HITACHI ABB

Perspectives

Second Edition
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HITACHI ABB POWER GRIDS

Powering Good for Sustainable Energy

Index

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Foreword

Welcome to this Second Edition of Perspectives – a collection of insights, opinions and ideas from technology and business leaders across our industries and beyond.

Perspectives was first launched on 1 July 2020 – the day we commenced operations as a joint venture – a business which has sustainability at its heart and has based its purpose on powering good for a sustainable energy future. Perspectives is a place for openly exchanging views on how we can accelerate the transition towards a carbon-neutral energy system, making it more **sustainable**, **resilient**, **secure** and **safe**.

It goes without saying that this past year has been highly demanding for everyone. Yet, as we start to emerge from the COVID-19 pandemic, I believe that there are reasons to be optimistic – more so than ever before. The energy transition remains one of the most important challenges of our times and now, in 2021, the level of urgency has significantly stepped up – amongst consumers, governments and industry.

We need the right policies and regulatory framework backed by appropriate investments and suitable business models. This is key to create, adopt and adapt policies as well as regulations to be able to deploy that technology – secure, scalable, and sustainable infrastructure.

As a society, there's growing evidence to suggest that the pandemic has made people more environmentally-conscious. In a recent Mastercard[1] global research study exploring the topic of consumer passion for the environment, 65% of participants admitted that it's more important than before that companies behave in more sustainable and eco-friendly ways; and 85% stated that they are willing to take personal action to combat environmental and sustainability issues in 2021. The pandemic continues to shift consumption and lifestyle behaviors across the globe. In parallel, governments have made commitments to new and ambitious targets relating to reducing carbon emissions.

According to the IEA's 'Net Zero by 2050: A Roadmap for the Global Energy Sector' flagship report[2], 'the path to net zero emissions is narrow' and staying on it requires increased investment in infrastructure, and specifically, an 'immediate and massive deployment of all available clean and efficient energy technologies.' By 2030, the world economy is expected to be some 40 percent larger but consuming seven percent less energy to be on track for net zero in 2050. By this time 'the energy sector will be dominated by renewables' and 'electricity will account for almost 50 percent of the total global energy consumption' – up from about 20 percent today.

There is no doubt that we need to boost the investment in the infrastructure to enhance capacity, resilience, flexibility, efficiency, and reliability. We also need to accelerate technology development and deploy it at scale and with speed. Now is the time for the green economic recovery to deliver upon the promise. **Every effort is needed from everyone across every part of our planet.**

As a business, we can and are making a purposeful contribution to sustainable society. Earlier this year, we released **Sustainability 2030** – the name of our own strategic plan for sustainability. Here, we summarize the main commitments that we are making to act and drive business in a sustainable way. Based around four pillars: Planet, People, Peace and Partnerships, our strategy draws from the UN's Sustainable Development Goals (SDGs), where each pillar has corresponding targets that drive our business to contribute social value, environmental value and economic value.

In the **First Edition of Perspectives**, I touched on the fact that the 2020's will go down in history, as a time of great crisis – and a time of human invention, innovation and societal progress. I still believe that this is very much true. I am immensely proud of our diverse team of 36,000 talented people based in more than 90 countries, who in spite of the pandemic, have continued to deliver great projects and co-create pioneering new technologies – all whilst socially distanced from one another.

Together, with customers and partners, we have throughout this pandemic continued to collaborate to deliver landmark projects and launch new solutions which are contributing to our sustainable energy future. Building sustainable partnerships is fundamental to the acceleration of the transition and in turn, supporting UN SDG 17.

Just one of the many exciting sustainable energy projects that we have been privileged to contribute to includes the energization of NordLink – a 623-km long HVDC electricity interconnection that, for the first time, links German and Norwegian power markets. The increased integration of renewables from both countries, in combination with the usage of pioneering technology, supports the green energy transition. And in this edition, Håkon Borgen of Statnett and Tim Meyerjürgens of TenneT share their thoughts on the project, which gives us a glimpse into the future carbon-neutral energy system – one which will be **highly interconnected**.

Achieving carbon-neutrality globally by 2050 requires every effort from everyone and in all aspects. An inclusive approach is key to achieving this common goal along with the recognition that there are different pathways that lead to the destination.

The Oil and Gas industry has an enormous role to play in speeding up the energy transition. Over the decades it has accumulated the necessary scale, financial muscle, ability to manage risk and deep expertise in delivering complex infrastructure projects in challenging environments. Within its DNA, it has also developed immense resilience and the ability to adapt and reinvent. Right now, the world needs the Oil and Gas sector to take hold of this energy transition and actively lead it from the front to drive the shift at the pace required to accelerate our sustainable energy future. I am convinced that in the next couple of years we will see some bold moves as the industry reshapes itself to seize the new opportunities and becomes the springboard for change.

In this Edition of Perspectives, we take a closer look at some of the exciting projects, developments and concepts that are all needed to speed up this next critical chapter. Shared ingredients include close team-working spirit and an environment fit for innovation – all united by a common purpose. The final article is a thought-provoking contribution from Gerard Reid of Alexa Capital who rounds off this Edition with a view on how to mobilize finance for the green energy transition. In his conclusion, Gerard sets out three things to address the question: 'What needs to be done to accelerate the path towards carbon-neutrality and ensure access to low cost capital?'

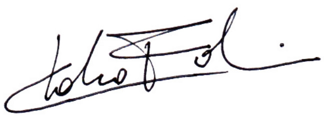
I would like to personally thank industry colleagues, for their insightful and thought-provoking contributions to this Second Edition of Perspectives, including:

Chris Peeters of Elia Group and Elia Transmission, Stefan Kapferer of 50Hertz (Elia Group), Tim Meyerjürgens of TenneT, Håkon Borgen of Statnett, Rajnish Sharma of Equinor, Tan Chee Hau of Singapore's Smart Nation and Digital Government Office and Gerard Reid of Alexa Capital.

I would also like to thank the members of my team who have further complemented these customer and partner Perspectives with their own forward-looking contributions.

Together, we are on one journey towards a sustainable energy future.

I hope that you enjoy this Second Edition of Perspectives.



Claudio Facchin

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1. Mastercard study conducted by YouGov surveying the views of >25,000 adults across 24 countries:
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2. IEA's 'Net Zero by 2050: A Roadmap for the Global Energy Sector': https://www.iea.org/reports/net-zero-by-2050

The carbon-neutral future is electric

Gerhard Salge
CTO, Hitachi ABB Power Grids

In this Perspective, Gerhard Salge, Chief Technology Officer at Hitachi ABB Power Grids, explains why electricity will be the crux of a carbon-neutral energy system. He argues that electrifying the globe can only work with a much more flexible and interconnected power system, enabled by the right conditions.

Electricity will be the backbone of the entire energy system

Electricity has improved our standards of living since its invention more than two hundred years ago. But the changes that deepen electrification in the name of sustainability will bring over the coming 30 years will go beyond anything that we've seen so far. Analysis comparing and contrasting multiple recent studies of the evolution of the total world energy system shows that global electricity consumption will more than double from 20 percent (today) to over 40 percent of total energy demand by 2050. And certain regions of the world will go far beyond this level of electrification.

The forecasts all come to the same conclusion: the carbon-neutral world is electric.

> **The forecasts all come to the same conclusion: the carbon-neutral world is electric.**

Three building blocks are stacking up to deliver this carbon-neutral electric future: connecting larger volumes of wind, solar and hydro to the grids; electrifying the world's transportation, building and industrial sectors; and, where direct electrification is either not efficient or impossible, introducing complementary and sustainable energy carriers, such as green hydrogen.

Combined, these blocks will give us the foundation upon which electricity will become the backbone of the entire energy system and on which sustainable societies can progress.

The most efficient, cleanest and cost-effective way to electrify the world is to build renewable energy capacity and to harness energy from wind, sunshine and water that nature provides in unlimited reserves. As a result, we estimate that global renewable energy capacity will grow by at least a factor of ten until 2050.

Challenges: overcoming complexity and expanding the world's grids

Electrification, powered by this huge growth in variable renewable power generation, brings a host of new challenges – but two stand out most to me: tackling the complexity arising from a greater number of widely distributed and less predictable power generation sites; and the need to significantly upgrade and expand grid capacity to accommodate the rapid growth in demand.

In order to manage fluctuating electricity production and new consumption patterns, our energy system needs to become more flexible and new tools are required to deliver this. Innovative grid components using power electronics will provide the operational flexibility needed to enable grids to become more efficient. Sensors will provide the necessary information and digital solutions will process the huge amount of information in intelligent grid control centers. This will enable faster decision making in a much more dynamic environment than we have ever seen in the past.

The second challenge, expanding grid capacity, can be tackled in two ways: optimizing the utilization of current networks and upgrading and extending power systems. Here, we can rely on clever combinations of power electronics and digital technologies to optimize copper and iron efficiencies on existing power grids. **A recent example of this can be seen in Scotland, where a new HVDC link is being added to connect the Shetland Islands to the UK transmission system**. The link will enhance security of power supply and help to transmit wind power generated on the islands, contributing to the UK's decarbonization target of bringing all greenhouse gas emissions to net zero by 2050.

Grid capacity will need to cope with more than twice the electrical energy of today. This includes the expansion of high-voltage networks and interconnections across regions, linking renewable energy generated in remote places, such as wind farms located kilometers offshore, to the grid. In the future, one could even imagine the ability to harvest the Arctic winds.

All market sectors will significantly grow in electrification. E-Mobility, industrial process conversion and heating are key drivers.

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From a demand-side perspective, this huge expansion will enable electrification to significantly rise in areas that have so far been low load regions – away from densely populated cities where demand is high. For example, through electrification it will become easier to locate a growing number of data centers in secluded areas. And we can expect to see more industrial sites, such as steel plants and mining operations, turn to electrification in a move to convert away from carbon-intensive processes whilst simultaneously, increasing efficiency.

Over the next thirty years, we are likely to see power systems also growing into geographical areas that, up to now, have rarely been taken into account in grid expansion planning.

Flexibility, storage and the role of complementary energy carriers

The journey towards a carbon-neutral energy system is dependent upon future power systems that are extremely flexible. They will need to cope with increased complexity, brought about by the need to integrate bulk and distributed variable power generated from renewable sources.

Whenever grid flexibility is required, the first and most proven technical solution is grid expansion and interconnection. Once this reaches its limit, energy storage starts to play an important role on the pathway towards a carbon-neutral energy system. Battery storage for electricity has already made impressive strides over the past years. With the rise of variable renewable power production comes a greater need for short-term electricity storage to ensure reliability of the power system. Battery technology is on its way to becoming the dominant solution for meeting short-term needs. It offers the highest flexibility and the most attractive cost-benefit ratio.

The buffers used in today's energy system to deal with the variations of electricity production are, next to renewable hydro-electric power, mainly fossil-based energy carriers such as oil, gas and coal. These types of emission-intensive elements of the energy system will need to be phased out in a carbon-neutral world fit for the future.

Where direct electrification is not possible or cannot be achieved, complementary energy supply is needed. The studies highlight the role of hydrogen as a technology that is gathering pace. When planning for seasonal storage needs, tapping the potential of hydrogen is likely to play an important role. However, for this to be sustainable, we are talking about green hydrogen – produced from renewable energy sources.

Green hydrogen could also be a facilitator in lowering the carbon-intensity of sectors that cannot easily be directly electrified, for example, certain elements of the transportation sector (e.g. airplanes and large ships). This takes us back to my main point of electricity being the backbone of our future energy system, as green hydrogen is produced using electricity.

When planning and designing the future energy market, an important aspect that decision-makers should consider is not to overly rely upon one direction only. Power system expansion and interconnection offer opportunities to link time zones and even climatic zones instantaneously. Nevertheless, the future energy system needs both interconnections and energy storage. It should never be a question of building one or the other – because they are complementary.

Creating the optimum climate for trust, collaboration and the right investment

Time is of the essence in the move towards a carbon-neutral energy system. There have been several welcome policy announcements and initiatives of late, setting ambitious targets for a carbon-neutral future.

This includes the stimulus initiatives and goals to accelerate the European Union's Green Deal, goals put forward by several countries including the UK, Japan, China and South Korea.

While this is laudable, it is imperative that planning and execution cycles are accelerated to unlock the necessary investments in our energy infrastructure. Policymakers need to set a clear agenda and enable this to happen, which includes putting in place the right regulatory framework and ensuring a degree of collaboration in key areas such as grid codes and market mechanisms. The area of interconnected electricity networks is also increasingly becoming important in order to maximize the penetration of renewables. Collaboration will clearly be a key success factor.

We are solving a fundamental societal problem – bringing affordable, reliable and sustainable energy to all people.

Be it Arctic winds powering electric vehicles to desert-harvested solar power feeding air conditioning systems, a carbon-neutral energy system will reshape the world. The challenge is so big that there is no room for picking winners – we need all sustainable solutions, current and future. We should not waste our energy and time on arguing about which is the better option, but instead focus on building sustainable partnerships, because only then will we accelerate and make an impact.

Building a global, interconnected and truly sustainable energy system for today's and future generations with the help of fascinating technologies will bring unbelievable value for sustainable societies. This is what makes me proud and excited to be part of bringing such a vision to fruition.

“We are solving a fundamental societal problem – bringing affordable, reliable and sustainable energy to all people.

Connecting the dots: The carbon-neutral energy system will be highly interconnected

Alexandre Oudalov
Manager, Power Systems of the Future Initiative, Hitachi ABB Power Grids

In this Perspective, Alexandre Oudalov, Manager, Power Systems of the Future Initiative at Hitachi ABB Power Grids, argues that interconnected electricity networks are the true enablers of the carbon-neutral energy system of the future. It is thanks to the smart technology of these ‘blood vessels’ of the clean energy world that we can reach our ambition: to efficiently bring in vast amounts of renewable electricity to power transportation, industries and buildings across the globe.

Delivering renewable energy to where it is needed

Governments around the world are facing a monumental challenge: a massive increase in renewable power production capacity will be needed to meet legally binding climate targets – how to deliver this huge wave of primarily variable electricity to where it is needed in a timely, efficient and reliable way?

The answer lies within the world’s power networks. To leap forward in reducing the carbon dioxide intensity of the global energy system, we need to go above and beyond to access the best green energy resources, which are often located in remote places.

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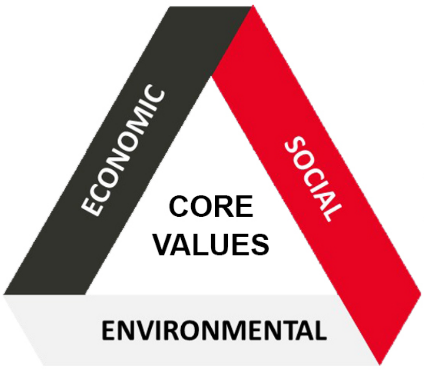
— Utilize more renewables
— Reduce peak capacity
— Share reserves
— Income from energy trading



— Increase reliability and resilience
— Stimulate cooperation
— Access to electricity for all
— New employment opportunities

— Reduction of CO_2 and other emissions
— Less fossil fuel waste disposal

Figure 1. Electrical grid interconnection value triangle

Advances in electricity transmission technology will allow us to connect the highest quality renewable energy sources with end consumers – from desert solar to Arctic winds, and powerful rivers to faraway oceans.

The electricity grids of the future will need to flexibly bridge time zones, climates and seasons. Connecting from west to east shifts peak demand and solar production times, while linking north and south will enable us to balance the varying electricity demand profiles of hot and cold or dark and light seasons.

Expanding the capacity of existing interconnections and adding new connections to link isolated electric power systems and remote renewables to deliver a broad range of social, environmental and economic values.

> The electricity grids of the future will need to flexibly bridge time zones, climates and seasons.

So how will this ‘bridging’ be possible?

Two or more power systems can be interconnected and operate synchronously – at the same frequency, using HVAC (high-voltage alternating current) transmission lines or asynchronously, keeping their own frequencies, using HVDC (high-voltage direct current) converter stations and lines.

The advantage of synchronously interconnected power systems is that they can remain stable while integrating gigawatt-size power plants. Scaling up and pooling generating units results in lower generation cost. Sharing reserves within a synchronous area reduces the system operating cost.

HVAC transmission lines are typically a preferred choice for shorter distances of a few hundred kilometers and when interconnecting power grids with compatible frequencies. Longer HVAC transmission distances are possible; however, they require special reactive power compensation which makes it more costly.

Enlarging the size of synchronously interconnected system increases complexity, vulnerability and cost. That is where DC technology comes into the spotlight and helps to overcome the fundamental limits of utilizing AC technology for:

- long-range power transmission via overhead lines;
- short- and mid-range subsea connections between countries, islands and offshore energy sources; and
- connection of regions with incompatible frequencies.

Maximizing the power of interconnection

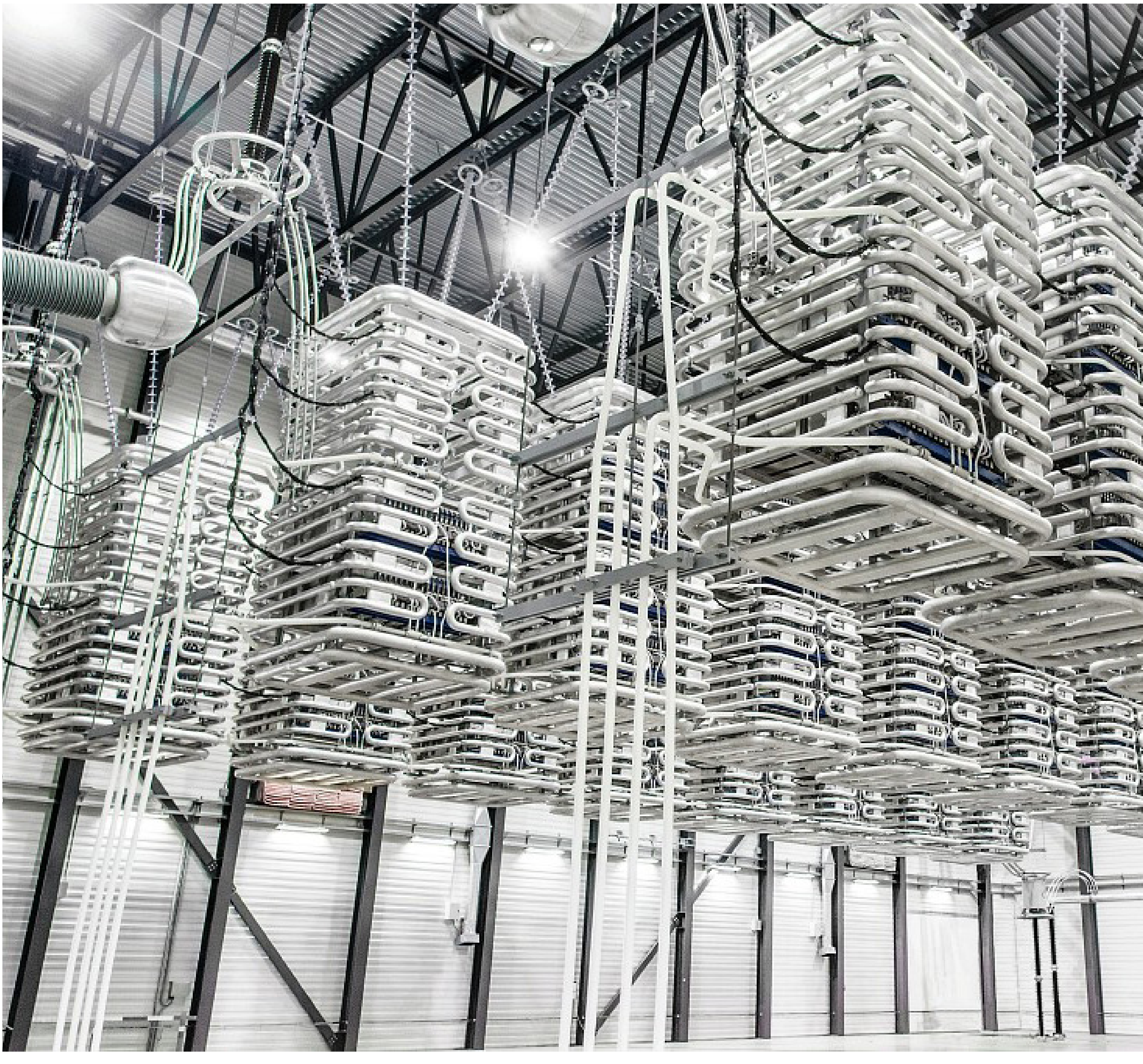
HVDC transmission technology has been used for decades for efficient bulk electricity delivery over long distances and the interconnection of asynchronous grids running at different frequencies via back-to-back stations or subsea cables. It has benefited millions of consumers around the globe.

