Getting to Net Zero: Increasing Clean Electrification by Empowering Demand

INSIGHT REPORT

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Foreword

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The year 2021 is a momentous year for humankind, with decisions hanging in the balance that may impact life on earth for centuries to come.

The COVID-19 pandemic serves as a sobering reminder that our survival and well-being on this planet depend on working together. People have risen to the occasion as never before as a global community, collaborating to develop multiple life-saving vaccines in under a year – a historical breakthrough. Now is the time to apply that attitude of heroic solidarity to one of the greatest challenges of our century: climate change.

The year began in that spirit, with announcements of more ambitious climate targets from every major world leader. Yet, following a brief period in 2020 when global carbon emissions sank by 5.8%, the International Energy Agency (IEA) has predicted that 2021 will see the second biggest emissions rise in history, as vast portions of stimulus funds flow into fossil fuels to jump-start economic recovery.[1]

In the meantime, the August 2021 Sixth Assessment Report from the UN's Intergovernmental Panel on Climate Change issues a very clear warning: current climate measures are inadequate both in scope and speed to meet the Paris Agreement target of limiting global warming to 1.5°C and avert a climate outcome with severe consequences for humanity.[2]

We have a few remaining years to act to complete the energy transition and build a new green economy based on net-zero carbon technologies. We must act swiftly, decisively and inclusively. For climate action to work for anyone, it must work for everyone.

Clean electrification is a global priority in the race to net zero.

The IEA announced clean electrification as a top investment priority for reaching net zero by 2050.[3] The clean electrification of transport, heating in buildings and industry would eradicate fully 73.2% of global emissions,[4] moving society considerably closer to a net-zero future. "Clean" depends first and foremost on completing the transition from fossil fuels to renewable energy in our power grids.

We must ensure that the power grid serves as the resilient and reliable principal source of electricity the world will depend on for its net-zero future.

Demand-side management holds a hidden key to the net-zero grid.

US President Biden recently proposed a Clean Energy Standard, which will require 100% zero-carbon generation in every state in the United States by 2035, 80% by 2030.[5]

Yet, the shift to clean energy generation alone will not suffice to achieve net-zero electricity. Electricity grids were designed to deliver a flow of reliable electricity to users. Renewable sources like wind and solar provide a variable supply. Grid infrastructure needs to evolve to fully capture and utilize such renewable energy. This means incorporating new digital technologies that can make the demand flexible enough to accommodate the fluctuations in generation.

Technology is ready to meet that challenge. Both hardware and software technologies are available that would enable us to optimize both the capture of clean energy and its delivery to consumers and businesses. What is missing now are the market mechanisms and governance to allow those technologies to be deployed fully and to make a new net-zero grid infrastructure economically viable.

This report, published under the auspices of the World Economic Forum Global Future Council on Clean Electrification, invites policy-makers, regulators and investors to focus greater attention on the user side of the electricity system. It presents the technology, business models and system governance necessary to unlock flexible demand in the grid infrastructure to achieve a net-zero grid.

Executive summary

As a decade of intensive electrification begins for transportation and industry and for heating in buildings and industry, progress must be measured against two principal goals. First, the energy transition must be completed and carbon neutrality in the world's power systems must be achieved. Second, power grids must be made resilient and reliable in the face of increased climate stress, rising electricity demand and much greater overall dependence on electricity.

Renewable energy generation will only get mankind part-way to net zero. The shift from combustion in centralized power plants (which provide controllable and consistent output) to renewable energy resources (which are variable and less controllable) creates a problem for existing grid infrastructure because it was designed for consistent, predictable power generation.

Adding more renewables to the energy mix through flexible demand

If 100% clean electricity generation cannot be achieved simply by increasing the supply of renewables, what else can be done?

The transmission grid is like a highway to channel renewable energy: the distribution grid provides the feeder roads, the final connection to end users. This is where the hidden key to reaching net zero can be found.

The distribution grid connects supply and demand. It has evolved naturally in the past two decades to support both new demand sites, like electric vehicles (EVs), as well as new electricity input sites in the form of distributed energy resources (DERs), including smaller wind farms, home solar panels, hydrogen fuel cells, battery storage and EVs with vehicle-to-grid charging.[6] Distributed generation supports enhanced resilience to climate shocks for individual users, as well as the possibility of satisfying rising electricity demand with more decarbonized energy, but it must be more deliberately managed to achieve its full potential.

This report presents the case for the technologies, business models and governance that would allow greater optimization of the further evolution of the distribution grid to: 1) effectively use more renewable energy; 2) make a new net-zero grid affordable for governments, operators and end users; and 3) ensure a seamless, resilient and reliable source of electricity to meet rising global demand.

This report outlines nine key mandates to get to net zero by increasing clean electrification through empowering demand:

Digital technology is the fundamental enabler of a resilient net-zero grid.

1. The rapid proliferation of renewable energy generation, DERs and EVs has driven an evolution of the distribution grid that must be closely managed going forward. Its full potential must be harnessed, ensuring resilience for individual users and serving increased demand with decarbonized energy.

2. Smart grid technology must be used to enable flexible demand, with the aim of integrating more renewable energy, while increasing grid resilience.

3. Existing distribution grid hardware must be digitally retrofitted with smart grid technology or replaced with new digitally-enabled equipment. The grid must be made resilient and reliable in the face of increased climate stress, rising electricity demand and much greater overall dependence on electricity.

New business models will make a net-zero grid affordable.

4. It is paramount to leverage the full expertise and potential of all stakeholders to contribute to a net-zero grid. To do that, barriers must be removed and regulation revised to empower both existing stakeholders (such as utilities) and emerging stakeholders (such as aggregators, prosumers and microgrid operators) to efficiently access and operate within the different sectors (power generation, transmission and distribution).

5. Interoperability and data transparency will be critical to providing the market signals needed to empower all market stakeholders to contribute to net-zero grid development.

6. New business models are needed that transfer capital expenditures and risk from prosumers, aggregators and microgrids to financial providers and institutional investors. Crowdsourcing for a net-zero grid is needed, by making it affordable and attractive for everyone.

A new comprehensive system governance model will be vital to ensuring a seamless and resilient net-zero grid.

7. Economic reform is needed to ensure that the forecast of the International Energy Agency (IEA) for $260-820 billion to be invested annually in the global transformation of the grid infrastructure from now to 2030[7] is dedicated to technologies, value propositions and business models that support a net-zero future.
8. An official system architect function is required, with the competence and authority to oversee the development of an integrated net-zero energy system that benefits all people.
9. Standardized audits must be implemented that use newly available system-wide data to ensure transparent and timely reporting against national and international net-zero targets.

1 Digital technology is the fundamental enabler of a resilient net-zero grid

Key mandates

1. The rapid proliferation of renewable energy generation, DERs and EVs has driven an evolution of the distribution grid that must be closely managed going forward. Its full potential must be harnessed, ensuring resilience for individual users and serving increased demand with decarbonized energy.

2. Smart grid technology must be used to enable flexible demand, with the aim of integrating more renewable energy, while increasing grid resilience.

