placed to act as ecosystem orchestrators, compared to global solution providers, by making use of the relationships they already have with key stakeholders: public bodies and enterprises. For instance, they could stitch together consumer propositions that combine connectivity, applications/devices (e.g. smart charging...
cable), the data insights needed (e.g. wholesale electricity prices, availability of local energy sources) and service/billing.

7. Develop appropriate monetisation models

The final consideration for telcos creating 5G-based business models for the energy ecosystem will be to develop monetisation models that are relevant to the target customer and meet their needs. Many mobile operators have nascent enterprise businesses, which are still focused on selling SIMs and charging for connectivity in “per MB” models. However, stimulating demand for 5G will require offering more than traditional connectivity services. This is particularly true in the early stages when enterprises, software developers and solution providers will not yet be aware of the benefits of 5G, let alone have the applications and services available to them to use it.

Broadly speaking, there are three high level business models telcos can consider, as shown in Figure 31. We are seeing early examples of telcos investing in new services related to the energy industry, primarily focused on energy management. For instance, AT&T working with Redaptive to provide Efficiency-as-a-Service and Telefónica’s Eco Smart Energy Efficiency Solutions.

**Figure 31: 5G business models for telcos in the energy industry**

| Solutions and Applications | Provide custom end-to-end solutions for customers, includes consulting and advisory services, systems integration and applications | E.g. building energy management solutions | AT&T
| Application Enablement | Aggregate applications and data from multiple partners to multiple users - data management & sharing, billing / transactions, app marketplace | E.g. APIs to enable real-time decisions on buying / selling electricity | octopus
| Networks-as-a-Service | Manage custom networks in a cloud-like way, i.e. ability for customer to scale up and down, define parameters (e.g. latency), and add other functionality | E.g. network slicing for smart grids | Huawei

Even at the networks-as-a-service layer, mobile operators will need to think about delivering connectivity in new ways and upskilling. For instance, 5G services at wind and solar farms may be more suitable provided as private networks, given that they are likely to be outside of traditional coverage zones and have stringent requirements for data security and privacy. Implementing and operating a private 5G network for an enterprise customer requires new skills for mobile operators, such as detailed (enterprise) network design and planning, systems integration, remote management and orchestration of edge compute services and solution requirement gathering.

Operators will need to consider the risks and potential returns for each type of business model, what they charge customers and how they invest and operationalise this internally. This is explored in more detail in a supplementary report *How mobile operators can build winning 5G business models*. 