Technological innovation in valves and processors for control systems has unlocked almost unlimited possibilities for managing electricity networks with a high share of renewable sources, with lower inertia and greater feed-in variations than ever before.

The true power of HVDC interconnectors is demonstrated when providing various dynamic grid support services to enhance system stability and resilience.

In addition, fully controllable and flexible HVDC interconnectors can effectively limit short circuit currents and help to restore power supply following system-wide blackouts.

One great example of an effective combination of power trading in the expansive region of southern Africa and the stabilization of weak AC power networks is the **Caprivi Link** interconnector, which joins Namibia and Zambia's electricity grids. The 950-kilometer overhead line ensures reliable power transfer capability between the eastern and western regions of the Southern African Power Pool and Voltage Source Converter-based HVDC technology helps to stabilize these weak networks and prevent blackouts under critical contingencies.



What are the main dynamic control benefits of HVDC?

Enabled by fast and independent control of active and reactive power output of HVDC converter stations, the three main benefits include:

1. Frequency regulation performed by emergency power control via droop characteristics and emulation of inertial response to compensate large active power imbalances usually caused by unexpected loss of large generating units;
2. Enhanced voltage control by fast modulation of reactive power during and after faults to stabilize the system and help to prevent voltage collapse by limiting active power transfer to increase reactive power supply; and
3. Damping of electro-mechanical oscillations of the rotors in the synchronous generators to maintain a safe power transfer limit in the AC system.

The connected dream: more unified electricity networks

Making optimal use of the world's green energy resources by extending and linking together regional interconnections makes the dream of more unified electricity networks a reality. Efficiently flowing electrons generated in windy, wet or sunny places to urban hotspots saves money on fuel costs, on building peaking capacities and on sharing reserves. It also reduces the cost of carbon emissions and other fossil fuel waste. Yes, the initial investments are high, but our analysis has shown that the long-term benefits far outweigh the capital requirements.

Europe is a stand-out example on this journey and the European Union has, since its inception, worked towards the creation of an integrated European power network. It started in the early 1950s with the main objective being to optimize necessary reserve capacity, connect hydro resources in the Alps and facilitate cross-border electricity exchange.

The invention of HVDC technology gave engineers a powerful tool to accomplish previously impossible tasks such as connecting the asynchronous power grids of UK and Nordic countries to continental Europe, and islands like Sardinia and Mallorca to the mainland with long subsea cables. Several back-to-back HVDC converter stations enabled power exchanges with asynchronous power grids at the Eastern extremes of the European system.

Europe is also a great example of implementing green policies beyond national borders to accelerate a transition towards a carbon-neutral energy system – which, let's face it, is not an easy task given the level of emissions we have today.

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The shift from fossil generation sources towards new renewables and the massive electrification of final energy use in sectors such as transportation, industrial and buildings (e.g. heating) are heavily dependent on stronger and more flexible power networks.

Interconnection goes hand-in-hand with flexible storage concepts. It enables users to take advantage of the full range of available storage technologies implemented across the total system – ranging from batteries for short-term energy storage, through to pumped hydro for bulk and longer-term storage. Interconnection especially complements pumped hydro energy storage plants, as these are location-dependent facilities that cannot be built everywhere.

Historically, interconnectors have been used to integrate remote hydro power plants, in the past decade the focus has extended towards a seamless integration of new renewables, such as wind and solar. The number of interconn ectors has increased significantly over the past 20 years, mainly driven by the increasing need for renewable integration and growing power exchanges.

Today, the European electric network already handles high shares of variable renewables which on some selected hours may reach a peak of almost 50% of total generation and stay above 30% of total generation during 2,100 hours per year. (Source: ENTSO-E Data Transparency Platform). The highest intensity is from February to March.

Some countries have even managed to run on pure renewable power for days, taking advantage of very favorable weather/wind conditions and an extended interconnection with the rest of the European system. However, transmission capacities and network flexibility need further investment to meet the ambitious targets, and possibly run fully on renewable power at all times.

The latest recommendations indicate that European member states should ensure cross-border interconnection capacity of 15 percent of peak demand or of installed variable renewable generation capacity, depending on which is higher, by 2030, to avoid any significant curtailments of wind and solar generation while providing high quality and continuity of electricity supply.

Today this percentage varies greatly between European countries. Denmark, whose cross-border transmission capacity is more or less equal to its demand, is an exceptional case, which highlights the benefits of a strongly connected power grid. When there is excess wind power generation in Denmark – it can sometimes reach 150-160% of local demand – it exports surplus electricity via subsea cables and overhead lines to its neighbors. Norwegian consumers, for example, can use Danish green electricity while Norway's domestic production is stored in hydroelectric reserves. When Danish domestic power supplies are insufficient, consumers receive Norwegian hydroelectricity.

The recent energization of the NordLink project, a 623-km long HVDC interconnection linking German and Norwegian power markets enables the integration of renewables from both countries. The connection provides the German power grid with reliable access to hydropower resources in Norway, and Norway access to Germany's substantial base of renewable energy, particularly wind and solar energy resources.

These are great examples of sustainable partnerships operating in both directions, which are enabled by a strong and flexible transmission network.

Between now and 2050, the whole range of connection types will be needed to establish connections within Europe and to other continents – from domestic offshore wind to remote renewables and from back-to-back stations to long distance subsea cables and overhead lines.

We need to speed up the process of making regional grids more flexible, controllable and resilient, by embedding HVDC links into existing AC networks.

When placed at strategic locations they will result in more stable and effective utilization of existing assets and optimal use of fast-growing distributed energy resources. Connecting islands, offshore O&G platforms and expanding offshore wind clusters into a highly reliable and efficient offshore HVDC grid is another important step towards sustainable energy supply.

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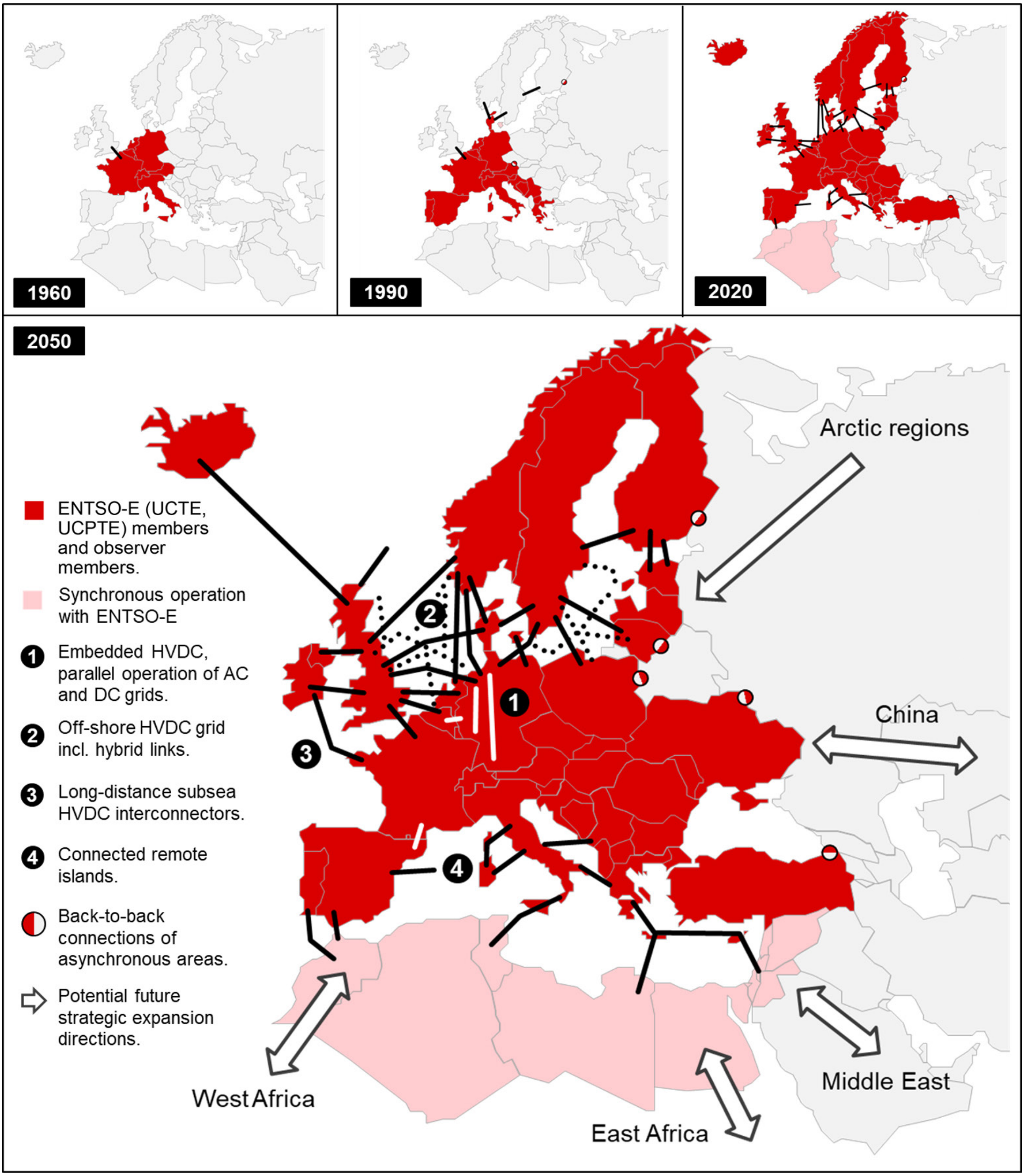

Figure 2. Evolution of interconnected pan-European power system and potential future developments needed to achieve carbon neutrality

Technically speaking – and looking beyond Europe – a global electricity network is also feasible. The latest technology allows us to transmit gigawatts of clean electricity over a wide range of distances in an efficient and reliable way.

In future, a truly integrated and interconnected European power system could use long-distance interconnectors to tap large-scale remote renewable resources – the solar energy of the Sahara and Middle East, the hydro resources of sub-Saharan Africa and the intense winds of the Arctic and Central Asian regions. And at some point, the power networks of China and India could even be connected with Europe.

“Technically speaking – and looking beyond Europe – a global electricity network is also feasible. The latest technology allows us to transmit gigawatts of clean electricity over a wide range of distances in an efficient and reliable way.

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Doubling the global share of electricity from 20 to 40 percent of final energy consumption and increasing the share of renewables from 27 to 75-85 percent of total power generation in the next 30 years requires a quantum leap forward.

Quantum leap

Doubling the global share of electricity from 20 to 40 percent of final energy consumption and increasing the share of renewables from 27 to 75-85 percent of total power generation in the next 30 years require a quantum leap forward.

The carbon-neutral energy system requires us to connect all the dots, including:

• local and remote clean energy sources;

• diurnal and seasonal energy storage;

• more electrified mobility and heating loads; and

• sites where excess renewable electricity can be converted to clean fuels in applications where direct electrification is impossible or economically not feasible.

A high level of interconnection will enable society to exchange and use clean energy at the highest levels of efficiency, resilience and reliability.

It is crucial that the foundations – specifically, the short-, medium- and long-distance interconnections – needed to accelerate us towards a carbon-neutral energy system, are laid down now. The technology is proven, but *trust* is also needed to build these cross-border links. Now is the time for deeper collaboration with and across regulators and policymakers. The combination of technology and trust will enable countries to reach their carbon-neutral goals.

One of the world's most powerful interconnectors: NordLink – a glimpse into the future carbon-neutral energy system

Tim Meyerjürgens
COO, TenneT

Håkon Borgen
EVP, Technology and Development, Statnett

Delivering the energy transition requires groundbreaking electrical engineering feats. The newly opened 1,400 MW NordLink interconnector uniting Norway and Germany for the first time is one such achievement that celebrates a decades-old TSO partnership and underlines the need to cooperate across borders to deliver the energy transition. With the European Union (EU) target for cross-border interconnection capacity at 15 percent of peak demand by 2030, the continent requires huge investments in interconnector projects. This puts NordLink, the world's most powerful VSC interconnector and cross-border HVDC electricity interconnector, at the forefront of an unprecedented engineering challenge that many can learn from.

We have invited two of the leaders behind the delivery of the 623-kilometer-long NordLink interconnector to share their experiences of bringing this pioneering project to life and to lay out their vision for Europe's future carbon-neutral electricity grid. Tim Meyerjürgens, Chief Operating Officer of Dutch-German TSO TenneT, recounts the project's complexity in how laying the cable across a Wadden Sea sandbank was dictated by the position of the moon, while Håkon Borgen, Executive Vice President of Technology and Development at Norwegian TSO Statnett, explains why building the NordLink cable was a bet on the energy transition that has already paid off.

Source: TenneT

We started thinking about connecting Norway and Germany as many as 25 years ago. The idea was really driven by the fact that we have a lot of renewable hydropower in Norway, whereas in countries like Germany there was mainly thermal power.

Håkon Borgen

The NordLink interconnector stretches from Tonstad, Norway to Wilster, Germany
Source: TenneT

How did NordLink come to fruition?

Håkon Borgen (H.B.), Statnett: I must say, it's been a long journey. We started thinking about connecting Norway and Germany as many as 25 years ago. The idea was really driven by the fact that we have a lot of renewable hydropower in Norway, whereas in countries like Germany there was mainly thermal power. Norway's hydropower is extremely flexible, but we also have dry years when we need to import electricity. The first concept of an interconnector to Germany was called the Viking Cable and we ended up using a lot of the engineering details from that time for NordLink.

Tim Meyerjürgens (T.M.), TenneT: In 1998 we had the change in European regulation with the liberalization of the energy markets. At that time the interconnector project was not really attractive anymore as the socio-economic benefit was at stake.

H.B.: But, together with TenneT, we still demonstrated that the technology works when we developed the interconnector project between Norway and the Netherlands. When NorNed was commissioned back in 2008 it was the longest interconnector in the world. That was a game changer because we proved that it's possible to connect power systems over long distances. From that we developed the idea that it could be possible to build even more interconnectors from Norway. We [Statnett] held discussions with TenneT about reviving our old plans and that was the start of NordLink. TenneT and KfW are our partners in the project. We made this decision jointly because we knew that NorNed was functioning. And with the commissioning of the fourth cable between Norway and Denmark in 2014, using the VSC technology at 525 kV for the first time. The ministries in Germany and Norway then harmonized the licensing which enabled us to take a final investment decision in 2015.

How important was the TenneT-Statnett partnership to the NordLink project?

T.M.: The key to such projects is to have one project team. For us the team did not only include Statnett and TenneT, but also our suppliers Hitachi ABB Power Grids, Nexans and NKT. You can only be successful if you deliver the project as one team. If you start fighting on these kinds of projects, you will get lost.

H.B.: In the beginning we worked on the project culture in a very professional way. We spent a lot of time developing the one-team culture and we needed that because we did encounter challenges that we had to solve together. We couldn't take a decision in Norway and then hear that in Germany they didn't agree. We needed to tie the decision-making together and that worked amazingly well.

I remember when the Statnett board asked me about the risks involved with constructing the NordLink cable in the Wadden Sea. I said: 'Well, we have a strong partner.' Without TenneT on board, I don't think it would have been easy for us to deliver the project. It's fair to say that with TenneT we lifted the technology to the next level because together we were the first in the world to up the converter voltage level on an interconnector to 525 kV.

We also got our partner KfW on board because when you commit to such large investments you need to have strong partners. With KfW also involved, we had the financing and the building capability in place.

What were some of the biggest challenges you encountered when developing NordLink?

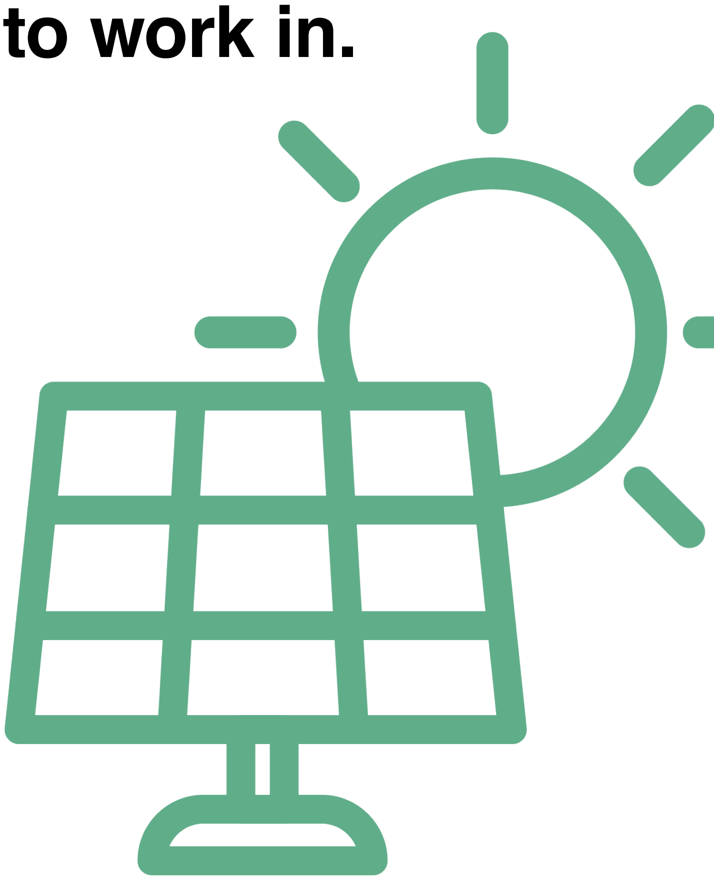
T.M.: The size of the project in itself was one of the challenges. It's currently the longest interconnector cable in the world and that also meant we had a lot of different environments to work in. We had to drill through the mountains on the Norwegian side, then we went into water that was up to 400 meters deep, and then we had the Wadden Sea which is on the one hand very sensitive and required innovative eco-friendly equipment and procedures but also had a sandbank which is so shallow that normal equipment can't pass through. Even with special equipment, we could only pass once a month when the moon was in the right position and the tide was a little higher than usual.