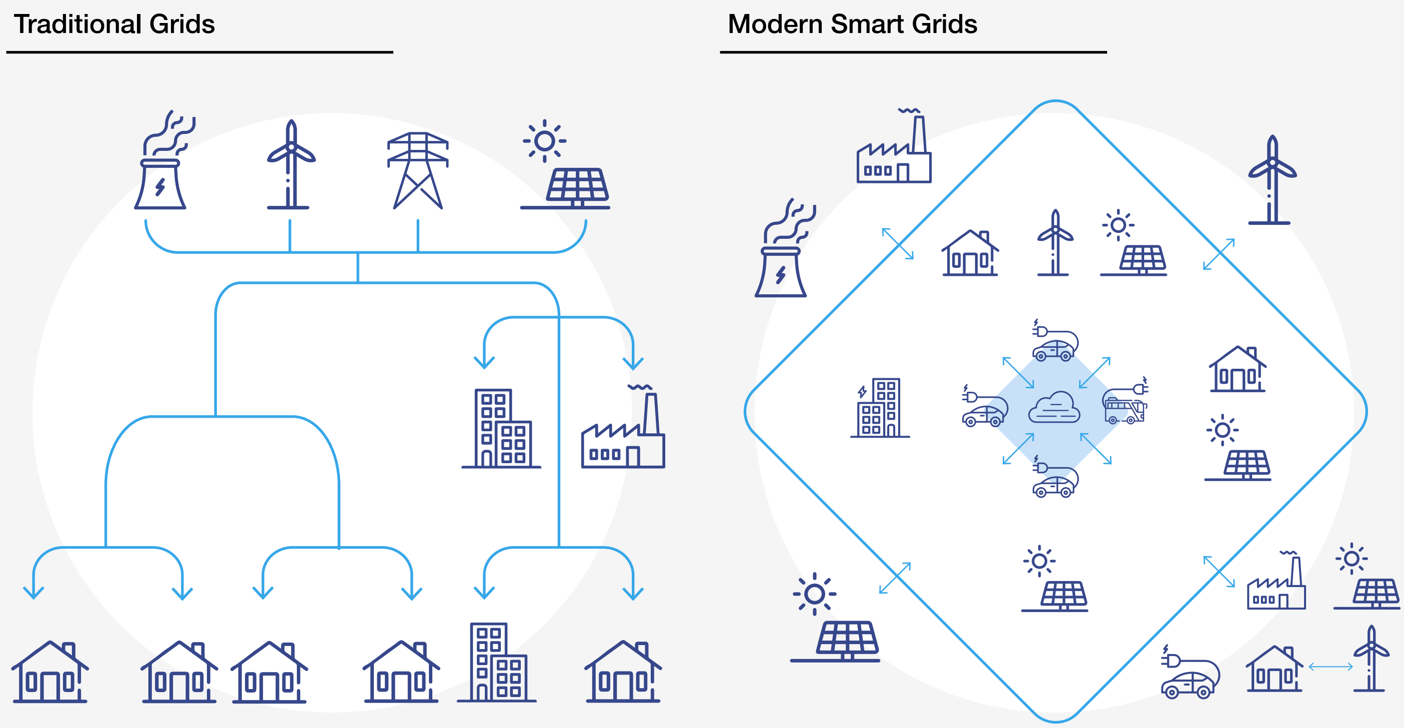
3. Existing distribution grid hardware must be digitally retrofitted with smart grid technology or replaced with new digitally-enabled equipment. The grid must be made resilient and reliable in the face of increased climate stress, rising electricity demand and much greater overall dependence on electricity.

Mandate 1 Digital technology in the distribution grid must be harnessed to accommodate more decarbonized energy while augmenting capacity and resilience.

The $2.6 trillion global renewable investment in the past decade has very effectively increased renewable energy generation, both from larger wind, solar and hydropower sources as well as from smaller distributed energy resources (DERs), like smaller wind farms, home solar panels, battery storage and electric vehicles (EVs) with vehicle-to-grid charging.

This has spurred an evolution of the power grid (Figure 1), entailing a shift from centralized power plant generation to a more decentralized energy supply.

FIGURE 1 | The evolution of the power grid



Source: Contributed by ABB

Newly observed, the potential of distributed generation can help people adapt to climate change as it supports enhanced grid resilience to climate shocks, such as flooding, forest fires and cold snaps, by offering individual users backup local generation. It also offers tremendous potential to help achieve a net-zero grid, by satisfying increasing electricity demand with more decarbonized energy.

However, to be successful, grid operators will need much greater observability of loads, voltage and flows between these new supply and demand points. A systems approach will need to be used, underpinned by digital technology that connects everything and gives operators comprehensive, detailed observability and precise, system-wide management of the complete power grid. This will allow operators to manage demand in a flexible way to align with a more complex and dynamic supply of electricity.

One example of increased observability and control that also allows the greater integration of decarbonized energy into the grid is active network management (ANM).

CASE STUDY

Facilitating renewable penetration through active network management (ANM)

ANM introduces new planning procedures and permissions to connect a larger installed base of renewable generation to the grid. In partnership with Iberdrola, the Spanish grid has introduced ANM in its operations, launching pilots in an area with numerous renewable generators.[8]

Distribution system operators use ANM to offer new renewable generators faster first-time connections to the grid, based on adherence to a schedule of curtailed generation, which ensures that peak grid capacity is not exceeded by peak renewable input. This allows more renewable generators to connect to the grid, without the need for additional grid infrastructure to increase grid capacity.

This serves the vital long-term goal of increasing renewable penetration by allowing the installed base of renewable generation to grow, despite the current constraints of grid capacity. The curtailment of existing installed capacity will reduce over time as the grid operator develops and expands grid infrastructure.

The next step must now be taken to digitalize the distribution grid, increasing awareness and allowing operators to make more informed decisions on how to increase the uptake of renewable energy, from all available sources.

Mandate 2 | Smart grid technology must be leveraged to make demand flexible to increase grid resilience and allow greater use of renewable energy.

Given dependence on the grid to supply power for nearly every aspect of people's lives, it is necessary to ensure enough generation capacity to cover electricity demands at all times.

Ensuring systemic generation adequacy with flexible demand

> Using smart grid technology to make demand flexible will play a pivotal role in decreasing daily mismatches between supply and demand.

Both electricity generation by renewable energy sources and electricity demand vary depending on the season, the weather and the time of day. Nevertheless, the forecasting of the total maximum demand in the overall system is fairly accurate.

Most of the time, with a sufficient installed base of renewable energy sources, demand peaks can be met by renewable energy. However, on the rare occasions when there is virtually no renewable generation – for example, when the wind is not blowing and a gigawatt wind installation produces mere megawatts – the gap is filled, currently, by fossil-fuel-based power.

If demand in the total system can be decreased, by introducing both greater energy efficiency and demand flexibility, the system balance can be preserved on those rare occasions when demand is high while renewable generation is exceptionally low.

In that way, it is possible to avoid pouring billions of dollars into new fossil-fuel-based power plants, which are only rarely needed, and instead direct that investment into the development of renewable resources and net-zero grids.

Hedging for the short-term variability of renewable energy through a hybrid approach combining energy storage with flexible demand

Even with relatively accurate supply and demand forecasting, mismatches still happen throughout the day. These mismatches between supply and demand present another challenge. Merely switching on a fossil-fuel-based power plant five times a year to cover exceptional circumstances is not what is needed, but actually keeping fossil-fuel-based power plants running constantly in a "hot" standby mode – ready to operate on short-term notice, which implies constantly burning fuel and emitting CO_2.