Additionally, the cable is so long that we needed two different manufacturers because one factory would have been overloaded with the amount of cable demand. This added another technical risk because we had to connect two different cables.

Source: TenneT

> **The size of the project in itself was one of the challenges. It’s currently the longest interconnector cable in the world and that also meant we had a lot of different environments to work in.**

Tim Meyerjürgens



At the open trench during the cable pull-in of NordLink in Warwerort Village, near Büsum, Germany
Source: TenneT

H.B.: In the end we didn't face problems in the Wadden Sea but on the mainland in Germany. The German licensing authorities had experienced a lot of challenges with wind projects and that turned into a change in attitude towards NordLink. We had to give very detailed specifications of the routing and as a result we had to shift the timeframe by around nine months. But otherwise we managed to really keep the project well within budget and time and it has been a great success.

We shouldn't underestimate the high level of quality assurance we implemented on the project. Can you imagine laying a 525 kV cable under the sea? It's not gas, it's electricity. We monitored every single meter of the installation which meant that sometimes we had between 10-20 vessels offshore and we also had full control over the manufacturing process. All this we learnt from previous experiences.

Another challenge for Statnett was that we were developing the interconnector to the UK, North Sea Link, at the same time. The lengths of the NordLink and North Sea Link cables add up to 1,400 kilometers, which equals roughly 50 percent of the world's cable production capacity. We had to be quite careful how we managed that, but we got all the suppliers on board and both Nexans and NKT delivered perfectly on time.

Our strong focus on HSE has played an important role in the project and should also be mentioned as one of the key contributions to a successful construction phase. The HSE mindset has been visible throughout the project and by all involved parties.

T.M.: It was not only Statnett which had parallel projects, so did we. We were developing the offshore wind connections in Germany and required around 12 cables of 100-200 kilometers in length each. This means that almost the other half of the world's manufacturing capacity was required by us to deliver also the offshore connections in time.

A vessel lays the first meters of the NordLink subsea cable in Summer 2017
Source: TenneT

Our investments in interconnectors are all driven by the fact that they bring value to the society because of the trade between our hydropower and the growing amounts of renewable power in continental Europe. The European energy system has shifted over the past 20 years from being a thermal power system to a green one.

Håkon Borgen

How is the NordLink interconnector performing today?

H.B.: We successfully completed trial operations on 31 March. The energy availability was beyond the contractual value and that's why we took it over. In that respect it was a success and we haven't had any major issues.

We had some issues during commissioning and the link tripped. One trip at 1,400 MW, that impacted the power systems on both the Nordic and Continental sides. We made changes to the control system and now it is working well.

The completed NordLink converter station in Tonstad, Norway
Source: TenneT

In the design phase we took the very wise decision to add fast DC breakers. These are installed to take in half the pole if we have a problem on only one of the converters. This ensures that we only lose half of the capacity when we have a failure.

Our investments in interconnectors are all driven by the fact that they bring value to the society because of the trade between our hydropower and the growing amounts of renewable power in continental Europe. The European energy system has shifted over the past 20 years from being a thermal power system to a green one.

T.M.: When we took the final investment decision in 2015, NordLink was still a bet because renewables were already important but not in the same way as they are today. They are now also on the political agenda as the energy transition has really accelerated over the past years. Today, this kind of link is more important than ever. We are happy we took the decision to invest even before the energy transition had really started.

H.B.: We had to bet on the renewable energy future and the price of CO_2. Back in 2015 we believed that the price of CO_2 would go up and that has now happened. Looking ahead, the business case will be even stronger because we'll have maybe ten times as much wind and solar power in continental Europe, which Norway can use to regulate its hydropower. It will be a huge transformation of the whole European energy system and it feels good to be able to say that NordLink fits perfectly into that outlook.

Having said that, it's important that the energy availability of the link is high and that the technology delivers these benefits.

What does the future hold for the Statnett-TenneT partnership?

T.M.: We [TenneT] are taking all the knowledge and experience gained to serving the German and Dutch energy transition. We have chosen the 525 kV specification used on NordLink for the large onshore corridors we are building from the northern part of Germany to the south. We are also using 525 kV for the next generation of offshore wind connections. The North Sea will be the powerhouse of northwestern Europe and we need its offshore wind to serve our demand for energy.

We are now building connections that are what we call hub-ready. For the 2 GW offshore wind projects we are just preparing to connect, we are leaving space on the platforms to be able to integrate future DC breakers. This helps us avoid making investments now that are not future proof.

To serve the European energy transition we cannot wait with our investments and we are working with other TSOs and our suppliers on technical standardization. We are currently running an open technology cooperation program for all potential HVDC suppliers of our project to connect 2 GW of offshore wind farms. We want to standardize these platforms so that it doesn't matter which supplier we choose. Interoperability is the next step.

H.B.: The scale of new production offshore will affect the entire European energy system, Norway included. We see building meshed grids offshore as a big challenge ahead in order to connect all this wind to the European onshore grid. Future investments will be difficult unless we solve interoperability, unless we have control over this issue in order to reduce the risks. What we want to avoid is that each operator chooses their own voltage and their own design because that will not deliver connectivity in a viable way. We have to cooperate strongly in order to make it work. Statnett and TenneT are working on this together and more broadly within the ENTSO-E committees. There's no doubt that time is pressing because the offshore grid in Europe will come.

T.M.: We only get there if we all get there. The energy transition is such a huge challenge for all of us, we cannot do it alone and it's also not a competition.

What will the future offshore grid look like?

H.B.: If we look at NordLink we are looking into the future because it is likely that there will be an increasing number of these large components connecting to the AC grid. We need a deeper understanding of how to run this system and how to deal with the reserve strategy. What we will see in future is the offshore and onshore grids merging. At Statnett we believe that it is important to look at the grid in a holistic way instead of onshore/offshore in order to assess grid strengthening as a whole. When looking at the next ten years, we need a holistic view of the grid in order to understand how best to deliver the energy transition.

T.M.: The ENTSO-E area was designed for a balancing power capacity of 3,000 MW in order to compensate the loss of two 1,500 MW nuclear plants at one location at the same time. But with our newest projects we're using larger units than nuclear power plants. Our new onshore links and offshore connections will have a capacity of 2,000 MW each. We have to deal with this and find ways to keep the grid stable if something unforeseen happens.

Another challenge of collaboration is that we still have different market models in different countries. An offshore wind farm, for example, is very difficult to connect to an interconnector because there is uncertainty among governments over wind farm subsidies bringing unintended benefits on the other side of the cable. These are all subjects that are solvable but it takes time to harmonize the market models.

There’s no doubt that the electricity grid is the backbone of the energy transition and without it we will not be successful.

Tim Meyerjürgens

Where is the energy transition heading?

T.M.: We are transforming the whole energy system in Europe from thermal-based power to renewables which brings completely new challenges as well as different needs for the grid. There's no doubt that the electricity grid is the backbone of the energy transition and without it we will not be successful. If we are not successful as TSOs, Europe will not be successful with the energy transition. To me that's really key and that's why I'm working in this sector. It's such a great challenge we are facing and what I like every day in my job is that you can really influence to meet best results.

One aspect that is often forgotten is that we in the power sector are quite advanced in the energy transition because we've been working on it for 20 years now and are reaching our goals. But now we are also seeing other sectors accelerating to decarbonize. Especially if you look at the chemical and steel industry, they are now going for electrification. That means that our electricity consumption will easily double in the next years. That's our next challenge, but we are working already on the solutions together with our partners.

H.B.: It's not difficult to build a renewable energy system in itself but what is difficult is making it secure enough for the customers in Europe. The huge challenge is to deal with the intermittency of renewable energy. We need to work together because the challenges are too big, we can't solve them alone anymore. We need cooperation and innovation in order to make this future system resilient. The goal of reaching zero emissions is an amazing task that is extremely motivating to work for. It's bigger than the moon landing, it's really something.

The NordLink converter station site in Wilster, Germany
Source: TenneT

Niklas Persson
Managing Director,
Hitachi ABB
Power Grids

I would like to thank Tim and Håkon for their valuable and interesting insights into the history and development of Europe's biggest renewable energy highway.

This is a benchmark project for the global power industry, which I'm convinced will inspire generations of engineers in years to come. It has enabled all partners to bring together their unique skills and experience to deliver a world-first project on time, in spite of the global pandemic.

I am immensely proud of my company's contribution to NordLink. Our HVDC technologies and the expertise of our people in designing and delivering complex grid interconnections of this kind have contributed to the project's success.

We have worked closely over many years with Statnett and TenneT on HVDC and other grid solutions. Together, we are enabling Europe to move toward a carbon-neutral energy system.

Accelerated grid development is indispensable for speeding up the European energy transition

Chris Peeters
CEO, Elia Group and Elia Transmission

Stefan Kapferer
CEO, 50Hertz

The European Union's (EU) recently sharpened climate goals have officially set the wheels in motion for Europe's speeding up of the energy transition. The challenge of increasing the share of renewables in energy consumption to at least 32 percent by 2030 will require tremendous efforts in terms of the building of green energy plants. Tremendous investments will also be required in Europe's electricity networks, which are essential for powering the continent with green energy.

We have invited Chris Peeters and Stefan Kapferer, two leaders from the frontlines of this transmission challenge, to share their thoughts about how speeding up the energy transition will impact their businesses. Chris Peeters is the CEO both of Elia Group and of one of its subsidiaries, Elia Transmission, which is Belgium's transmission system operator; Stefan Kapferer is CEO of Elia Group's second subsidiary, transmission system operator 50Hertz, which operates in eastern Germany and Hamburg. They are jointly investing close to €1,5 billion this year in new and existing power lines and have earmarked offshore energy as one of the cornerstones of the energy transition. They argue that local acceptance and political support are crucial to accelerating green energy growth and that it is only through cooperation with each other that member states can reach their full renewable energy potential.

What does the increased renewable energy target included in the European Green Deal mean for your businesses?

Chris Peeters (C.P.), Elia Group: It is acting as a catalyst for necessary increases in investments in the grid. The electricity sector has a central role to play in reaching those targets, but the only way to reach them is by integrating renewables into the value chain more rapidly. The consequence of this, of course, is that the grid needs to be adjusted in line with this new reality: more of the energy generated offshore needs to be brought onshore to demand centers. There is quite a lot of pressure on us to grow our infrastructure within the given timeframes and, if possible, to do so even faster than was previously thought necessary. Finding ways to accelerate those investments – that is a clear consequence of the European Commission (EC)'s ambition.

The most important challenge with regard to building more infrastructure is local acceptance. Everybody agrees that the targets the EC has set are the right ones, but when you spell out their consequences, people complain about the cost and the impact on their neighborhoods. This is a difficulty we, as a society, face: we don't necessarily accept the consequences of the goals we set ourselves. That is a challenge for us as grid operators, because we have to spend an enormous amount of time on permitting processes.

Everybody agrees that the targets the European Commission has set are the right ones but when you spell out the consequences, people complain about the cost and the impact on their neighborhood.

Chris Peeters

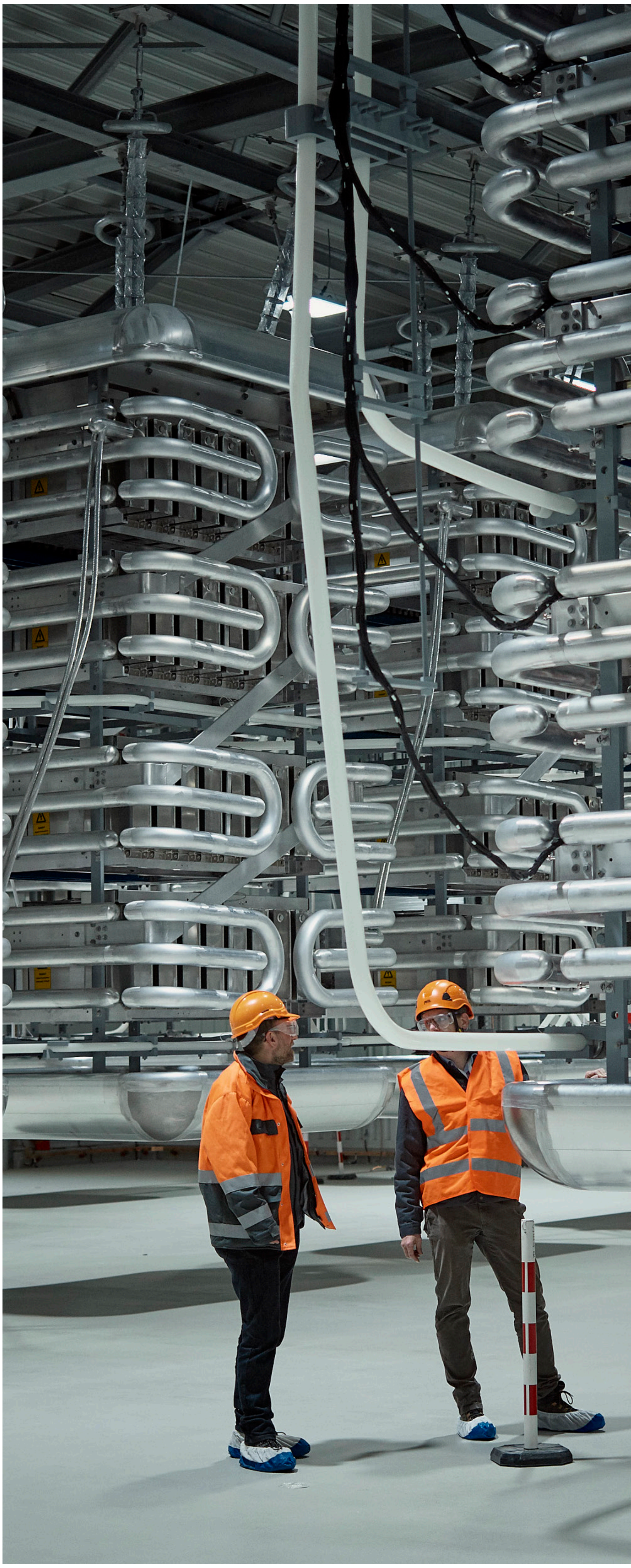
Stefan Kapferer (S.K.), 50Hertz: The climate-neutrality target has made it clearer than ever that electricity has a key role to play in all sectors, not just in the energy sector. It is also becoming more relevant for the mobility and heating sectors. The grid infrastructure is the backbone of that transformation process.

At 50Hertz, we have set ourselves the target of meeting 100 percent of the electricity demand across our grid area with renewable energy by 2032, up from 62 percent in 2020. 2032 is only 11 years away. In Germany, the issue is not a lack of capital to be invested in renewable energy: often, there is a lack of investment opportunities, especially in the area of onshore wind. This needs to change. How long does it take for a public body to respond to an investor about a permit application? How long does it take for legal claims to be addressed by a court? The German authorities should be very clear in establishing their priorities in areas such as these. If climate neutrality is a top political priority, politicians should ensure that public bodies are recruiting additional staff to match the rise in the number of infrastructure projects. This would be a relatively affordable step to take which would greatly help us to speed up the energy transition process.

Both of your grids have offshore wind farms connected to them. What role is offshore energy playing in the energy transition?

S.K.: Offshore energy will become increasingly relevant for the energy transition because of the EU's very ambitious goal of becoming the world's first climate-neutral continent. It is obvious that offshore energy can make the biggest contribution to the transition because offshore wind turbines have higher full load hours than photovoltaic energy sources or onshore wind turbines. Moreover, we all know about the restrictions which prevent the expansion of onshore capacity in densely populated countries in Europe, so the volume of energy we will be able to create with offshore technologies is extremely relevant.

Additionally, it is obvious to me that the integrated EU energy market will include connections across the Baltic and North Seas. As transmission system operators, we are discussing the building of more interconnectors, the creation of offshore energy islands and the laying of hybrid connections like the **Combined Grid Solution (CGS)**. Indeed, we have started making plans with Energinet for an energy island on Bornholm, and, in fact, this project is open to the involvement of other countries with a Baltic Sea coastline. I can imagine that, for example, Sweden or Poland will also eventually be connected to the island. The more connections we create across the Baltic and North Seas, the better. Projects like Bornholm are blueprints for how we can come together and connect and grow the EU energy market.



> As transmission system operators, we are discussing the building of more interconnectors, the creation of offshore energy islands and the laying of hybrid connections like the Combined Grid Solution (CGS).

Stefan Kapferer

Source: 50Hertz

C.P.: Given that we operate in two countries which will not be able to produce enough renewables to meet their energy demand, it is important that we are involved at an early a stage in the further development of the Baltic and North Seas. The vision driving our energy island projects is that without our early involvement in the process (as other countries are developing their offshore strategies), developments may occur which are not beneficial for all EU countries. Countries that have an excess of renewables might consider other options, or not fully capitalize on their potential. So it's necessary for us to engage in dialogue and project development at an early stage, to ensure that everyone can benefit from development in the North and Baltic Seas.

A growth in offshore energy capacity also means a higher influx of direct current electricity, which needs to be converted onshore. How are your businesses dealing with this?

S.K.: Of course, we need additional investments to be made in the onshore grid, but we shouldn't overestimate the challenge this presents. In terms of production, offshore wind is comparable to other forms of baseload energy, which makes it much easier to plan the onshore grid infrastructure in line with the needs of offshore wind farms. On top of this, large investments are needed in the distribution grid at local levels to meet the capacity of onshore renewable energy sources like solar and onshore wind farms. Having a good understanding of the additional offshore capacity which can be fully utilized in the North and Baltic Seas over the next decade means it's relatively easy to plan out the onshore grid infrastructure. Over the past five years, we have been able to reduce onshore grid constraints and, as a result, costs have been shrinking in Germany. We have been very successful in preparing the grid for the connection of offshore capacity.