At this point in time, two possible alternatives to fossil-fuel-based reserves exist: storage and demand flexibility.

Batteries provide excellent critical backup power and can also supplement electrical grid power on a small to moderate scale. However, it would be impractical to fill the gaps between demand and generation solely with batteries.

Using smart grid technology to make demand flexible will therefore play a pivotal role in decreasing daily mismatches between supply and demand. It will allow the development and operation of the grid based on gradually decreasing fossil-fuel-based reserves. It will also increase system reliability and resilience by balancing the power input and output, mitigating the risk of shutdowns.

In fact, the world's largest power utility and largest user of smart meters, the State Grid Corporation of China, is now partnering with the International Renewable Energy Agency to implement a nationwide smart grid strategy that will address the user side of the grid, using digital technology to create flexible demand and meet the demand–renewable energy gap.

CASE STUDY

Enabling demand flexibility with a smart grid

On 12 April 2021, the International Renewable Energy Agency (IRENA) and the State Grid Corporation of China (SGCC) signed a memorandum of understanding outlining a partnership aimed at advancing the global energy transformation towards a net-zero energy future and meeting Paris Agreement objectives and the UN Sustainable Development Goals.

According to the press release, "IRENA and SGCC will conduct joint activities and collaborative studies to enhance flexible operation of power grids, [the] decarbonisation of urban energy systems and [to] facilitate grid development with a special focus on application of smart grid [technology] and sector-coupling strategies," seeking to align energy end use with supply.[9]

Implementing such an advanced digital programme nationwide in the world's most populated country will provide a rich testing and learning ground for other countries.

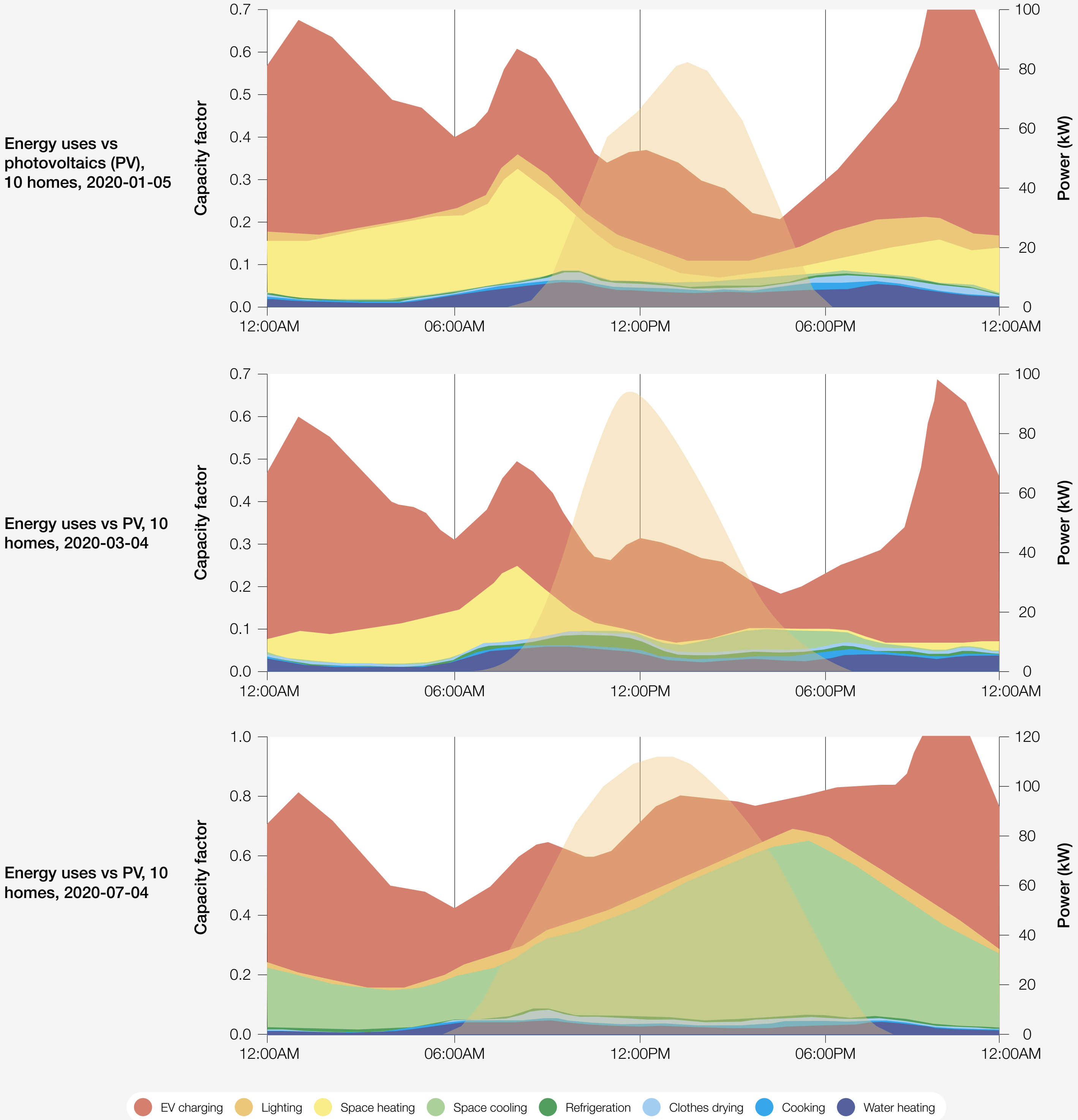
Promoting peak shaving and relieving grid congestion through prosumerism

Congestion in the distribution grid is an additional problem, which occurs when too many end users are simultaneously using electricity, for example, turning the kettle on at half-time during the World Cup soccer finals, or turning on electric heating during a cold spell. In extreme situations, this can lead to overloads or even local shutdowns.

Figure 2 shows real examples of the stark differences in electricity use peaks (demand curves) across devices and on different days for a group of US homeowners.

FIGURE 2

US homeowner differences in electricity use peaks per device, 5 January 2020, 4 March 2020 and 4 July 2020



Source: US home aggregated load data provided by Saul Griffith, Otherlab, 2020.

"Peak shaving" – so named because it smooths the demand curve by shaving off the demand peaks – can help to avoid grid congestion. Peak shaving can bolster the reliability of the grid while also reducing the over-dimensioning of the grid (the expansion of grid hardware just to accommodate peak use), thus saving valuable and dwindling natural resources.

Homeowners can play a powerful role in peak shaving. Rather than merely consuming energy, homeowners with solar panels or EVs can become prosumers – both producing and consuming energy, and even selling it. Homeowners with solar panels and batteries, for example, can contribute to peak shaving by storing excess solar energy in a battery during the day and using it to power their electrical equipment at night. In fact, they can go a step further and sell that stored energy back to the power grid, to augment grid capacity during peak demand periods.

Building and equipment owners can also support flexible demand by equipping or retrofitting air conditioners, water heaters and other power-intensive equipment with automated digital energy management systems, which not only save energy and money but also contribute to community-wide peak shaving, eliminate grid congestion and increase grid resilience.