C.P.: The challenges we face vary according to geographical locations. In Germany, the north-south connection needs to be completed. You're essentially replacing thermal capacity in the south with wind power from the north, so you have to adjust the grid in line with that reality. If you look at a small country like Belgium, it's about connecting regions that have the most potential in terms of renewables with regions that have the least potential. This means the focus in Belgium needs to be on building interconnection capacity – and, indeed, we have made significant progress on this over the past few years. We have focused a lot on reinforcing existing interconnection capacity, for example with the Netherlands. Last year, we also commissioned the first direct connection with Germany. It's an HVDC connection that ensures security of supply in an environment where thermal capacity is being replaced by renewables at a relatively high speed. We have also created new interconnections by building a direct link to the UK via the Nemo submarine cable.

How has your presence in both Belgium and Germany helped you tackle the challenges caused by the energy transition?

C.P.: This gives us enormous advantages as a Group. At a macro level, both countries face the same challenges, but in terms of concrete details, they are very different. If you look at the 50Hertz area, it's already one of the leading regions in the world today in terms of renewable integration. A 62 percent coverage of demand by renewables is extremely rare, especially considering there is not much renewable power that can be dispatched (like hydroelectricity), which is able to compensate for less windy and sunny days. That makes Germany a very unique place, where a lot of learning is happening. In addition, 50Hertz is one of the front-runners in offshore wind development. We have brought many of the lessons we have learnt about offshore wind to Belgium. **Our Modular Offshore Grid (MOG)** platform, for example, was a direct result of this sharing of expertise and our collaboration.

If we look at what Elia's experience in Belgium brings to the Group, we are a highly interconnected country with lots of experience in market coupling and bringing electricity to energy-intensive industries. We are also a leader in Europe in terms of the development of flexibility in the power system, and this expertise has been used by 50Hertz. Every day we learn from each other, and that makes Elia Group an interesting and truly European company for young talent to join.

As we pursue our European goal to become climate-neutral, collaborating with EU member states will become more and more relevant. We at Elia Transmission and 50Hertz already have to collaborate a lot, which creates an opportunity for the future in that a culture of collaboration is already embedded in our teams.

The flexibility that decentralised generation brings is very relevant. What we can see is that more and more people will not only have the ability to produce their own energy, but will also be able to store it, through technology like electric vehicles or heat pumps.

Stefan Kapferer

The Belgian and German governments have decided to phase out nuclear and coal-fired power, respectively. What challenges have these decisions caused for your businesses?

S.K.: 50Hertz's control area has traditionally been influenced by coal power production, because it includes the coal-producing areas of Lausitz and Mitteldeutsche Revier. A few weeks ago, all four German TSOs published a report about the situation and concluded that in terms of security of supply and market stability, we are ready to handle the phasing out of coal-fired plants. Obviously, however, the situation will involve a change for Germany: it has traditionally exported electricity, but it will now gradually become an electricity importer. This is one more reason why these investments in renewable energy are so relevant for Germany in the future.

C.P.: In Belgium, it's obvious that the decision to phase out nuclear power is a purely political one. We as a TSO only provide facts and figures in order to support politicians in their decision-making. Once a decision has been taken, we have to ensure that the right measures are in place to manage the situation. At the moment, we are supporting the Belgian government as they set up a capacity remuneration mechanism, which is currently under review by the EC. If it's approved – it is necessary for fully phasing out nuclear power by 2025 – we will be responsible for managing the capacity auction process. We will support the government in selecting the plants that can be connected to the grid over time, so that we can ensure a smooth transition.

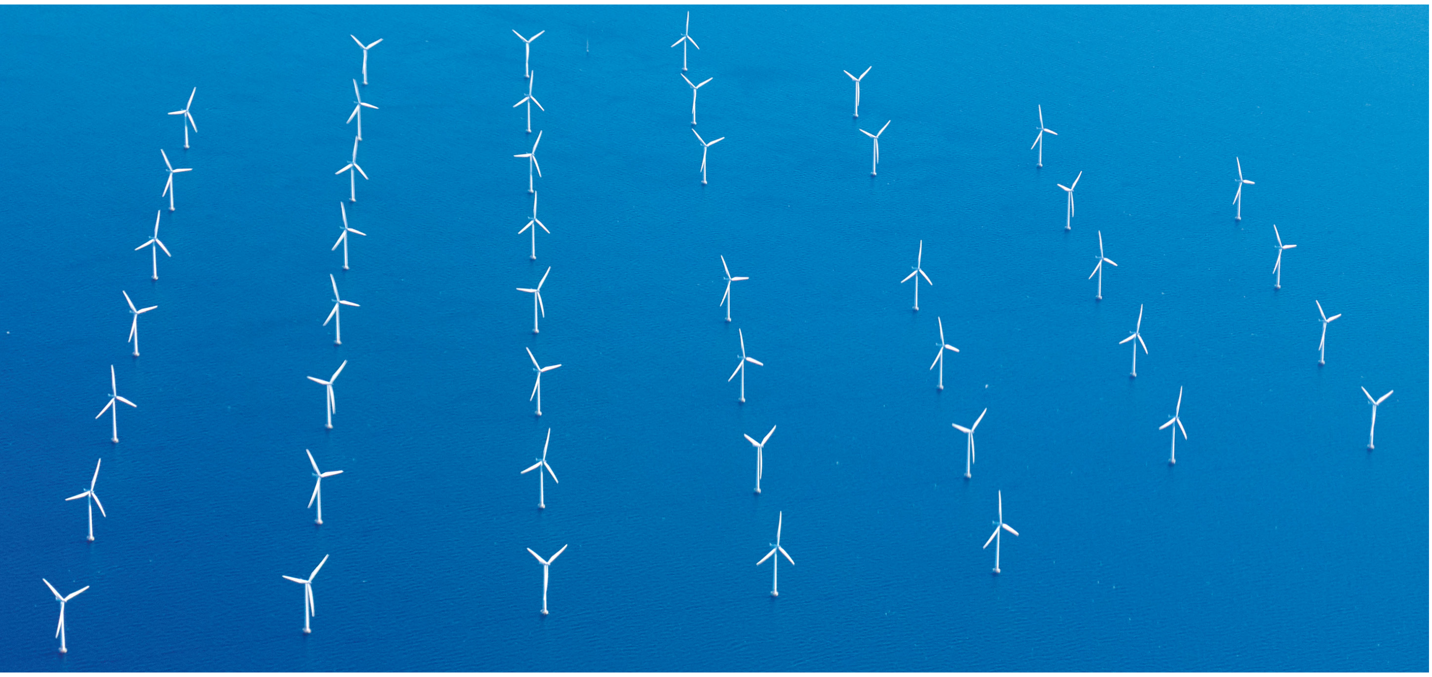
An important change brought about by the energy transition is the rise of prosumers. What impact has decentralized generation had on your businesses?

S.K.: Coming from a TSO, this may surprise you, but it is of course a development we welcome. We welcome seeing more people engaging with the energy transition and being interested in producing energy themselves. Obviously, Germany's energy system has changed: it was traditionally based on a few big power plants, but it now has millions of dispersed renewable generation sources. We need more digital technologies to run the business in future, meaning that the need for us to transform into a fully digital TSO is becoming more and more pressing.

The flexibility that decentralised generation brings is very relevant. What we can see is that more and more people will not only have the ability to produce their own energy, but will also be able to store it, through technology like electric vehicles or heat pumps.

How do we communicate with and integrate the flexibility of these prosumers into the system? This is one of the most pressing questions we need to answer for the coming decades.

C.P.: The big game changer is not so much solar panels themselves – because they are already being used - but what happens when you add the option of flexibility to the equation. We will see an increase in optimization of supply and demand, with people saying: 'I see I am producing electricity at the moment, so I might use it to charge my vehicle.'
There will be a real change in the dynamic.
For us, as grid operators, this is a real opportunity. We are active in a part of the sector that will continue to grow, whatever happens. Consumers can build as much generation capacity as they want, local communities can build as many energy cooperatives as they like, at the end of the day you will need more grids because the bulk of the energy needed for industry and big cities will come from the sea and large installations.



Combined Grid Solution and Bentwisch Converter Station
Source: 50Hertz

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Chris Peeters

Offshore synergy – combining oil & gas experience with grid technology leadership for sustainable energy

Rajnish Sharma
Vice President, Renewable Projects, Equinor

Adrian Timbus
Chairman, ETIP Wind and Head of Portfolio and Strategic Marketing, Hitachi ABB Power Grids

Alfredo Parres
Head of Renewables, Hitachi ABB Power Grids

In this Perspective, Adrian Timbus invites wind power experts and energy transition leaders to share their perspectives on how the offshore wind sector is evolving. Rajnish Sharma, Vice President of Renewable Projects at Equinor, sets out how the Norwegian company is helping to bring down costs in the offshore wind sector by applying knowledge and transferring technologies from its oil and gas business, including drones that assess wind farm blades and autonomous inspection vehicles that can operate both on subsea and above sea levels. Alfredo Parres, Head of Renewables at Hitachi ABB Power Grids, explains how HVDC technology is central to connecting wind farms located increasingly far away, and how sharing data and evolving the operation and maintenance practices need to become the norm to help cut costs.

Wind power is one of humanity's biggest hopes for an affordable, carbon-neutral energy future, being one of the preferred technologies – alongside solar – for energy companies to invest in. Although wind power is abundant on land, we must go to the seas and oceans to satisfy our current and future sustainable energy needs. But this is not a task for everyone – it takes courage, expertise, and a pioneering spirit to do it. And not many companies are capable of operating offshore assets, which need to stand up to constant exposure from nature's harshest elements.

Norway's Equinor is one of the first oil and gas majors to enter the offshore wind market. The company has decades of experience with building and operating large offshore energy infrastructures, scaling up new technologies, setting standards, and excelling at health and safety.

Since the early days, Hitachi ABB Power Grids has supported wind turbine manufacturers and operators of wind farms with innovative solutions. Together with customers and partners, the wind pioneer is contributing to the transformation of the industry – making wind energy a resilient and reliable power generation technology.

Both companies are planning to take the offshore wind sector to the next level.

What will the 'next level' look like?

It must be affordable, floating and intelligent.

Offshore wind has shown its competitiveness compared with other sustainable energy sources, such as solar and onshore wind, which are easier and cheaper to develop. The segment however needs to use all the available intelligence to further innovate and prove its competitiveness.

Affordable

"If we look at the development of the Levelized Cost of Energy (LCOE) of offshore wind power, it has declined a lot in the past five to seven years. There are many factors that have contributed to that, but the key ones are technological development, increased competition, learning rate, scale and volume, and cost of finance. We believe that with further technological innovation we will see even lower LCOE towards 2030 and beyond to 2050," says Rajnish Sharma.

It must be affordable, floating and intelligent.

Rajnish Sharma

Technological development of the wind turbines has been one of the key factors contributing to the reduction of LCOE for offshore wind. Their size grew dramatically in the last years, reaching sizes of 14 MW today. "My personal view is that we will see 20 MW+ turbines by 2030," continues Rajnish.

Scaling up power levels makes turbines more efficient and harvests more wind energy.

"But to optimize costs across the overall system, one needs to also consider the voltage level at which the equipment operates. For 20 MW+ turbines, our studies show that we can get a higher efficiency and a lower cost of the overall system if we use 132 kV voltage levels," explains Alfredo Parres.

Equinor's Hywind Scotland is the world's first floating offshore wind farm
Source: Equinor

And offshore wind continues to go larger, farther, and deeper. Just a few years back, we were developing 600 to 700 MW wind farms. Now 1.2 GW has become the typical size. The addition of 1.5 to 2 GW wind farms that we see ahead creates constraint-related questions for grid connection capacity. For these wind farms, we need efficient and resilient transmission solutions such as HVDC operating at extra high voltage levels.

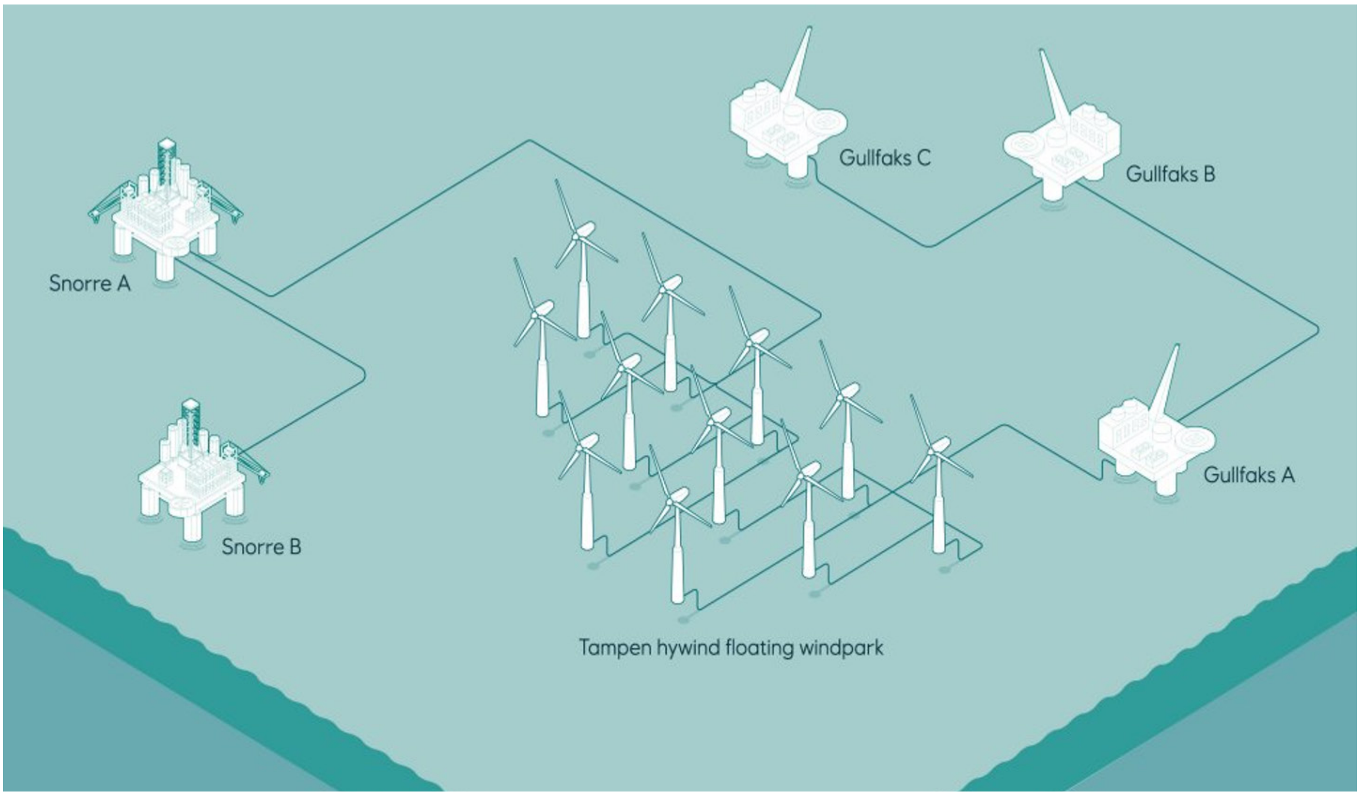
"But can we go to 525 kV DC? That's something we would expect to work on together with technology leaders like Hitachi ABB Power Grids," says Rajnish.

Floating

Not all seabeds and ocean floors are suitable for developing wind farms on fixed structures, and there is a limited area of seas suitable for wind farms on bottom-fixed structures, which will not fulfill our energy needs. Therefore, we need to look into developing floating wind solutions.

"At Equinor, we think that floating wind is going to be a key technology for achieving our climate ambitions towards 2050.

Rajnish Sharma



Equinor's Hywind Tampen is the world's first renewable power for offshore oil and gas
Source: Equinor

At Equinor, we think that floating wind is going to be a key technology for achieving our climate ambitions towards 2050.

"With **Hywind Scotland**, we have shown that the technology works. In the first two years of its operations, it had the highest capacity factor in the UK with an average of 54 percent, while other offshore wind farms in the UK are at 40 percent.

In that last 12 months up to March 2021, we even saw an average of 57 percent. Because of its incipient state and undeveloped supply chain, the cost of floating wind is still higher compared with fixed wind. We have proven however that we can considerably bring the costs down through industrialization and scale.Between our **Hywind Demo** and **Hywind Scotland** projects, we managed to reduce capex by 70 percent. Between Hywind Scotland and **Hywind Tampen**, our ambition is to reduce capex by another 40 percent," he continues.

"Scaling these projects from one turbine to five turbines to 11 turbines has brought these cost reductions. Scale is really important to make further cost reductions and to make floating wind more competitive.

We expect that in the next ten years it will be very competitive with fixed wind, but scale is needed for that and that comes with industrialization and volume through mass production. We need policymakers and authorities to be clear on their ambitions and to make statements about deploying offshore floating wind. The UK, for example, has done a good thing in proposing a third pot for the Contract for Difference (CfD) dedicated to floating wind technologies, incentivizing developers to develop and mature floating wind solutions. The UK has in fact set a clear target of developing 1 GW of floating offshore wind by 2030. In this way the projects don't compete with fixed offshore wind farms in the subsidy allocation rounds," concludes Rajnish.

"Together with our partners, we analyzed and concluded that floating solutions are very much feasible. We simulated and **tested the behaviour** of electrical components in both wind turbines and substations. There are no technology barriers to develop and scale up floating solutions," says Alfredo. "We need to standardize the floating systems in order for the industry to align and contribute to the scaling up," the continues.

Intelligent

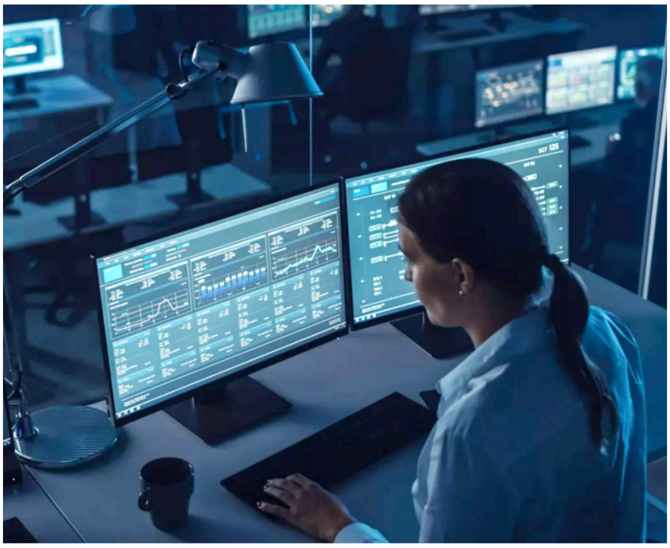
Digitalization brings a lot of intelligence and offers great opportunities to optimize costs, maximize efficiencies, and increase health and safety for the offshore industry. With proper instrumentation of wind farm assets and utilization of modern, **mission-critical communication technologies** and latest **Operations and Maintenance (O&M)** software, we enable the ability to operate and diagnose the assets from thousands of kilometers away - from our offices and even from our homes. Reducing the number of trips to the seas not only reduces O&M costs but also health and safety risks of personnel.