Applied on a mass scale, shifting the consumer demand can provide district-wide relief of grid congestion and obviate large-scale over-dimensioning.

CASE STUDY

Reducing peak demand through digital building energy management

Jones Lang LaSalle (JLL), a global commercial real estate services company, uses building automation to manage air quality, light and temperature, for healthier and more comfortable buildings. It partnered with Schneider Electric and Automated Lifestyle to design an ideal workspace, a smart office, that allows operators to measure and manage energy usage as well as office wellness conditions. Using Schneider Electric's EcoStruxure, JLL created a single platform to manage all facility systems, optimize energy usage and enable operational efficiency and sustainability. It reduced both energy usage and operational costs by 30%.[10]

Such energy savings in commercial buildings can contribute to peak shaving, as well as to overall energy and emissions reductions in the power grid.

Increasing vehicle-to-grid prosumerism

The number of EVs on the road is predicted to rise to 559 million, with 33% of global fleets expected to be powered by electricity by 2040. EV charging stations are forecast to increase from 1 million today to 290 million by 2040.[11]

EVs save energy through superior energy efficiency: they are 3.3 times as efficient as internal combustion engines (ICEs).[12] However, they do require electricity. By 2040, EVs are expected to constitute at least 5% of global electricity demand.[13] That may be a conservative estimate, considering the rapid acceleration in EV uptake that continues to exceed forecasts, and the rolling bans on ICEs by governments, including the European Union's proposal to ban them by 2035.[14] In fact, by 2050, EVs in the EU are expected to constitute at least 74% of all vehicles.[15] There can be no doubt that mass conversion to EVs will be a powerful driver of increased electricity demand.

Fortunately, charging stations can be digitally connected to the power grid, allowing them to contribute to system-wide flexible demand management. Ensuring a daily optimized charging schedule for EVs will be critical to preventing potential congestion and flattening peaks, and will be especially helpful to allowing EVs to draw on renewable energy at peak generation periods.

Vehicle-to-grid (V2G) technology – EVs with digitally enabled bidirectional charging (Figure 3) – will provide additional support to the power grid.

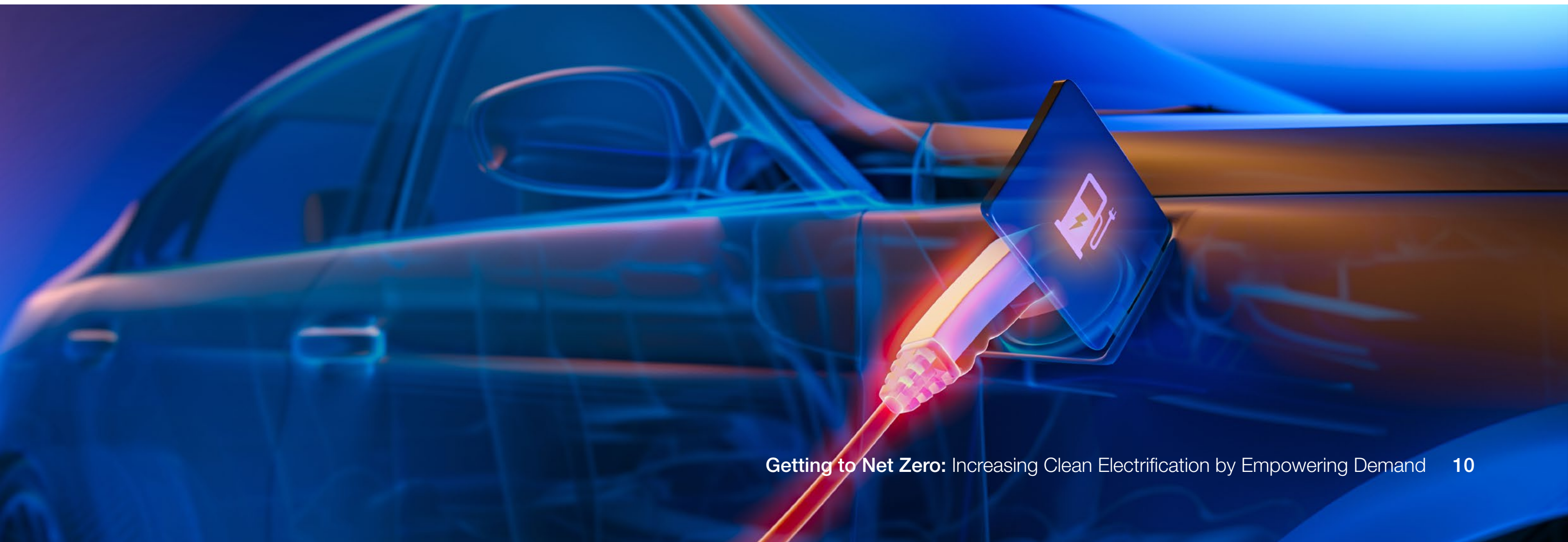
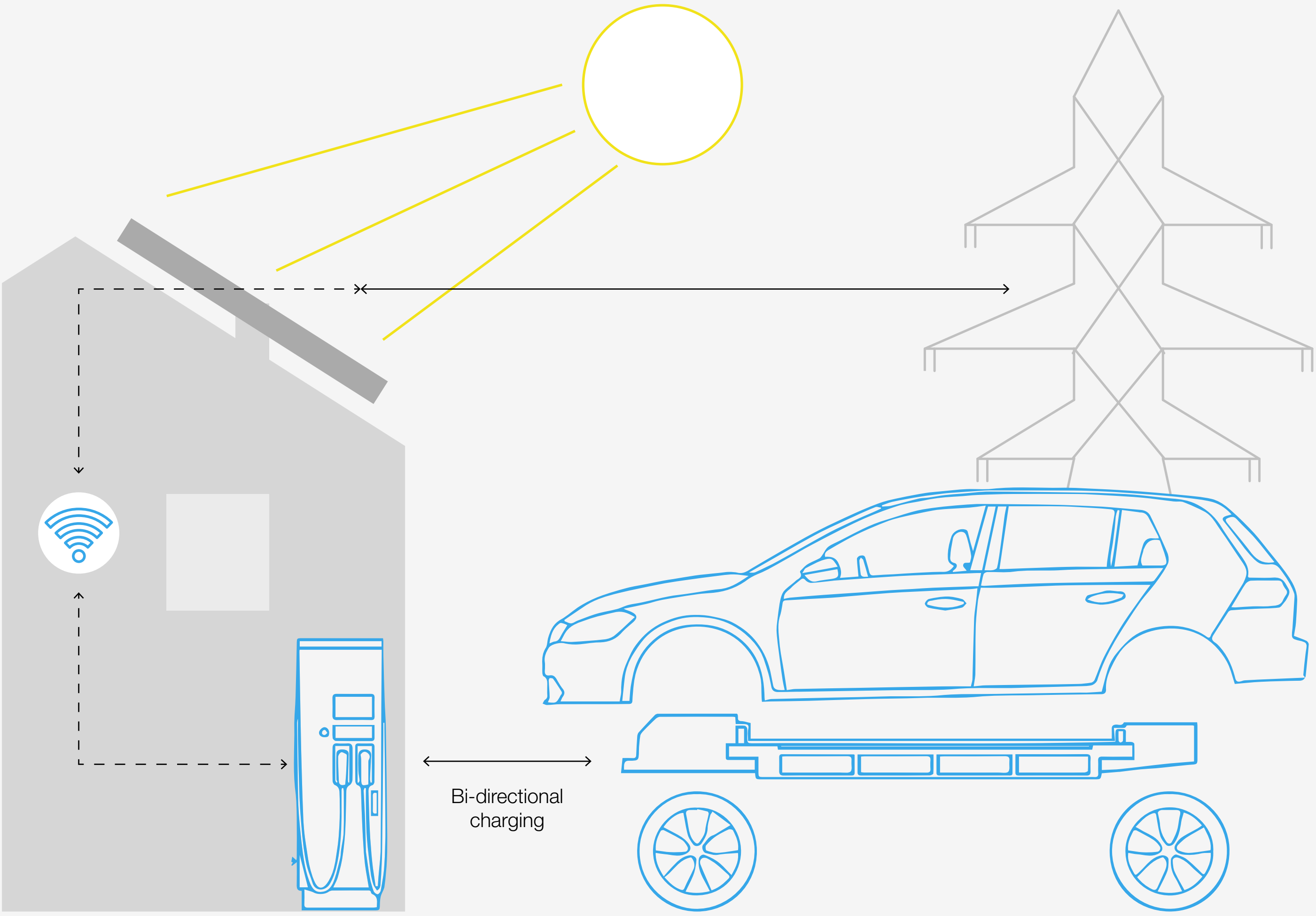