"We are bringing a lot of technical development from our oil and gas business over to offshore wind. Equinor has always been at the forefront of utilizing new technologies and we've been working a lot with digitalization. For example, we have been using drones for the inspection of blades. In oil and gas business, we have used autonomous subsea inspection vehicles which we can also utilize for offshore wind," explains Rajnish.

"The wind industry was very much developed around turbines, and they are really sophisticated and intelligent machines. But the industry can do more with integrating the data across the whole system and using the information from the turbines, the substation, and grid connection, and consume this in a smart way to further reduce operational expenditure.

Production and revenue forecasting is very important for developers before investing, beginning with the design and during the operation of the wind farms. And for accurate forecasting, we need to integrate data across many areas, such as wind data from the site, equipment design data, grid connection details, and of course offtake energy prices.

Furthermore, **energy management** and **prognostic asset management** are critical solutions for wind farm operators to ensure the investment case is achieved," says Alfredo.



Intelligent data monitoring is becoming key to the operations and maintenance of wind farms

Drones are now being used to inspect wind farm blades

> **Furthermore, energy management and prognostic asset management are critical solutions for wind farm operators to ensure the investment case is achieved.**
>
> Alfredo Parres

"Predictive maintenance is really important and a low-hanging fruit. Sharing data and utilizing it for decision making is also very important. We have a lot of data today and we need to exploit it better and utilize it to improve operations and maintenance," adds Rajnish.

How do we ensure that we get to the 'next level'?

Align and commit on all sides.

All of this will simply remain a dream of few pioneers if we don't actuate all the levers to make it happen. We need good planning across policies, technology and solutions development, as well as risk management activities.

But more than ever, we need the tight collaboration of all stakeholders - the developers, the maritime sector, the grid planners, and the technology providers.

First and foremost, we need to ensure industry growth through proper policies across all markets in order to confirm the volumes for the supply chain. Visibility and stability of the policies always play an important role to bring an industry to maturity. We also need to agree on the areas of exploitation and ensure we have the proper grid connections to plug in the wind energy.

"The grid is a constraint that needs to be addressed. You can already see in many markets that these constraints are limiting the development of offshore wind. We need modernization of the grid and the surrounding infrastructure to ensure speed of development and reach net-zero targets," says Rajnish.

"The grid is central to offshore wind conversations, and designing the offshore grid and expanding the onshore grid are part of the solution. It's investing into the future that ultimately brings prosperity. We need strong infrastructure for the future and with electricity as the backbone of the carbon-neutral world, the grids need to be in good shape," adds Alfredo.

"

But more than ever, we need the tight collaboration of all stakeholders - the developers, the maritime sector, the grid planners, and the technology providers.

Rajnish Sharma

> **The grid is central to offshore wind conversations, and designing the offshore grid and expanding the onshore grid are part of the solution. It's investing into the future that ultimately brings prosperity.**
>
> Alfredo Parres

Innovating and co-creating together

Pushing technological boundaries and developing innovative solutions are also critical to ensure that offshore wind delivers on its promises. Scaling up requires new and more effective materials in order to build lighter but stronger wind turbines. Recyclability is also important. We need to guarantee that turbines jump from the current 85-95% recyclability rate to 100% rate.

As we continue to anchor wind projects on the existing grid infrastructure, we also need to start designing the offshore grid to give us the necessary capacity and flexibility to export the offshore wind energy to all corners of the grid. As HVDC becomes a key technology for offshore grids, interoperability between players and a proper DC grid concept capable of exporting to all countries to support the envisioned growth of offshore wind power are necessary.

But the story does not stop here. We also need to evolve our energy and grid management solutions to suit the future – more dynamic state – of the system, driven by variable generators and loads. Besides, as we build more and more wind power in the waters around us, we must guarantee that consumers are able to profit from it. Electrification solutions for transportation, industrial, and heating and cooling sectors must therefore be adopted. With these efforts combined, we will achieve our carbon-neutral ambitions in time and at an affordable cost – with electricity as the backbone of the entire energy sector.

Carbon-neutral society needs a better energy-mobility nexus

André Burdet
Product Managament and Strategy,
Hitachi ABB Power Grids

In this Perspective, André Burdet, Hitachi ABB Power Grids, explores how the emergence of electric mobility interconnects with sustainable energy to deliver on the promise of future cities as we journey towards a carbon-neutral society.

Transportation is integral to sustainable cities

The move towards cities of the future is an exciting journey. Despite the current global pandemic, cities will continue to be the powerhouses of economic growth. Home to big businesses, policy makers and billions of urban dwellers, cities are intense, dynamic and vibrant places.

The rapid growth and evolution of cities presents huge opportunities and challenges for societies and the communities who live, work and relax in them – ideally, in harmony. UN Sustainable Development Goal (SDG) 11 sets out its Members' commitment to make cities inclusive, safe, resilient and sustainable. As part of a green economic recovery, the world's governments are in the process of planning stimulus projects. Sustainable infrastructure investments will help to serve as a springboard for human progress.

Transportation is integral to the success of any city. Sustainable urban development requires the efficient transportation and movement of people and goods – to, inside and between cities – a pre-requisite for societies to thrive and prosper. For example, the creation of the London's Metropolitan Railway in 1863 made the City, the UK and its people an early entry into the Second Industrial Revolution. Interestingly, this was not only enabled by the Railway itself, but also by the implementation of the supporting infrastructure, from coal mining to tracks construction. The later scale-up of the Metropolitan definitely changed the face of the urban environment of the UK and created whole new socio-economic sectors.

Our expectations of living and working in urban environments will continue to increase, stretching far beyond what the Second Industrial Revolution could ultimately deliver. Across the world, city dwellers expect an even greater standard and quality of life – cleaner, safer, more convenient, more reliable, more flexible, more accessible and more mobile living. Electric mobility epitomizes these expectations: intelligent cars, lorries, buses, trams and trains that run on net zero-emission energy will move life everywhere and more sustainably.

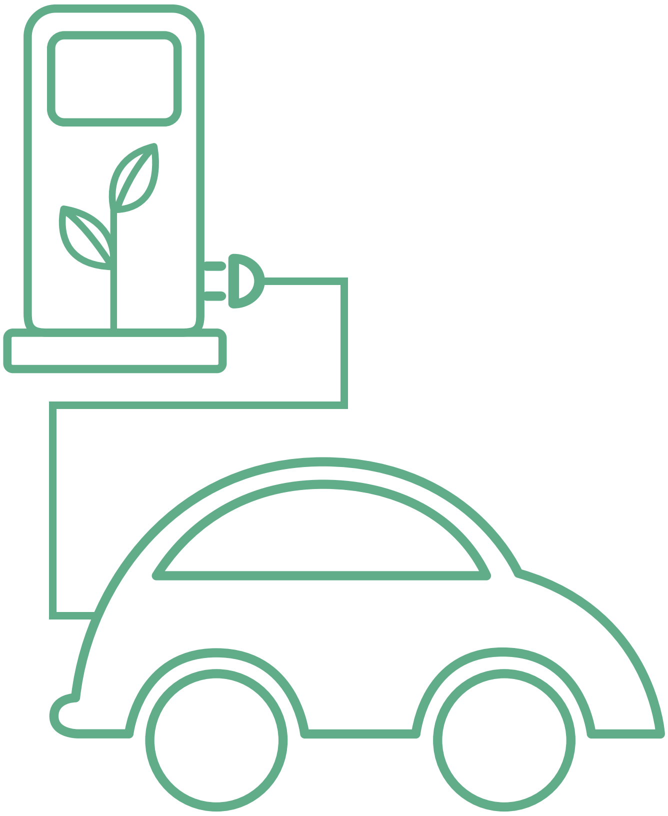
Across the world, city dwellers expect an even greater standard and quality of life – cleaner, safer, more convenient, more reliable, more flexible, more accessible and more mobile living.

Powering the future of green mobility

A phenomenal number of electric cars – more than 100 million – are forecast to be on our roads by 2030. This is a phenomenal 30-fold increase from today. Similarly, more than one million electric buses are expected to transport people in cities across the world's five continents. And for sustainable society to keep flowing, these electric vehicles (EV's) will need to be charged from renewable sources of energy.

By 2030, more than 500 TWh of electricity will be required to power these EV's – resulting in a potential saving of several Gt of CO2 emissions. To give a sense of scale, France's annual consumption of electricity in 2019 was in the same range. And 2030 is just a first step along the path. By 2040, electricity demand for EV's will be near to ten percent of global electricity demand. The rate of EV adoption will only continue to rise – and so too will global demand for flexible, reliable, sustainable and affordable electricity.

To fulfill the vision of sustainable cities and transportation, the world's energy systems need to be evolved to accommodate this rapid pace of change. Moving towards carbon-neutral society takes more than filling our cities with electric vehicles. To succeed, we must also install energy systems that act as the backbone for powering future cities and the transportation network, whilst keeping the lights on at an affordable cost.



"Moving towards carbon-neutral society takes more than filling our cities with electric vehicles. To succeed, we must also install energy systems that act as the backbone for powering future cities and the transportation network, whilst keeping the lights on at an affordable cost.

The new energy-mobility nexus

Electricity networks are the glue that will enable a truly sustainable electric mobility system and are integral to our future smart cities. Two building blocks are essential:

1. **Energy-mobility connection point:** an intelligent and convenient charging infrastructure spread across cities and national geographies alike that will work for cars and lorries driven by individuals, as well as public transport like buses, trains and trams.
2. **At the power network level:** an adapted and digitally-enhanced grid infrastructure that can host large volumes of renewable power and bring it reliably to an extended spectrum of consumers.

Both pose essential challenges to the realization of the electric transportation vision.

However, they can be technically managed and consequently, tremendous opportunities result from taking a holistic new 'energy-mobility nexus' – ultimately, making the connection between a better quality of life and economic development.

Tremendous opportunities result from taking a holistic new 'energy-mobility nexus' – ultimately, making the connection between a better quality of life and economic development.

It’s time to team up!

One of the major challenges for the new energy-mobility nexus is to bring several industrial sectors together.

Specifically, as electric mobility ramps up, energy and mobility stakeholders need to converge to a common set of systems and the way they interface. This is not only about technology, but also relates to business models, regulations and policies.

For example, when a public transport operator switches from internal combustion to electric propulsion, it is reliant on new sources of energy and new alternatives will be offered to integrate its network within the urban environment. Conversely, electricity providers will suddenly need to support new forms of ‘take-out’ from their network.

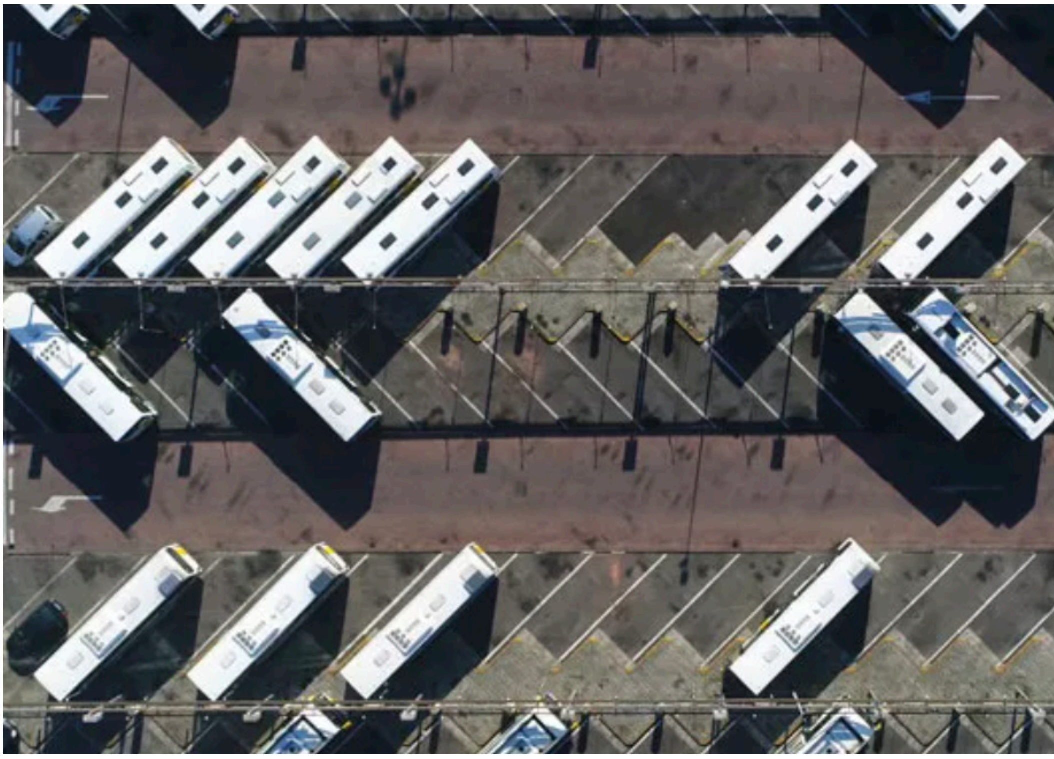
At present, the process of stakeholder cooperation is not yet laid down. As such, the risk is that not only the vehicle and the supporting energy infrastructure are not optimized, but also that they do not work together as one cohesive system. Without closer collaboration, the likely result is expensive retrofits at a later stage, which is not sustainable.

Scale-up is the challenge

So why are we still waiting to see greater collaboration? Mostly because until today the electric mobility market has just been emerging. Only a tiny fraction of vehicles are electric and therefore the need for charging has been addressed by ‘just’ installing a charger – resulting in no significant impact to the existing fleet operations or the electric grid.

However, as we move forward, the scale-up of electric vehicle fleet operations is on its way to making the energy-mobility nexus very apparent.

We are moving from kW’s to MW’s – from low to high utilization.



Energy and mobility actors feel this coming, albeit, it is still unclear what will be the role and responsibilities of everyone involved. Some big questions are on the table:

- How should the transportation networks and power grids of tomorrow be co-designed and operated?
- What would be the most appropriate technologies to connect both?
- What would be the most efficient business models of trade between them?

In order to address these questions and deliver effective solutions, we need to first establish a dialogue and strong cooperation between the expert stakeholders – ranging from technology providers, energy suppliers and vehicle manufacturers to transport operators and urban planners. The formation of sustainable partnerships across these stakeholder groups will help break the silos along the ‘grid-plug-vehicle value-chain’, enabling a greater system-wide approach to make rapid scale-up a reality.

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Electric mobility hubs

But what about the specifics of a greater system-wide approach?

At present, EV charging infrastructures are being developed in very disparate ways across the world. Flurries of single charging stations for cars are popping up all over urban areas and charging facilities for public transport are considered separately.

To prevent against a potentially very messy system that is difficult to maintain and somewhat redundant, **electric mobility hubs** are recommended.

These hubs – essentially 'charging centers' – offer a more efficient approach to planning in urban and sub-urban areas, and will also aid the switchover to more digital forms of mobility-energy management. For cars, hubs could be installed in existing infrastructure like car parks, or car rental centers. For public transportation vehicles, depots and terminal stations provide ideal locations. And a system of hubs within and around cities can be planned for efficient energy-mobility integration.

The wide-scale implementation of electric mobility hubs would seamlessly integrate grid connection systems together with configurable charging ports over an area.

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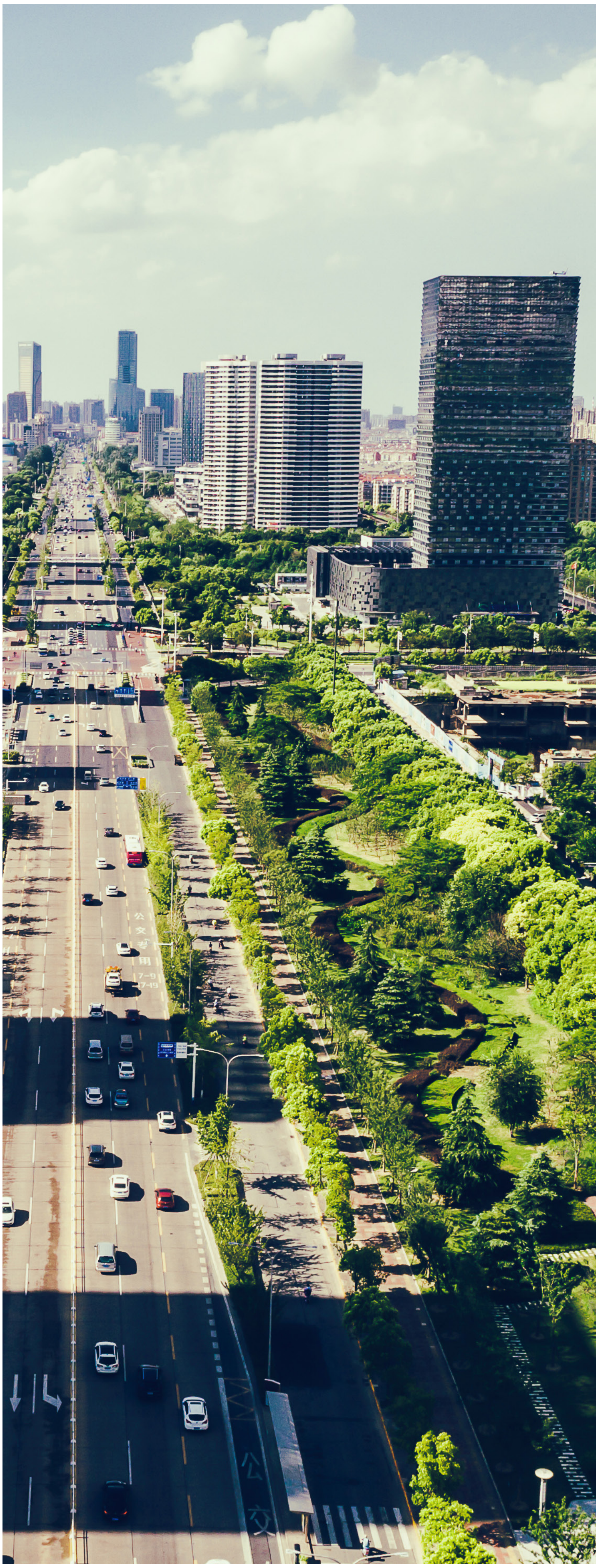


Whilst we may think these hubs would simply replace gas stations, they would in fact be able to do much more. They would include digital platforms for managing fleets and energy flows altogether. They would be able to operate flexibly 'on and off' grid, host solar panels and storage facilities, as well as other commercial activities. They would also help to maximize energy conservation and affordability locally, acting as 'micro energy hubs'. These hubs would indeed offer the opportunity to effectively organize micro energy trading between fleet operators, energy providers and end-consumers.