FIGURE 3 | **Vehicle-to-grid two-way electricity exchange**



Source: Contributed by ABB

V2G will augment the capacity of the power grid during peak demand hours (peak shaving), relieve local congestion and hedge for power intermittency. It will also help to reduce the total cost of ownership for EV drivers, by enabling owners to sell excess battery energy back to the grid.

CASE STUDY

V2G Demonstration Project E-Flex in Great Britain

Project E-Flex is a V2G collaboration between industry, government and academics funded by Innovate UK. It is the first project in Great Britain to demonstrate EVs performing grid services.

Travel patterns of 70 commercial vehicles have been analysed by Imperial College London to assess V2G suitability and economic benefits. In current market conditions, V2G chargers can reduce costs for commercial fleet operators on dual electricity tariffs. Given a more open market that allows, for example, time-of-use tariffs and smaller bidding requirements for grid services, V2G fleets could earn up to £100 a month, per vehicle.

V2G fleets can also be charged at times of maximum renewable input and make a real contribution to meeting a commercial entity's carbon emission targets.[16]

Adding industrial-scale prosumer input and resilience through microgrids

The interconnectedness of the electrical grid is highly beneficial for systemic efficiency but, when part of the grid fails, it can affect everyone connected to it. Microgrids, like homes with solar panels and V2Gs, can help with peak shaving, resilience and decarbonization, but on an industrial scale.

A microgrid is its own self-contained, local ecosystem of electricity generation and use. Normally, a microgrid operates connected to and synchronous with the regional electrical grid, but it can also disconnect from the regional grid and function autonomously in case of major weather events or regional power outages.

Microgrids use digital energy and asset management to optimize energy generation, storage and use in single campuses, like commercial sites with offices and factories, or throughout entire districts. They can provide only additional district resilience through backup power, and can also allow regions to draw on their renewable energy to reduce emissions.

CASE STUDY

Industrial-scale peak shaving, decarbonization and resilience

Factories are not only one of the largest drains on local power grids but also one of the largest contributors to emissions. ABB introduced the “Mission to Zero” concept at its Busch-Jäger campus in Lüdenscheid to turn factories from energy and carbon liabilities into net-zero assets.

At the subsidiary in Lüdenscheid, a solar power plant generates 1,300 MWh of climate-neutral power a year, which amounts to a year of electricity for 340 private households, and enough power on sunny days to supply 100% of the factory’s power requirements, including EV charging for employees. The technology at Lüdenscheid currently saves 744 tons of emissions annually and the site is on its way to becoming carbon neutral.

In combination with a co-generation plant, at Lüdenscheid ABB generates 14% surplus energy, which it feeds “into the public grid, contributing to the region’s power supply with sustainably produced energy”.[17]

Mandate 3 Existing grid architecture requires a digital upgrade to ensure resilience and sustainability.

The future grid will be put to the test continuously by increased climate stress, rising electricity demand and greater overall dependence on electricity. Power system asset lifetimes can be 40 years or more, so today’s investment decisions must support the ability to meet the double challenge of decarbonizing and reinforcing the power system for several decades.

Grid components, like circuit breakers that protect and insulate healthy equipment from short-circuited equipment in the grid, must be robust enough to withstand the harshest climate conditions through decades of operation.

Beyond that, existing distribution grid hardware must be digitally retrofitted or replaced as necessary with new digitally-enabled equipment. Embedded, cloud-enabled sensors combined with artificial intelligence and machine learning will allow continuous predictive maintenance. This will be essential to ensuring the reliable operation of a complex distribution grid with heterogeneous resources, even in the harshest conditions.

While digital technology is now the fundamental enabler of a distribution grid that is smart, resilient and net-zero, new market models are required that will fully empower all stakeholders to use that technology to contribute to the energy transition and the achievement of a net-zero grid.

2

New business models will make a net-zero grid affordable

Key mandates

4. It is paramount to leverage the full expertise and potential of all stakeholders to contribute to a net-zero grid. To do that, barriers must be removed and regulation revised to empower both existing stakeholders (such as utilities) and emerging stakeholders (such as aggregators, prosumers and microgrid operators) to efficiently access and operate within the different sectors (power generation, transmission and distribution).

5. Interoperability and data transparency will be critical to providing the market signals needed to empower all market players to contribute to net-zero grid development.

6. New business models are needed that transfer capital expenditures and risk from prosumers, aggregators and microgrids to financial providers and institutional investors. Crowdsource for a net-zero grid is needed, by making it affordable and attractive for everyone.

Mandate 4

Both old and new players must be empowered to contribute fully to accelerate the transition to a net-zero grid.

Historical deregulation

Traditionally, power systems were operated by a single or by several non-competing entities that were responsible for the total power supply, including the operation of power generation, power transmission and distribution grids.

Independent energy producers were mostly located at large factories or similar industrial facilities, and provided heat and electricity for the industrial process. Transmission and distribution system operators were responsible for integrated system development, and investment in the grid was frequently coordinated with the government. In effect, in most countries, utilities were natural monopolies.

In an attempt to demonopolize, many countries instituted deregulation schemes, prescribing clear and non-overlapping roles for power generation, transmission and distribution.