In short, no matter how vehicle technology evolves and power demand grows, electric mobility hubs would enable municipalities to have greater control over how they upgrade their infrastructure as EV usage expands and leverage them to organize a better energy system in their area.

This will mean much more dynamic power flows at all levels of the grid – we will move from broadcasting to ‘networking’ electricity.

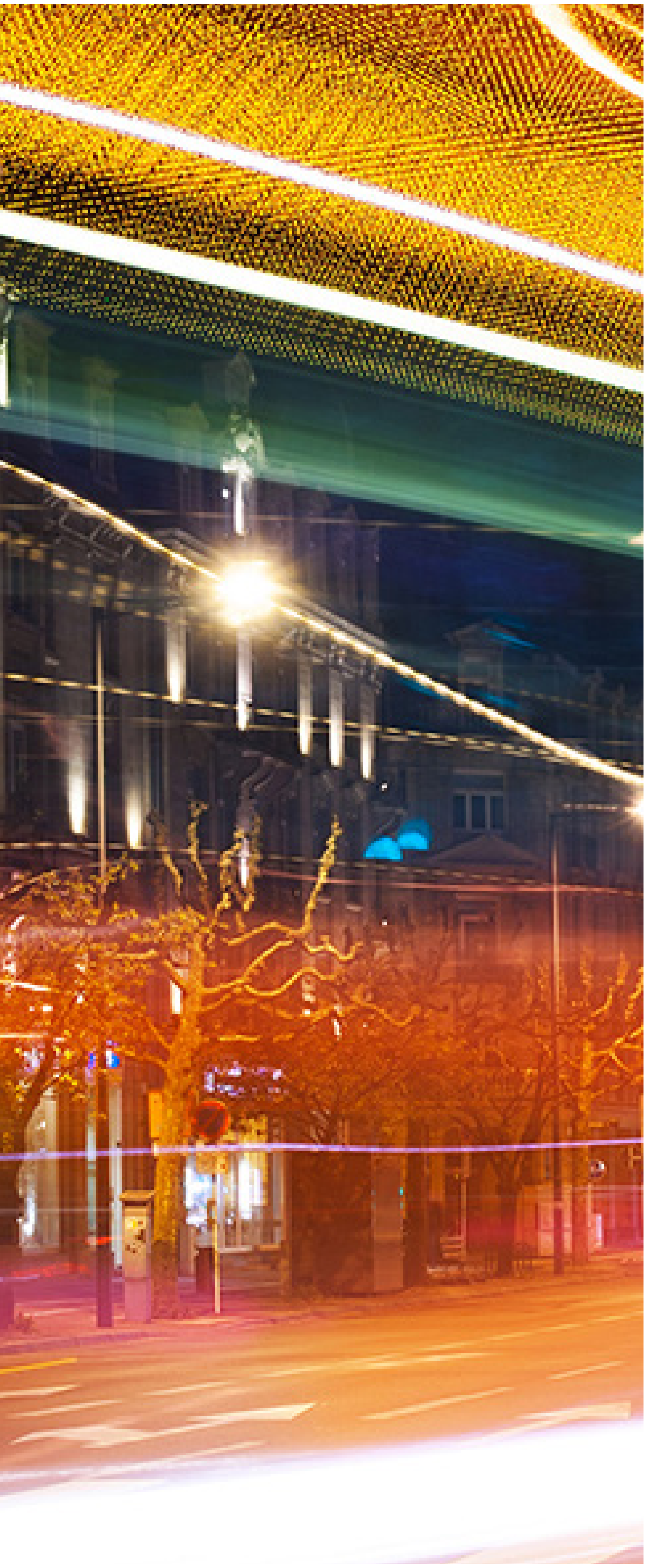
The intelligent grid

To close the loop on sustainability, we must develop the grids of the world to cope with very high shares of renewable energy sources to enable the reliable delivery of clean electricity towards carbon-neutral society.

This will mean much more dynamic power flows at all levels of the grid - we will move from broadcasting to ‘networking’ electricity.

An *intelligent grid* should have the ability to balance a higher variability of supply and demand, whilst being able to support of all forms of storage systems – including electric vehicles themselves.

The good news is that the existing grids of the world can be adapted for this more elevated mission. Recent advancements in grid technologies, systems and services offer a line of sight. Some essential technologies revolve around power electronics and digital solutions and a combination of the two. Examples of multiples, such as HVDC, Statcom and Grid Edge systems can be beefed up with digital connectivity from their core to cloud platforms. These systems and many others will allow the upgrade of existing assets and the creation of new corridors of energy – more versatile than ever – through our lands and cities whilst massively reducing their visible footprint. Combined, this will empower the new nexus of electric mobility to truly deliver upon our society’s call for greater green consciousness.



Moving forward…

Global energy and mobility systems are at an inflection point. The decisions that we make in the next decade will define how people move for the next generation.

Now is the time to get this right. Delivering new transportation systems for carbon-neutral society requires the formation of cross-industry sustainable partnerships to bridge the silos. It needs a system-wide approach in the interconnection point of the energy-mobility nexus. And investment is needed to enhance the grids of the world to be future fit to accommodate the rapid adoption of electric vehicles, which are powered by renewable energy sources.

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The decisions that we make in the next decade will define how people move for the next generation.

Shaping a smarter Singapore

Tan Chee Hau
Director of Planning and Prioritisation, Singapore's Smart Nation and Digital Government Office

Singapore's Prime Minister Lee Hsien Loong highlights that Singapore is an outstanding country for people to live, work and play in, where human spirit flourishes*. This focus and spirit is in evidence across the board as Singapore pushes the envelope of technology deployment to improve quality of life for its residents.

Today, Singapore runs one of the world's most reliable and robust electricity networks in the world. It addresses the growing energy demands of its residents and industries, while moving towards a low-carbon economy, through integration of renewables, 'green living' initiatives and implementation of viable market structures. Singapore's mobility landscape is also undergoing a transformation with the aim to phase-out fossil fuel-powered vehicles by 2040, improvement of last mile commuting for residents and innovative technologies such as autonomous vehicles and smart charging infrastructure.

We asked Mr. Tan Chee Hau, Director of Planning and Prioritisation at Singapore's Smart Nation and Digital Government Office (SNDGO) for his insights on Singapore's strategic priorities in the area.

What does it mean to be a 'Smart Nation'?

Our vision to turn Singapore into a Smart Nation is not just about pushing technology for the sake of digitalization. We need to translate the use of technology into tackling real-world problems and respond to different and changing needs. Our goals and objectives must absolutely be grounded in real-world results.

Our priority is to harness technology to address national challenges. We want to improve all aspects of people's lives and therefore we must drive transformation in domains such as health, education, finance, transport and urban solutions.

To facilitate this transformation, we cannot simply apply the latest technologies on top of our existing processes and organizations. It will require a fundamental rethink of our long-held assumptions and how we operate. It requires a whole-nation effort, involving every government agency, every business, and our people.

Therefore, Singapore has laid out mutually reinforcing plans to build a Digital Economy, Digital Government and Digital Society, involving the public, private and people sectors, to propel the nation forward.

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How does sustainability tie in with Singapore's Smart Nation efforts to digitalize the nation?

Singapore invested S$55 million in a Research & Development (R&D) program called Grid 2.0 to develop a next generation grid system. Grid 2.0 will transform how energy supply and demand are managed, creating a single intelligent network that is more efficient, sustainable and resilient.

Singapore's vision is to be a smart, green and liveable city in which our people and future generations can enjoy a high quality of life. Sustainability has been central to Singapore's development since our independence, and we have always adopted a long-term view in our planning. Digital innovation by companies, using technologies such as artificial intelligence (AI) and Internet of Things (IoT), will create new ways for our city to "do more with less". In other words, give our citizens a high-quality living environment despite being in a dense urban landscape, while reducing our carbon footprint and use of resources.

While we may have many new systems and infrastructures such as more efficient energy grids, solar photovoltaic cells to harness renewable energy and sensors to switch off water and light when not in use, the government is thinking about how to employ machine learning and AI to optimize resource

> **Grid 2.0 will transform how energy supply and demand are managed, creating a single intelligent network that is more efficient, sustainable and resilient.**

efficiency further. For instance, past data could help a smart grid to "learn" how to better manage energy storage from renewable sources such as solar energy and predict peak demand. This would lead to greater overall energy consumption efficiency. Sensors are important in collecting data needed for analysis and allow for optimization, and this is done through the nation-wide Smart Nation Sensor Platform (SNSP). With SNSP, public agencies can collect, analyze, and share data from sensors deployed island-wide.

How can Smart Nation drive transformation in the area of energy and mobility?

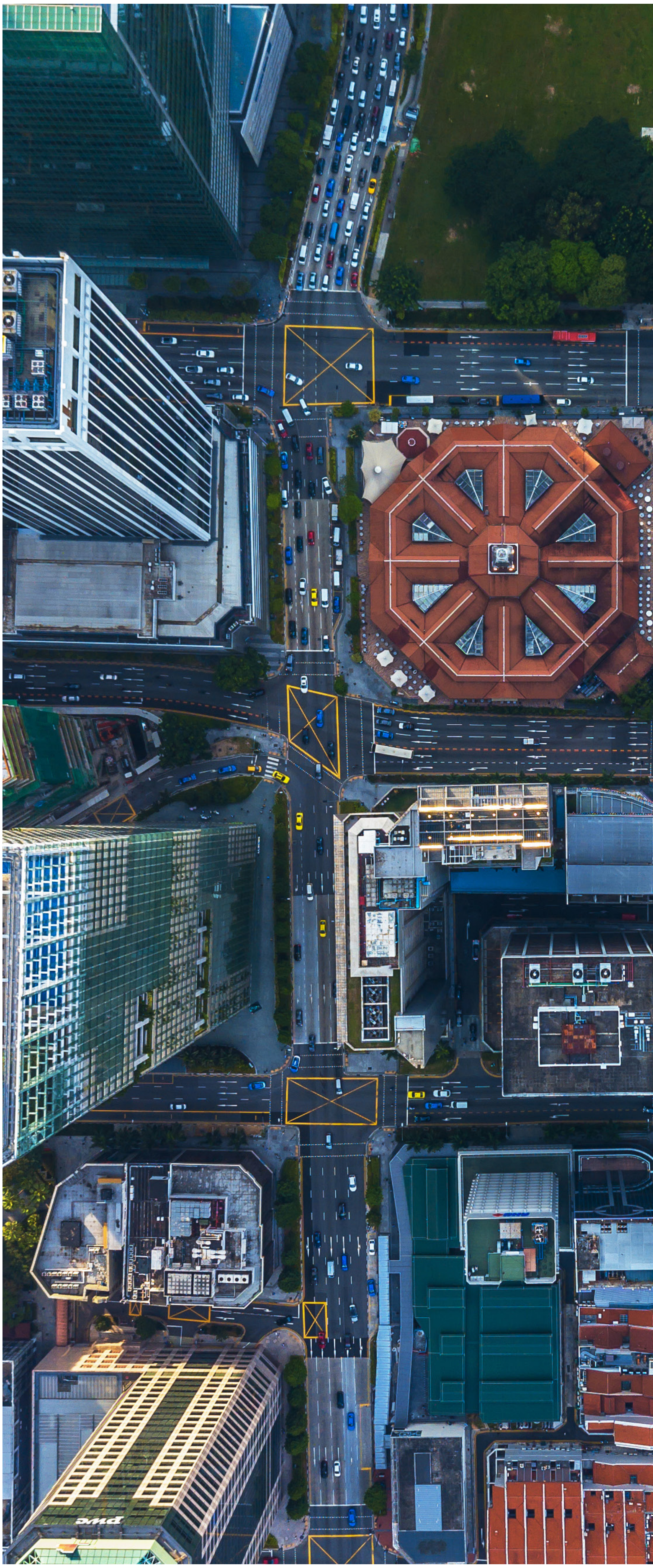
The government is also making major investments to enhance public transport and active mobility infrastructure to ensure that by 2040, nine out of 10 peak period journeys are made in "walk, cycle and ride" transport mode, where "ride" refers to public and shared transport. This includes the expansion of the rail network from 230km today to 360km by the 2030s. With convenient, connected and quicker public transport options, we hope to reduce reliance on private transport. This will reduce carbon emissions and create a healthier environment for Singaporeans to enjoy. To reduce emissions even further, we have also set a target of 100% cleaner energy for public bus and taxi fleets by 2040.

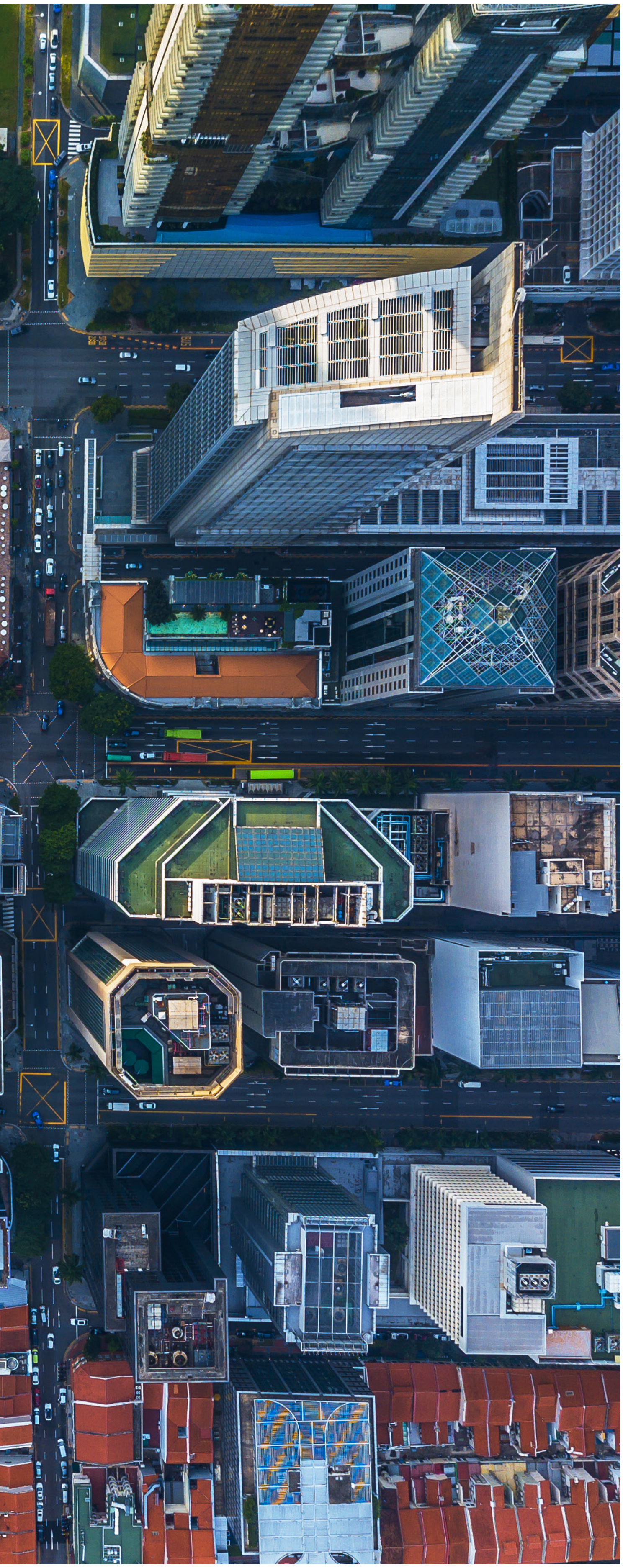
How does Singapore integrate smart and green technologies into its citizens' lives?

Eighty percent of Singapore's population live in public housing.

If we are able to integrate smart and green technologies into our housing estates, we can achieve a nationwide impact. Work is ongoing to embed smart technologies and eco-friendly features into towns and homes.

The Punggol Digital District will be an inspiring demonstration of what we can be as a Smart Nation and drive the adoption of digital and smart urban solutions throughout Singapore. Existing sustainable initiatives in Punggol such as smart lighting and smart water pumps provide the opportunity to use technology to stretch the boundaries of energy, water, and waste management, which will lead to a better lived experience. Newer homes are fitted with built-in smart sockets and smart distribution boards that enable smart applications for the home, such as better monitoring of household energy consumption. Around the estates, features such as smart lighting are also installed to help save energy.





Progressively from 2023, Punggol will serve as a living lab to test new concepts and work towards becoming a green and sustainable town that minimizes wastage and maximizes resource efficiency. The Punggol Digital District experience will be helpful for the development of new towns: new solutions that are tested and deployed here can be scaled up for the rest of the country.

How does a Smart Nation like Singapore address climate change?

Climate change, like digitalization, is a complex, multi-faceted issue. A government-wide approach ensures that our ambitions are set high, our cross-ministry efforts are well-aligned, and our actions are decisive and effective.

One practical and very visible example of ambition, alignment and action is the SolarNova Programme, which is our largest driver of solar adoption across Singapore. The traditional model of large solar farms is not feasible in land-scarce Singapore. The SolarNova Programme helps to promote and aggregate demand for solar photovoltaic (PV) systems across government agencies to achieve economies of scale, as well as drive the growth of Singapore's solar industry. This is only possible with a government-wide approach.

A similar approach is needed to meet the ambitious target of phasing out internal combustion engine vehicles and have all vehicles run on cleaner energy by 2040. The Land Transport Authority is working with various agencies to make sure there are more charging points for electric vehicles. Tax rebates and incentives for early adopters are also being offered to make electric cars more attractive.

As we strive to meet these ambitious targets in areas such as solar deployment, vehicular electrification and energy efficiency, I am sure that digital technologies will come into play in a bigger way.

"We must strive on all fronts and push the boundaries of technology and innovation. We must rely on all our stakeholders, individuals, small and business owners, corporations and like-minded international partners to co-create solutions and open up possibilities to enable our transition to a low-carbon climate-resilient future."

Artist's impression of Punggol Digital District located in the North-East region of Singapore.
Photo credit: JTC Corporation

> **We must strive on all fronts and push the boundaries of technology and innovation.**

What is Singapore's Grid 2.0 strategy and what is the role of public-private partnerships?

Our initiatives are focused on enabling a smart grid that will be able to adjust and regulate its performance, incorporate varied power infrastructure and enable multiple business models. The new paradigm in grid systems aims to enable decarbonization of electricity supply while maintaining overall system reliability and resilience. The transition from smart grid to Grid 2.0 can be facilitated by the multi-directional flow of data and energy without compromising grid reliability.

As part of the energy transition, Singapore is focusing on developing an interoperable network, integrating information and communication technologies with power delivery infrastructure, enabling the flow of energy and communications.

For smart grids to be implemented, Singapore aims to leverage strategic R&D initiatives and pilot projects that bring together academia, end users and technology providers.

Singapore's Energy Story and the Four Switches

At the Singapore International Energy Week (SIEW) 2020 Singapore reinforced its commitment to decarbonizing the grid with the "**Four Switches**".

Limited by land availability and natural resource constraints such as wind speeds, Singapore needs to find new ways to meet its commitment to address the climate challenge. These are the "Four Switches" envisaged as part of its blueprint.

1st Switch: Natural Gas: Natural gas will continue to be the dominant fuel for Singapore with around 95% of Singapore's power generated from natural gas today. The government will help generation companies improve the efficiency of their power plants.

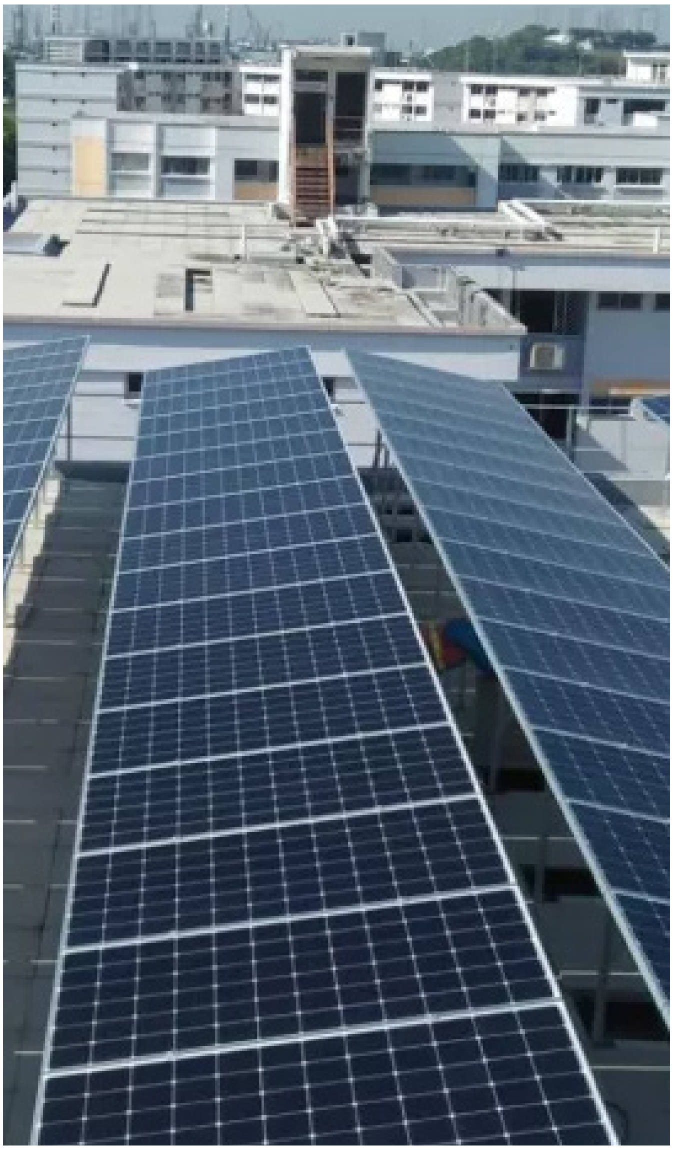
2nd Switch: Solar: Singapore is committed to achieving at least 2 gigawatt-peak (GWp) of solar power deployed by 2030 and energy storage deployment of 200 megawatts (MW) beyond 2025.

3rd Switch: Regional Power Grids: Singapore will explore ways to tap regional power grids to access energy that is cost-competitive. This could be realised through bilateral cooperation or regional initiatives.

4th Switch: Low-Carbon Alternatives: Carbon capture, utilization or storage technologies as well as hydrogen have the potential to reduce Singapore's carbon footprint.

"It has been said that urban societies, if well planned, well organised and well executed, can be the most energy and resource efficient way to organise human societies. We believe in that. This is why, while Singapore is known as the little red dot, we also aspired to be a "Bright Green Spark" where our energy generation and our energy management system can be an inspiration to urban societies across the world," said Mr Chan Chun Sing, Minister for Trade and Industry.

***Transcript of speech by Prime Minister Lee Hsien Loong at Smart Nation Launch, 24 November 2014**



Solar photovoltaic (PV) systems on the rooftops of public housing. Photo credit: Housing Development Board (HDB)

The Great American Reset: Building a resilient and sustainable grid

Anthony Allard
Executive Vice President and Head, Hitachi ABB Power Grids, North America

In this Perspective, Anthony Allard, Executive Vice President and Head of Hitachi ABB Power Grids' business in North America, makes the case for using the momentum generated by the Great American Reset to modernize and decarbonize the North American power network. Managing renewable energy variability using the latest technology, adding transmission capacity between states and provinces, as well as increasing infrastructure efficiency, will all help to create a more resilient grid. He also urges for more inter-regional planning to ensure coordinated investments are made quickly and efficiently across the continent.

Placing electricity at the heart of the Reset

The impact of the global COVID-19 pandemic has presented North America with a golden opportunity to focus growth investments on modernizing its aging energy infrastructure. The North American electricity grid, whose origins are more than a century old, needs to become more resilient and flexible to enable a carbon-neutral future. The grid is under pressure to integrate growing amounts of variable renewable energy, adapt to shifting electricity demand patterns and more electrification (transportation, infrastructure and buildings sectors), and withstand changing environmental patterns (e.g. extreme weather conditions). These challenges need to be addressed in parallel to stimulating the American post-pandemic economy and the time to act is now.

The country requires additional transmission infrastructure to integrate new solar, wind, hydro, and other natural energy sources, to better match production and demand centers by allowing regions to better exchange electricity when power systems are under stress.

In the US, President Biden is taking very encouraging steps with his proposal to spend $100 billion on grid resilience, underscoring the fact that electricity will be central to the economic reset and to meeting climate targets. I welcome this increased focus on electricity infrastructure spending and call on the wider energy industry to build on this momentum and make its investment commitments. The country requires additional transmission infrastructure to integrate new solar, wind, hydro, and other natural energy sources, to better match production and demand centers across the country by allowing regions to better exchange electricity when power systems are under stress. Economic and financial consultants, **The Brattle Group**, estimates that this modernization and expansion requires investments of up to $690 billion by 2050. The great news is that the technology to address these challenges is ready and available and the investments will create jobs.

Connecting renewables in bulk

The most pressing shift concerns the integration of renewables as electricity producers are adding gigawatts of green energy. North America, like other regions across the world, has ambitious targets to increase green electricity production. Canada plans to source 90 percent of its electricity from clean energy sources by 2030, and President Biden aims for the US power sector to be carbon-free by 2035, leading to a **net-zero emissions economy by 2050**.

This fast-paced growth in renewable energy needed to support the 2030 carbon-free goal poses several new challenges to the North American power system.

Firstly, their variability brings stress to the transmission network, which was built on centralized, baseload electricity generation that was largely predictable. The influx of wind and solar resources, which cannot be produced on demand, also reduces the network's inertia because, unlike traditional, thermal power plants, they are connected to the grid through power conversion systems based on power electronics and do not have the same kind of large, rotating turbines that produce grid inertia. Changes within the power generation mix which may lead to lower levels of grid inertia may result in a faster decrease in frequency when grid disruptions occur, which significantly reduces the resiliency of the grid. The answers to this threat to the network's resilience can be found in utilizing digital capabilities combined with most modern power electronics. Hitachi ABB Power Grids has, for example, provided such a technological solution to a **wind farm in Mexico**, where a static compensator helps maintain high-quality electricity and stabilizes the network.

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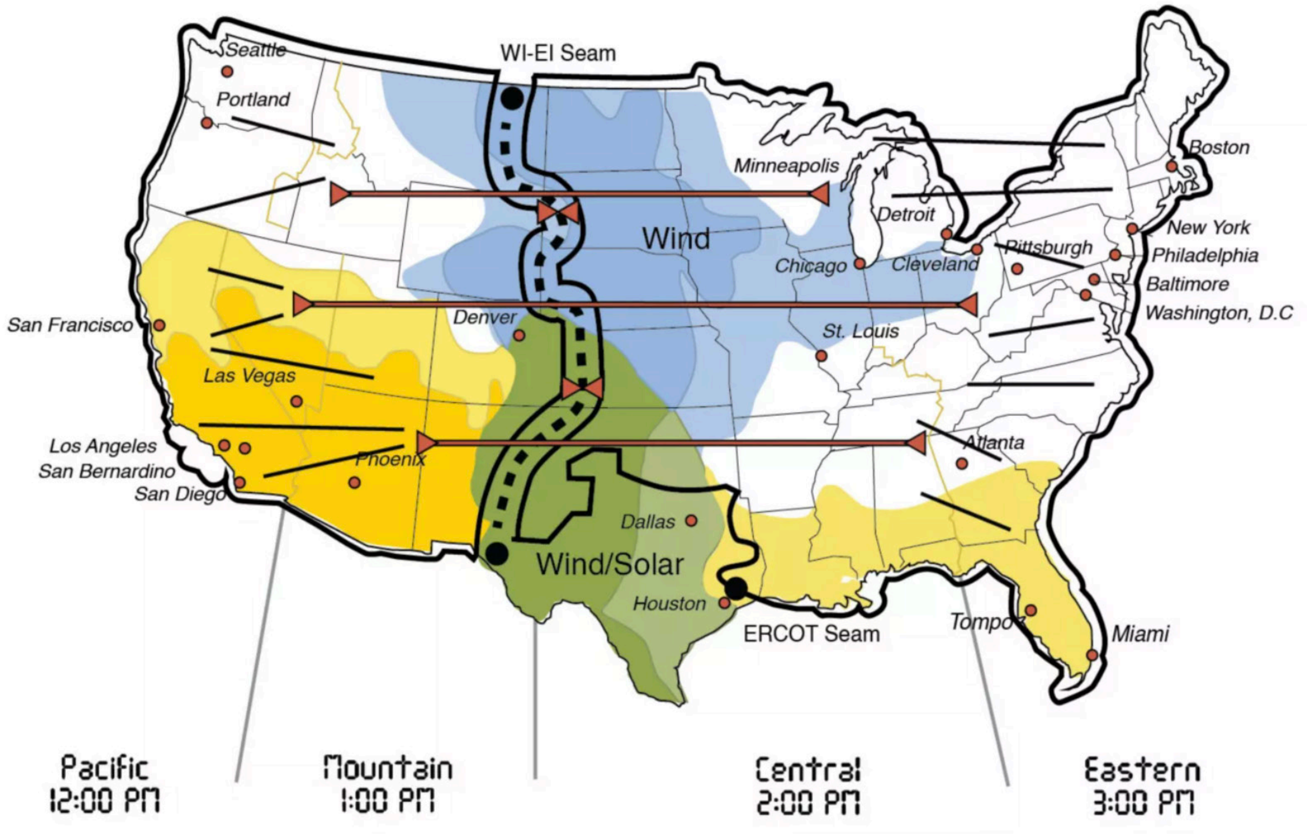
The answers to this threat to the network's resilience can be found in utilizing digital capabilities combined with most modern power electronics.

Secondly, high-quality renewable energy resources are often located far away from demand centers, such as mountain ridges in remote areas or offshore.



Source: National Renewable Energy Laboratory, Interconnections Seam Study

A study by the American Council on Renewable Energy has shown that the 15 US states between the Rocky Mountains and the Mississippi River account for 88 percent of the country's wind potential but are home to only 30 percent of expected electricity demand in 2050. This geographical mismatch between supply and demand creates a need for building both new intraregional transmission lines as well as expanded connections between the grid interconnections, which are not synchronized and require high-voltage direct current (HVDC) to exchange power.

Deepening grid connections also addresses the third grid challenge posed by growing renewable energy: addressing the timing mismatch between production and demand. For example, peak solar production around the middle of the day does not coincide with the traditional peak of daily power demand in the early evening. Again, it is electrical engineering that is the answer here as HVDC transmission can help transport electricity over long distances with very few efficiency losses and its ability to control load flow, to places where it is needed at the time of production.

Another way of handling excess renewable electricity is to store it. Hydroelectric dams offer one way to do this. Managing reservoir levels, by pumping water into a reservoir and releasing it when electricity is needed, is a traditional method of bridging supply and demand gaps. Pumped hydro storage represents the bulk of electrical storage on the grid today. This method is working well on the north-eastern border between the US and Canada, but North America can apply it even more widely. As well as offering storage capability, the use of hydro and solar and wind power to operate pumps to fill storage reservoirs provides a carbon-neutral alternative that is in line with North America's various strategies to cut greenhouse gas emissions.

Building resilience with more interconnection, microgrids, and energy storage

Strengthening the network by expanding the grid is not only important in the context of integrating renewable energy.

The power outages in Texas earlier this year highlighted how crucial it can be for a grid to be well connected to other regions, particularly distant areas that may experience different weather patterns and that can provide support at times of system stress. Case studies of interconnected electricity networks across the world, for example in the European Union, have proven that grids become more resilient when regions can exchange electricity when dealing with unexpected events.

Building more resilient networks does not only happen across large distances, it also happens at the local level. Microgrids play a key role here and their application comes in many different shapes and forms. They help to improve resilience in mission-critical locations such as hospitals, for example, where a loss of power has to be avoided at all costs. Here, the microgrid serves as a reliable backup system in case of failure at the utility level.

Elsewhere, microgrids have helped communities in remote areas increase power supply reliability, reduce the need for more costly generator fuels and boost renewable energy production. Hitachi ABB Power Grids developed one such project, working with **ATCO**, a global essential services company based in Alberta, and Three Nations Energy (3NE) for Fort Chipewyan, a remote First Nation community in northern Alberta, Canada. The microgrid includes solar panels with battery energy storage and is expected to significantly reduce diesel consumption while meeting about 25% of the community's electricity needs over an average year.

Combining storage solutions with a microgrid can also be an effective way to avoid the construction of new transmission or distribution lines, for example, in areas where space restrictions or local opposition complicate building new infrastructure. This option will become increasingly important as we move towards a future where electricity will be the backbone of the entire energy system.

Efficient and flexible infrastructure

Making the best use of our infrastructure and equipment in the name of sustainability is a request we are receiving from more and more of our customers. Where in the past investment costs were the top priority, energy infrastructure investors are increasingly opting for solutions that last longer, are more efficient, and help meet sustainability targets. HVDC transmission lines can be one of these solutions as minimal transmission losses allow for a more efficient way of sending electricity over long distances than AC lines. At Hitachi ABB Power Grids, we also deliver technology that detects equipment failure prior to a fault, allowing utilities and network operators to make their assets more reliable by better targeting maintenance work.

In line with anticipating factors that can threaten the resilience of a power grid, network operators and utilities need to constantly update assumptions around weatherization. If we return to the example of Texas, it has demonstrated that some of the weather-related assumptions applied were outdated given the increased level of severe events, including extreme cold, extreme heat, wildfires, floods, and hurricanes. Weatherization and grid hardening are not new issues, but utilities and network operators must apply the correct technology to work with the latest weather-related risks. Anticipating a threat from stronger and more frequent hurricanes, Puerto Rico, for example, commissioned us to build a weather-resilient energy system. This resulted in the deployment of a unique mobile solar system with foldable racking to protect equipment from weather-related dangers.

Coordinated planning

Anticipation and planning are crucial in the electricity sector. To be able to build all the transmission lines that are required to address the abovementioned challenges, an appropriate policy framework needs to be in place. Currently, this is not the case in the US, let alone in North America. Across the continent, each country, each state, each province has different capabilities which, if combined through a coordinated plan, can help building a more resilient overarching power network. This also includes designing a coordinated incentive mechanism for regions hosting long-distance transmission lines. A centralized approach is needed here to attract and efficiently invest the dollars in our future electricity system. Once the foundations are laid, the technology is ready to be deployed to render the grid as resilient as possible.

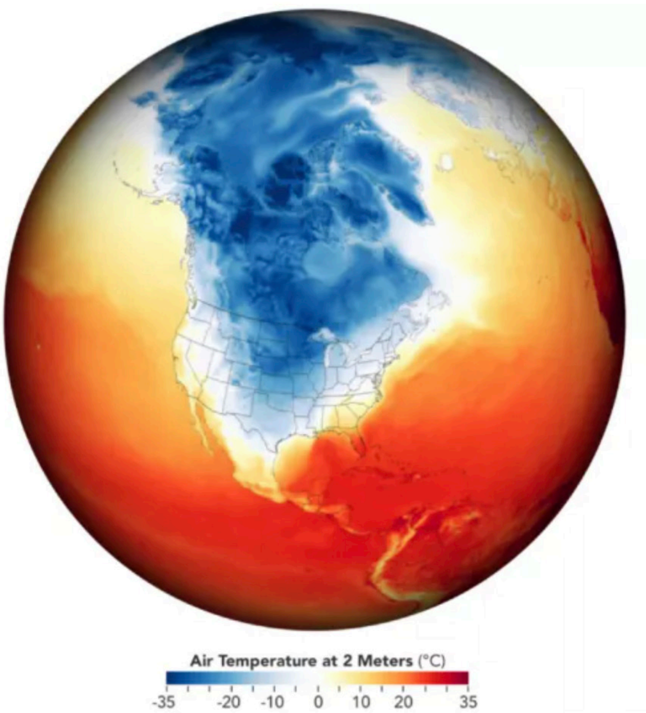
Aerial view of Fort Chipewyan microgrid site near Lake Athabasca, Alberta's oldest established community
Source: 3NE

Where in the past investment costs were the top priority, energy infrastructure investors are increasingly opting for solutions that last longer, are more efficient, and help meet sustainability targets.

A winter storm brought heavy snow in Texas causing the State's power grid to also collapse

Now is the time!

As the need to expand and make North America's grid more resilient has been recognized on the political agenda, the power industry must tap this momentum and speed up initiatives. The Great American Reset is underway, and it is up to us as the industry to plan for the grid of the future today and to apply the latest technology to ensure funds are invested most efficiently. Given the long development cycle and criticality of electric infrastructure to national security, changes need to take place now.