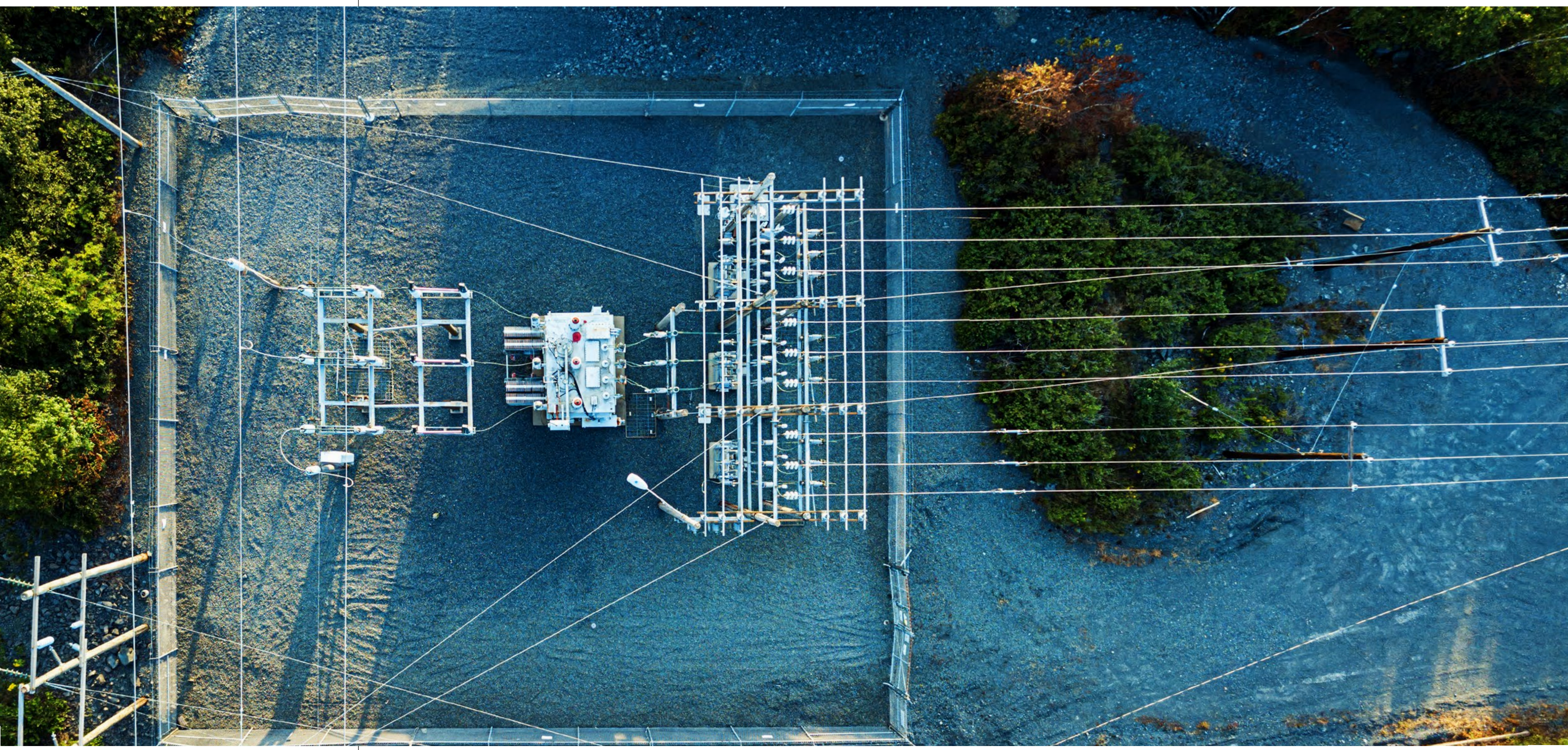
Effective market models for new net-zero technologies

Unfortunately, what worked for the previous power grid has become obsolete and clunky in the evolving distribution grid market of DERs and prosumers.

Thanks to sizable public incentives and maturing technology, the past two decades have witnessed the increased adoption of renewables and DERs into the grid, including wind and solar, battery storage and EVs. However, DERs are frequently located close to a customer and they have significantly smaller capacity than traditional generation plants. DER players are too small to be competitive in a traditional energy trading landscape.

As a result, an important new role has emerged, that of the aggregator, who uses digital tools to consolidate and package electricity from different DERs. The aggregator is a new, professional player who receives a commission to manage energy trading and grid service trading between prosumers and traditional grid operators. It is a key role in the new distribution grid system, helping to create an economy of scale in demand flexibility, and adding an element of oversight and management in balancing the input and output of electricity across an array of smaller connection points.

Aggregators are present in many countries. Their roles have been supported by regulation that allows new financial and technical mechanisms, and market development. Swift regulatory change in more countries will be critical to enabling aggregators and supporting flexible demand between DERs and traditional operators.



Fair competition framework to balance large- and small-scale net-zero acceleration

In some cases, the deployment of controllable DERs may allow utilities to further optimize grid investments and grid expansion. For example, installing storage systems in specific locations of the grid might enable utilities to collect renewable energy generated by prosumers and then deploy it intelligently to offset peak demand. For a variety of reasons, however, including a potential conflict of interest with generating companies, some countries currently prohibit utilities from owning and operating storage assets. An open and progressive dialogue on the future use of storage assets is required to ensure that the utilization of these assets can be optimized to increase demand flexibility, accelerate renewable integration and optimize grid development and expansion.

New market models should empower both new and smaller players like aggregators as well as highly competent traditional players to serve and integrate prosumers and DERs into the grid. Utilities, and even companies that originally developed business in oil and gas energy, have deep competence in the industry and on the consumer side. They also have deep pockets to advance net-zero progress.

A fair competition framework can engage both small and large players in the accelerated development of a resilient net-zero grid.

Enel invites both old and new, large and small grid players to test out net-zero grid parameters in a variety of scenarios via their dedicated network simulator, helping players to prepare for market activity.

CASE STUDY

Testing flexible demand parameters via a network simulator

The Enel Flexibility Lab is a network simulator open to third parties that reproduces a typical power grid and consumer behaviours. All power grid stakeholders, from technology manufacturers and energy communities to transmission and distribution system operators, can test various grid performance parameters, from flexible demand and digital interoperability to interfaces, communication protocols and security.

Mandate 5

Interoperability and data transparency will be critical to providing new net-zero market signals.

By offering greater transparency, pricing indicators and market stability, digital data has the potential to attract enormous investment.

To fully develop a new net-zero grid model, the transition to a new set of market signals is necessary.

Smart grid connectivity will offer system-wide management and systemic market insights, as well as dynamic and granular market signals that can help authorities, operators and investors stay on top of changes. Digital data will also provide signals on local grid capacity for renewable uptake and energy demand patterns, and other markers will allow investors to make more informed decisions on which technologies should be deployed, and where. By offering greater transparency, pricing indicators and market stability, digital data has the potential to attract enormous investment.

Once again, large and small players should be allowed transparent and non-discriminatory access to grid insights that would facilitate renewable energy uptake and fair competition. In the meantime, it is also important to note that data scientists are applying methods of data sharing, like anonymization or aggregation, which will allow such critical insights while preserving the privacy of individual users.

Harnessing digitalization to strengthen the accuracy of market signals will also allow governments to step back from the kinds of blanket interventions like those that have left the market in its current siloed condition, and which cannot accurately respond to a rapidly evolving and unpredictable technology mix.

A new standard of collaboration and interoperability

Interoperability is another important aspect of power system transformation. Its scope reaches beyond ensuring technologies work together to ensuring commercial flexibility for consumers. For example, EV users should be able to charge their vehicles easily, using any payment option.

To succeed in implementing the technology that will achieve net zero in grids and in communities, it is necessary to disincentivize proprietary platforms and incentivize a new spirit of collaboration and open ecosystems.