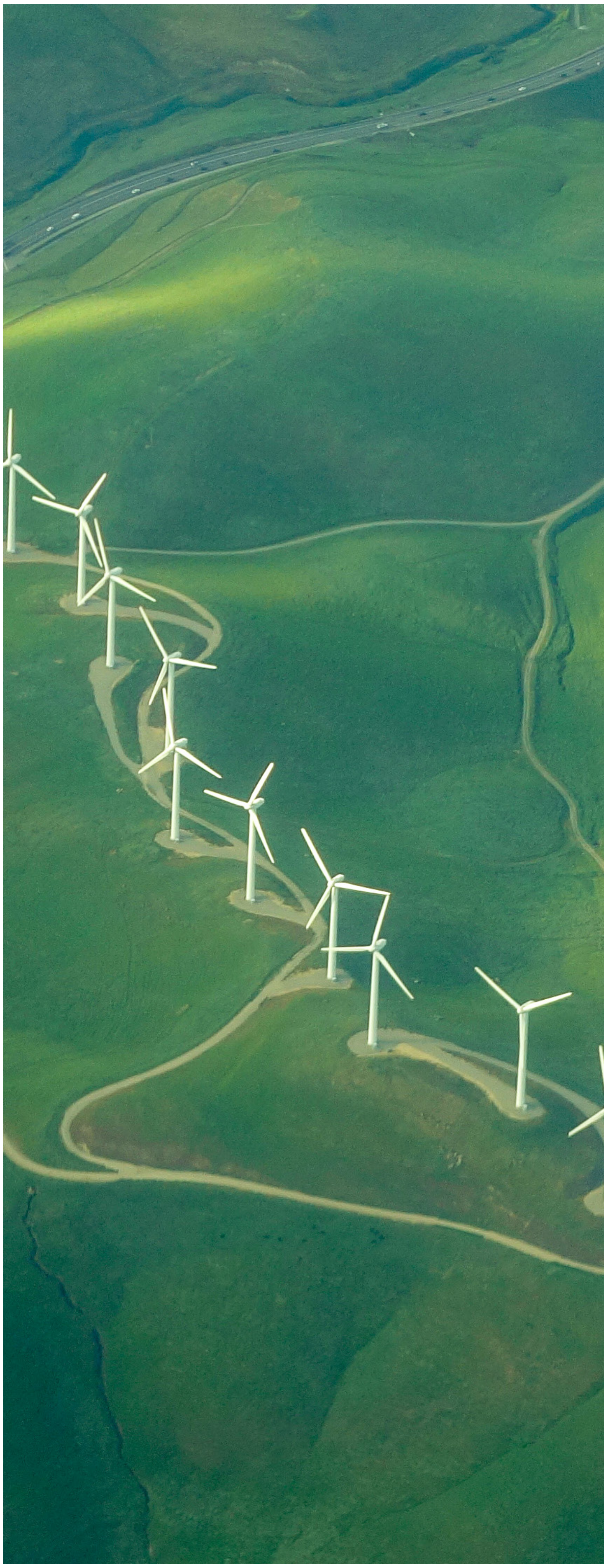
A map showing very cold weather in Texas and key parts of the country. Image credit: NASA

Mobilising finance to accelerate the green energy transition

Gerard Reid
Co-founder and Partner,
Alexa Capital

The declining cost of clean energy technologies opens an important pathway leading to a new, lower-emissions era. An unprecedented increase in capital spending however is required to help countries, especially emerging and developing nations, in achieving net-zero emissions. Funding clean energy projects however remains a challenge given the fiscal and political structures that affect clean energy investments. In this Perspective, Gerard Reid, co-founder and Partner at Alexa Capital, shares his views on the challenges and opportunities in ramping investment in cleaner energy sources, while outlining key actions that both the public and the private sectors need to take to mobilise the necessary capital to accelerate the clean energy transition and ensure a more sustainable future.

As part of the Paris Climate Accord in 2015, over 180 countries agreed to reduce greenhouse gas emissions and limit global temperature increases to below two degrees Celsius. One of the key parts of the Agreement is the objective of 'making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.' Five years on and the results are mixed at best.



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One could say that an inflexion point has been made with investors increasingly seeing climate risk as both investment risk and an investment opportunity.

The good news is that over the last 18 months there has been more movement and change than there has been over the last two decades. In fact, one could say that an inflexion point has been made with investors increasingly seeing climate risk as both investment risk and an investment opportunity. Going forward, a lot needs to be done to mobilise capital to significantly expand investment in low-cost clean energy technologies such as solar and wind, which are needed to achieve carbon-neutrality. But I must admit that I am very positive about the future.

It is easy to criticise the finance industry for financing billions of dollars of new fossil fuel assets that are built every year. The justification has always been that this investment is needed for our economies and that the returns are there to be made. One of the positives of Covid is that it has given the investment community a view of what peak fossil fuel demand will be like.

Thanks to weak demand for oil caused by the travel restrictions related to the Covid pandemoniac, oil prices turned negative on April 20, 2020 – meaning that producers had to pay customers to take their oil. A first for oil, but a wake-up call as well!

This event gave investors a view of peak oil, but not peak oil supply as many formally touted but peak demand. The result was that investors rushed for the door on their fossil fuel investments with share prices collapsing across the border. The ExxonMobil share price, for instance, finished 2020 down nearly 40%. In addition, businesses such as BP and Shell made asset impairments totalling $40bn sighting long-term risks around carbon price and oil demand. All three combined generated losses totalling $70bn for 2020.

What we are now seeing is the financial market pulling forward risk as investors seek to avoid 'stranded assets' and reallocate funds to greener investments such as the US electrical utility company NextEra, which for a while last year became the biggest energy company in the Western world.

Its share price finished 2020 up 20% as investors jumped on the decarbonisation opportunity.

What we are also seeing is that investors across the world are increasingly seeing climate risk as investment risk. There are two aspects to this: the first of which are physical risks, such as storm damage; and the second, climate policy. The latter is a risk particularly for owners of fossil fuel assets or those who are dependent on fossil fuels as an energy source – however, it is also an opportunity as new regulation and legislation drive growth, demand and capital flows into clean energy.

How we produce, use and transport energy is at the heart of the energy transition. The challenge, however, is much greater, requiring structural change in areas as diverse as housing, transport, agriculture, and heavy industry. We require creative thinking, technical solutions, business models, market mechanisms, and financial offerings to achieve net-zero. More importantly, the energy transition also calls for a profound rethinking of how we live and work. We also need to switch the thinking in the finance world from just measuring the risks of climate change to focusing on the opportunities that this transition provides.

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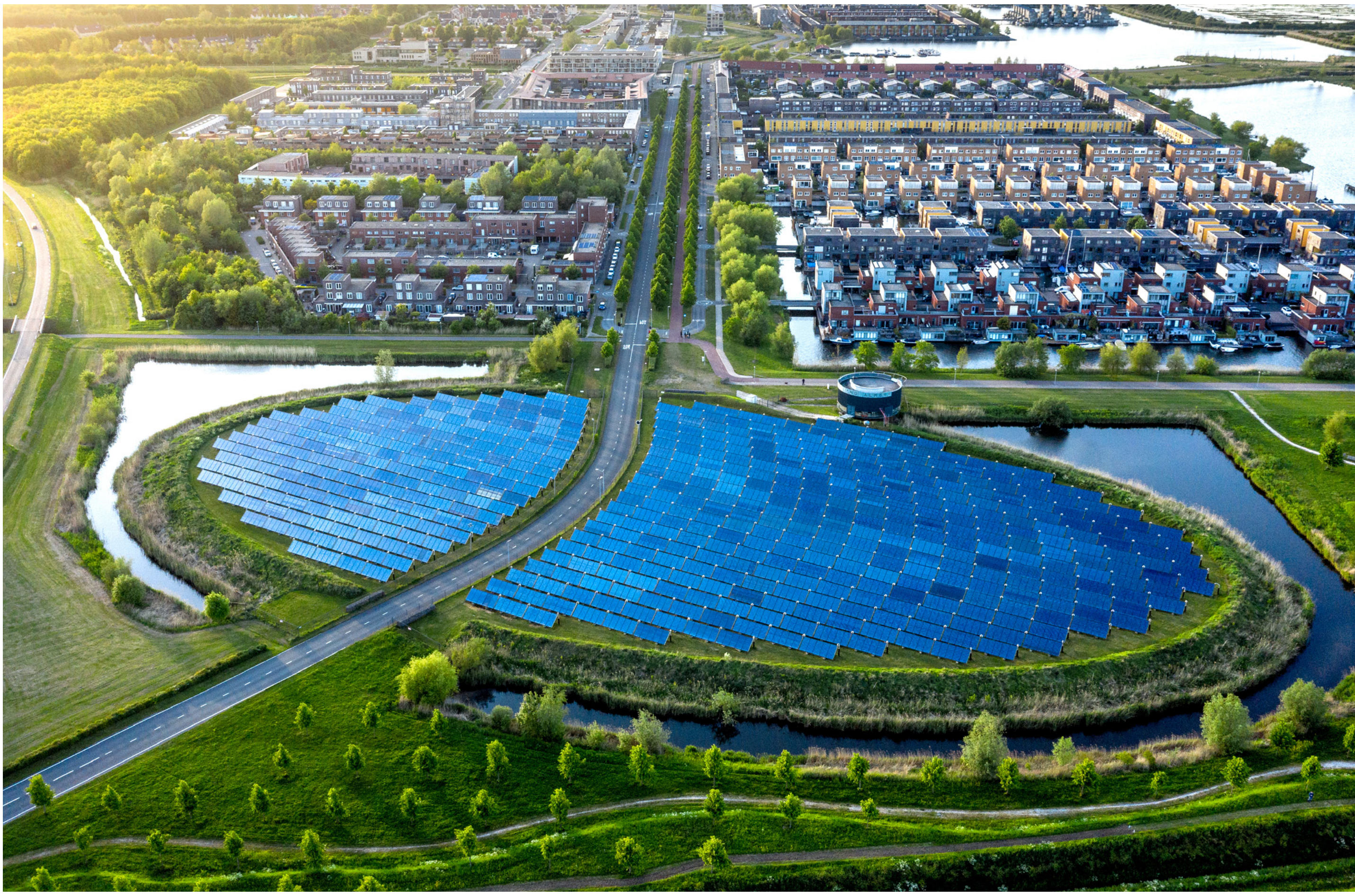
Nurturing the financial conditions to enable a rapid deployment of clean energy technologies across the world is one of the defining challenges of this era.



The cheapest form of energy has always led to great periods of economic growth and comparative competitive advantage. Think of Britain with its cheap coal during the industrial revolution or Saudi Arabia with its low-cost oil. Today, the most affordable ways to produce electricity are with solar and wind, and as we electrify more and more of society, these technologies will become the bedrock of a 21st century economy. What makes these renewable technologies really interesting is that they have no fuel costs with minimal and highly predictable operating costs. In this new world the way to drive down costs and thus increase competitive advantage is to push down capital costs while at the same time building up the necessary skill set to ramp up and run an energy system based on these technologies.

The good news is that there is no shortage of capital across the world. In fact, the world is flooded with low cost money looking for a home. But this capital is not finding its ways to sectors such as hard to decarbonise ones like cement and countries where it is most needed. Nurturing the financial conditions to enable a rapid deployment of clean energy technologies across the world is one of the defining challenges of this era.

To deliver the global net-zero goal of 2050, the IEA estimates that over $1,500bn of capital will need to be deployed a year, which is a five-fold increase over the current $300bn investment levels. The bulk of this capital, some $1,000bn per year, needs to be invested in emerging and developing economies which have increasing populations and desires for the products and services that those of us in richer countries take for granted. Mobilising capital on this scale will require a joint effort of both public and private capital, as well as an enhanced role for development banks both international and national.

This is a humongous growth opportunity for the whole world, but especially among many developing countries, which are endowed with excellent weather resources and a need for jobs and inward investment to grow their economies. Accelerating the inflows of capital will require far-reaching changes to improve the political and regulatory environment in these countries. The value that this growth opportunity brings is multi-faceted – starting with job creation to access to low cost and clean energy for people and their businesses, and the society and world they are part of. It is also the easiest and lowest cost way to decarbonise our world, as it is much easier and cheaper to integrate sustainable clean energy solutions into growing economies with their new homes, factories, and vehicles than it is to retrofit existing infrastructure.

In practical terms, this increase in investment means replacing the global capital stock of all fossil fuel-powered devices from vehicles to boilers with low and possibly zero carbon alternatives.

Mobilising capital on this scale will require a joint effort of both public and private capital, as well as an enhanced role for development banks both international and national.

Robben Island, north of Cape Town, South Africa

The size of the required investment is heavily influenced by the cost of capital. The higher the cost, the more expensive the transition will be. In addition, the maturity level and the potential of technological innovation for key technologies such as solar and batteries are critical. This can all be impacted by policy, where poor policy increases risks and lowers capital flows or makes them more expensive, while good policy aligns investor incentives around climate goals as well as reduces risks and thus pulls in lots of low-cost capital.

This low-cost capital is particularly critical for clean energy technologies such as wind, solar and EVs which have higher relative upfront investments costs than fossil fuels but lower lifetime costs. This shift towards a much more capital-intensive energy system is a key difference to the fossil fuel world. This cost of capital issue is particularly critical in emerging and developing economies which currently have financing costs up to sevenfold higher than in Europe and the United States. What this practically means is that the costs of generating electricity with solar in Pakistan are currently higher than Netherlands even though the Pakistani solar system generates 50% more electricity per year!

Transforming the energy system is no easy task and requires a core focus on electrification which is the most important form of energy we have. Without electricity the mass of digital devices that make up our modern lives would not function, and as we saw in the Texas blackouts, heating and water systems did not operate because of the lack of electricity. Almost unbeknown to us, electricity has become indispensable and going forward it will become come more so. As electricity is the most controllable form of energy we have, it plays an incredibly important role in the decarbonisation pathway, as the more controllable the energy is, the less the heat losses are which means they are also cheaper to operate. Boosting investment in clean electricity, grid and other enabling technologies such as batteries will not only drive emissions reductions to meet climate and other environmental goals, but also create local jobs, noting that all these new infrastructures need to be installed, operated and serviced.

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We need to change fiscal incentive structures, price carbon and establish an international platform for best practices in climate.

This leads us to the final question, which is: 'What needs to be done to accelerate the path towards carbon-neutrality and ensure access to low cost capital?' I would suggest **three things**:

1. Change fiscal incentive structures

We need to change fiscal incentive structures, price carbon and establish an international platform for best practices in climate. Across the world, we have put in place tax incentives and subsidy structures that favour fossil fuels over clean energy solutions. These structures are often difficult to change either due to political reasons or due to resistance from conservative tax offices and finance ministries. One example is in Germany where retail electricity prices are around $35 cents per kWh while natural gas prices are around $9 cents. The former is high because more than 50 percent of those costs are different government taxes and levies, leaving residential customers with no economic incentive to run their heating system on cleaner alternatives instead of fossil fuels. At the same time, it weakens the economic case for buying an EV.

It is thus critical that if we want to decarbonise quickly and effectively, that fiscal tools are aligned with CO_2 reduction goals. A suite of fiscal incentives such as tax credits is needed to kick off early-stage markets and to enable related technologies to reach critical mass. This, for instance, is what we are seeing with EVs across many countries. We also need fiscal incentives to drive research & development and investments in sectors where it is difficult or expensive to decarbonise such as heat for buildings. Finally, financial incentives should also be put in place as part of post-Covid green recovery plans.

2. Price carbon

One of the critical questions in economics is how best to price externalities that negatively impact third parties, like residential customers, who are not otherwise involved in the market of a particular product. Fossil fuels are a good example, which are burned and are paid for by a customer. The associated negative cost of CO_2 released from burning fossil fuels is unfortunately not paid by the original producer and buyer of those fossil fuels.

One of the critical functions of government is to put in place regulations that counteract these externalities. In the case of automobiles in Europe, for example, one of the major reasons for the push towards electrification is that automobile manufacturers are being fined for not meeting CO_2 emission targets. The other way to do this is to price the externality and put a marketplace in and around the levels of emissions allowed.

In the case of carbon there are lots of schemes to do so, the most successful of which is probably the **EU-ETS system**. This system of carbon pricing is a crucial tool in Europe for aligning market incentives to ensure an effective and efficient use of capital. The reduction, for instance, in UK coal usage in recent years is largely because of this system which has made coal uneconomic for power generation.

The other positive impact of carbon taxes is they provide revenue to governments which can be used to push further decarbonisation or to ensure carbon equality to make sure that the poor in our societies become beneficiaries of decarbonisation. Going forward, we are likely to see a system of border tax adjustments which will ensure that carbon intensive industries do not just move to a location with no carbon taxes.

3. Establish an international platform for best practices in climate

The only way to save our climate is if we all work together. This is why it is critical to share best practices, particularly around regulations and fiscal incentives, but also the ramping up of people skills needed to transform our energy system. In addition, low cost capital, both equity and debt, needs to be made available to enable countries, regions, cities, and communities to deliver on their climate commitments. This new era of cooperation could take the form of institutions such as the Indian-led International Solar Alliance, which could be used as a vehicle for driving low cost capital for this transition.

The EU-Emissions Trading System (EU-ETS) is a cornerstone of the EU's policy to combat climate change and its key tool for reducing greenhouse gas emissions cost-effectively. It is the world's first major carbon market and remains the biggest one.

A final thought

Gerhard Salge
CTO, Hitachi ABB
Power Grids

I hope that you enjoyed this Second Edition of Perspectives.

The Edition was built on the feedback and ideas that we received after publishing the First Edition last year. I would like to thank all the authors for their fascinating contributions, which explore pertinent and timely topics in a very human way.

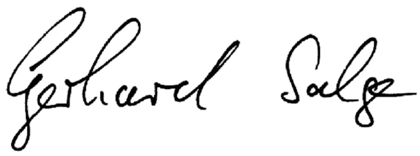
The energy transition is one of the most important and urgent issues of our time. We know that electricity is increasingly becoming the backbone of the entire energy system. Yet what's crucial is the speed at which investment is made available and the infrastructure deployed, as this will set the new pace for how fast and far society can shift towards carbon-neutrality.

Key technology themes highlighted in the projects mentioned in this edition recognize the importance of increasing sustainability, resilience, security and safety of the world's energy systems. They also reinforce the need for digitalization as an enabler for the transition. Perspectives from TenneT, Statnett, Elia Group, 50Hertz, Equinor and Singapore, and our own colleagues, all showcase examples of great progress in technology and business models. It is super encouraging to see that the pandemic has not stopped all of this purposeful innovation.

In the Perspective from Gerard we also discovered more about the potential pathways to mobilize finance to accelerate the energy transition. It was insightful to contemplate that money is not in fact the major obstacle, as long as both private and public sectors make a joint effort. In addition to technological innovation and financial stimulus, unlocking the acceleration that we strive for, needs more sustainable partnerships and trustful collaboration – a core foundation for the transformation to succeed. And this is exactly what I see in our own company: the best innovation always arises when teams work together with trust.

The whole purpose of Perspectives is to trigger the exchange of ideas that will help us all to accelerate the sustainable energy transition. Inclusive by intent, topics range from the integration of large-scale renewables to the electrification of transportation, industry and buildings sectors, along with other related topics that help to unblock and propel change.

Coming soon in Perspectives I am looking forward to finding out more about how different sectors are embracing this challenge of our time and trying out new possibilities. When we look back at history, it is often noted that following periods of great struggles come times of great innovation. Your feedback and ideas for future Perspectives are highly appreciated. Only by means of lively and fruitful exchange of different perspectives and a mindset of ‘co-creation’ resulting in idea implementation, can we create social, environmental and economic value for business and sustainable society.



Gerhard Salge

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