Business Finland demonstrates how easy it can be to balance the societal goal of achieving net zero with the need for a return on investment, by incentivizing collaboration and open innovation between technology companies, with the aim of creating a net-zero electricity platform.

CASE STUDY

Green Electrification Programme to Make Finland Carbon Neutral by 2035

Finland's target is to become carbon neutral by 2035. To achieve this, the country has established a robust government-funded programme that applies an open collaboration model to developing technologies that will advance Finland's net-zero goal.

Business Finland (the funding, trade and innovation arm of the Finnish Ministry of Employment and the Economy) has prioritized the Green Electrification 2035 programme. Several leading technology companies are collaborating to create a new integrated electricity platform that will combine 5G communications, data management, electrical engineering and power grid technology. The aim is a new interoperable, carbon neutral electricity platform that is controllable, safe and scalable and that optimizes system-level energy efficiency and reliability.[18]

Mandate 6

New business models should transfer capital expenditures and risk from smaller players to financial providers, effectively crowdsourcing for a net-zero grid, by making it affordable and attractive.

It is clear to all that the initial investment in technology for the energy transition pays off over time and can create system value for the environment, society and the economy.[19] At the same time, government subsidies were largely responsible for the expansion of solar and wind technologies to the level of economic feasibility.

But this is a new era of global consensus on climate change and the need for climate action. Large energy players, institutional investors and insurers are showing a much greater appetite to fund and thus accelerate this phase of the energy transition and the achievement of net zero. As a result, a powerful new business model has emerged that offers the opportunity to crowdsource for a net-zero grid, by empowering prosumers and other players of restricted capital means to monetize their contributions to the new distribution grid market.

Energy as a service to act as a major net-zero catalyst

DERs empower consumers to become prosumers, thus making them an integral part of the new user-empowered distribution grid. However, several hurdles could stand in the way of that opportunity. Chief among them are capital costs, operational and maintenance costs and, of course, the skills to assess, buy, install and manage such equipment.

This is one reason why the market for energy as a service (EaaS) is expected to grow from $49.6 billion to $88.4 billion by 2027.[20] EaaS shifts the cost and responsibility of the design, installation, maintenance and even management of DERs from prosumers to service providers. Those service providers, in turn, can now look to insurers, energy companies and institutional investors ready to take over both capital for retrofitting and even operational expenses, in exchange for reasonable policy premiums and performance paybacks.

To fully enable the market uptake of technologies that will help achieve a net-zero grid, it is vital that all stakeholders are empowered to contribute. A market with fair competition and data access to all must be created, where participation is affordable and easy. After that, the final step in fully activating the system-wide efficiency of flexible demand will be a new governance model that enables overseeing the system and aligning it to national and global net-zero targets.

3 A new comprehensive system governance model will be vital to ensuring a seamless and resilient net-zero grid

Key mandates

7. Economic reform is needed to ensure that the forecast of the IEA for $260-820 billion to be invested annually in the global transformation of the grid infrastructure from now to 2030[21] is dedicated to technologies, value propositions and business models that support a net-zero future.

8. An official system architect function is required, with the competence and authority to oversee the development of an integrated net-zero energy system that benefits all people.

9. Standardized audits must be implemented that use newly available system-wide data to ensure transparent and timely reporting against national and international net-zero targets.

Mandate 7 Economic reform must ensure all future investment is dedicated to a net-zero future.

After a brief drop in energy demand in 2020 due to the effects of the COVID-19 pandemic, which resulted in a drop in global emissions of 5.8%, the largest decline since World War II,[22] the IEA forecasts that the resurgent demand for coal in electricity generation will drive up global energy-related CO_2 emissions by 1.5 billion tons in 2021.[23]

With $260-820 billion to be invested annually in the development of the global grid infrastructure from now to 2030, it is paramount that steps be taken now to ensure those funds are dedicated to the technologies, value propositions and business models that support a net-zero future.

Governments can enable billions in savings by incentivizing demand-side flexibility to meet rising energy demands.

The first step will be to assess current policies and support schemes, and to ensure that demand-side flexibility solutions are not discriminated against. State aid schemes often view demand-response solutions as less effective than traditional incentives, like capacity remuneration (paying generators to be ready to supply electricity according to demand) or infrastructure expansion. This is largely due to the highly distributed and therefore potentially less manageable character of demand-response technology.

Often, demand response is not part of the incentive scheme at all because the focus is purely on generating clean electricity. As already mentioned, one-sided generation investment misses the vital balance of supply and demand in the grid.

Like China's strategy for developing a flexible demand response, the EU Energy System Integration Strategy acknowledges the role of distributed energy sources and demand flexibility in supporting a more energy-efficient system overall and in bringing clean electrification and the inclusion of renewable energy to all end-use sectors (building, transport and industries).[24]

Here again, putting DER on an equal footing, this time with infrastructure expansion or capacity remuneration schemes, represents an untapped opportunity to empower everyday consumers and businesses to become active contributors to a net-zero electricity market.

In fact, the case of REV in New York illustrates how successful this balanced approach to creating a viable market for both large and small operators can be in accelerating net-zero grid development.

CASE STUDY

Reforming the Energy Vision (REV) in New York

In 2014, faced with a $1 billion substation expansion to meet rising electricity demand, New York decided to explore another option. The Reforming the Energy Vision (REV) was born, a set of multi-year regulatory proceedings and policy revisions intended to transform the way electricity was produced, bought and sold in New York.

REV's major goal was to create a distribution grid that balanced DER and utility input. It restructured New York's utility ratemaking and revenue models to align with the drop in renewable energy prices and to support the greater integration of renewable energy generation and smart grid technologies.

An innovative project for its time, REV has not been without its share of challenges, from storage to questions of fair competition. Nevertheless, over time, the model has proven that putting demand-side flexibility on an equal footing with generation opens up a new dimension of mass net-zero grid engagement.[25]

The European Commission estimates that non-wire alternatives (using "distributed energy resources and microgrids to defer or replace the installation of more traditional wires and poles"[26]), including the activation of demand-side flexibility at the distribution grid level, would save up to billions per year across the European Union from now until 2030. Those savings would be the result simply of avoiding unnecessary grid reinforcements, backup generation and fuel costs.[27]

Mandate 8

An official system architect function is required with the competence and authority to oversee an integrated net-zero system.

“ To effectively achieve net-zero targets, system architects will need to take a society-wide approach, not only within their own national borders but in collaboration with their counterparts in other countries.

Several factors along the path to a net-zero grid present challenges to the current system of governance. First and foremost is the absence of an entity with both the authority and the competence to orchestrate the further development of the digitalized integrated energy system and steer it to net zero.

Accomplishing that will require a new multidisciplinary function – a system architect – with an extraordinarily broad knowledge base, from national and intergovernmental policy to climate science, renewable energy, digitalization, traditional grid operation, distribution grid architectures, DERs, microgrids, EVs, buildings, industry and consumers. Nevertheless, that level of system coordination will be needed to move with the speed and agility necessary to accomplish a decade of urgent and intensive work to meet the Paris Agreement targets.

The system architect has a key role to play in identifying and developing the standards needed to enable the systemic adoption of renewable energy, DERs and flexible demand response. It must ensure the timely integration of existing and new technologies and services to support acceleration towards a net-zero future.

Under this systemic approach, governments should focus on shaping enduring policy frameworks around net-zero outcomes that address climate, economic and also societal considerations. To do that, policy-makers should review existing regulation and introduce a system of regulatory and market incentives/ disincentives to engage both traditional and emerging market players to operate across power generation, storage and management.

The system architect will need to counter escalating climate hazards with climate resilience in the grid.

While the endeavour to improve the global climate outlook continues, extreme weather events in recent years also highlight the need to counteract increasing climate stress by planning for more frequent or more extreme contingencies in order to ensure resilience in the power grid.

The system architect will be responsible for making the grid resilient to more intense climate stressors, an integral part of policy and planning, not only in grid construction and operation but also for industries that are very grid-dependent. Tools like the IEA Climate Resilience Policy Indicator can help system architects compare their country's climate hazard levels with their policy preparedness.[28]

For climate action to work for anyone, it must work for everyone.

To effectively achieve net-zero targets, system architects will need to take a society-wide approach, not only within their own national borders but in collaboration with their counterparts in other countries. Climate change is a border-free affliction, and the energy transition can only truly be solved if all people everywhere are included in the remedy.

The United Nations Sustainable Development Goals (SDGs) offer guidelines for ensuring that net-zero initiatives are inclusive and therefore effective for all.[29] In particular, targeted net-zero grid community-wide implementation, market opportunities and regulations should provide opportunities for disadvantaged populations to improve their socio-economic status, in alignment with SDG 7, ensuring access to affordable, reliable, sustainable and modern energy for all; SDG 8, promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all; SDG 10, reducing inequality within and among countries; and SDG 11, making cities and human settlements inclusive, safe, resilient and sustainable.

The role of the system architect must be politically independent.

> Actions to achieve net zero must be performed in a global context, with a long-term integrated view, assuring policy, regulatory and economic stability for net-zero programmes.

The vital importance of the system architect's role demands that it remain independent of short-term politics.

A global review of low-carbon policy and regulation to date reveals disparate and fluctuating standards and approaches influenced by short-term political decisions. This has proven a major barrier to both investment and the successful completion of projects. It has also resulted in a disharmonized international low-carbon landscape and a lack of interoperability.

Actions to achieve net zero must be performed in a global context, with a long-term integrated view, assuring policy, regulatory and economic stability for net-zero programmes.

The function of the system architect can be implemented in various ways institutionally; the key is to ensure that the person has the mandate and powers to execute the role well, and appropriate funds to be able to attract the required multidisciplinary skills in sufficient quantity.

To date, no countries have a single entity with such broad and profound oversight.

Several countries have created organizations to tackle various aspects of a system architect's role. Duties vary from advisory to legislative responsibilities.

One example is the Electric Power Research Institute (EPRI) in the United States. The EPRI is an independent, non-profit organization that conducts research on electricity generation, delivery and use to enhance the quality of life in the US and internationally by making electricity safe, reliable, affordable and environmentally responsible. However, the EPRI does not have legislative responsibility. Other relevant organizations in the United States to take this role include the Federal Energy Regulatory Commission (FERC), an independent agency that "regulates the interstate transmission of electricity, natural gas and oil"[30] as well as natural gas and hydropower projects, and the North American Electric Reliability Corporation (NERC), a not-for-profit international regulatory authority that aims to "assure the effective and efficient reduction of risks to the reliability and security of the grid".[31]

Independent energy regulatory authorities in the EU could take up this role at the national level, based on their political independence and strategic role in the implementation of Europe's energy and climate policies.

In China, the China Electric Power Research Institute covers the same advisory and research function as the EPRI but it has more authority and is directly responsible for the implementation of the Department of Energy's strategy.

CASE STUDY

An independent adviser to governmental regulation bodies

The Future Power Systems Architecture programme, undertaken by Energy Systems Catapult in collaboration with the Institution of Engineering and Technology and sponsored by Innovate UK, has used systems engineering techniques to articulate complex, systemic electricity issues.

The programme aims to "identify the new capabilities required by the electricity system in 2030".[32] The work identified and validated needed functions and innovation requirements, and explored new ways to overcome barriers and deliver agile, flexible and stakeholder-inclusive change governance. The key challenge identified was the need to build intensive engagement by government and the whole energy industry, and create a shared vision across this emergent and highly complex stakeholder group.

This work continued in later phases and is now included in the current Code Governance Review in progress in the United Kingdom.

Mandate 9 Progress against the Paris Agreement's nationally determined contributions and the UN Sustainable Development Goals must be tracked.

The system architect will seek to fully understand the needs of all stakeholders to establish a shared strategic direction. The architect will undertake the analysis necessary to build a "living" roadmap for net zero and will assure the translation of the roadmap into practical execution. Another responsibility is to align public energy-sector strategy and policy mandates with carbon budgets, national net-zero goals and nationally determined contributions to the Paris Agreement.

By leveraging new and robust data insights from digitalized grid systems, the system architect will be able to make more timely decisions on strategic direction, planning and implementation. The architect will be able to monitor and measure success regularly and transparently to ensure that, at every step, the journey is moving in the direction of net zero and that the entire national community is included in that journey.

A multidisciplinary audit function should be established as a complement to the system architect to ensure ongoing energy system resilience, to assess the allocation of funds to projects supporting net-zero progress, and to assess the accuracy of progress reports both within the system and against national and international climate targets.

Digitalization will once again be the chief enabler for both the system architect and auditor roles, providing both granular and system-wide data insights and controls.

The new system architect role will offer vital system-wide oversight and strategic development of the smart grid to ensure coherence and interoperability within the system, foster fair and robust market competition, align grid investment and development with net-zero goals at the national and global levels, and ensure society-wide inclusion in net-zero progress and benefits.

Conclusion

Act now, act as one, for a net-zero future

A net-zero future by 2050 is possible. Many of the technologies needed to achieve a net-zero future are available today. On the supply side, the cost of utility-scale solar energy generation is now cheaper than fossil fuels in many countries.[33] On the demand side, the transport, buildings and industry sectors are undertaking an intensive decade of electrification. Still, with only 29% of global electricity generated by renewables in 2020,[34] the job is not finished; the energy transition remains incomplete.

Fortunately, a new era of global consensus on the urgent need for climate action has dawned, and public sentiment has given rise to a global trend towards clean electrification. This has resulted in a power grid that is continually evolving to support both new demand sites, like EVs, as well as new electricity input sites in the form of DERs, including smaller wind farms, home solar panels, hydrogen fuel cells, battery storage and EVs with vehicle-to-grid charging.

The digitalization of the power grid also offers a historic opportunity to change the way of thinking about electricity. Instead of one-way delivery, today's grid has the potential to offer a two-way exchange to virtually every electricity user. It is a profound development that offers the chance to crowdsource for net zero, by empowering everyday citizens to shift from pure demand and consumption to prosumerism – that is, both producing and consuming electricity, and even selling it back to the grid.

To utilize these technologies fully, new market models and regulations are necessary to transfer capital investment and risk to institutional investors and empower all stakeholders to become active contributors to a net-zero power grid.

In addition, a new governance model harnessing the insights provided by digitalization will help to develop an integrated and efficient electricity system that benefits all people and delivers against national and international net-zero targets.

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