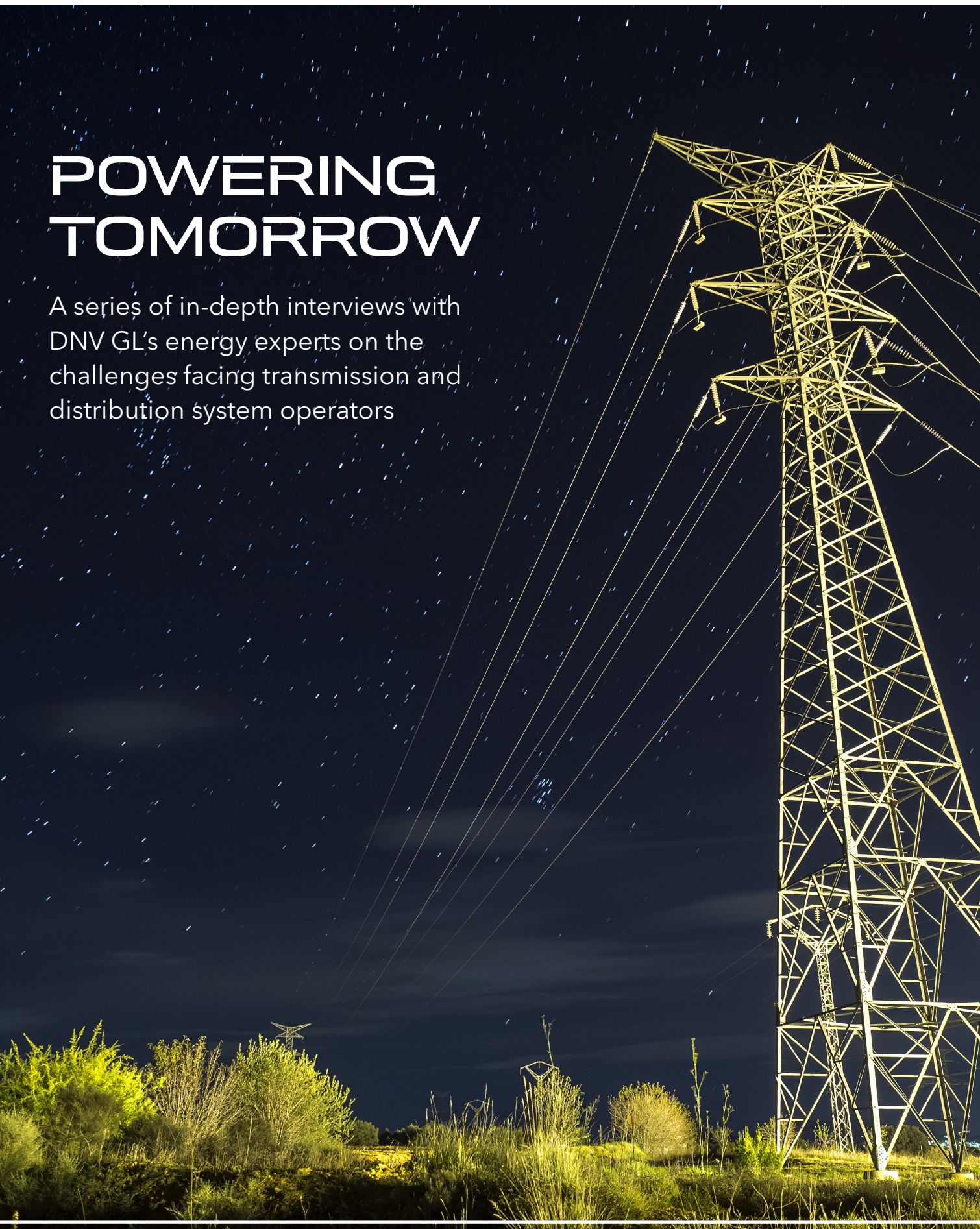


POWERING TOMORROW

A series of in-depth interviews with DNV GL's energy experts on the challenges facing transmission and distribution system operators



How are transmission and distribution system operators (TSOs and DSOs) coping with the radical changes taking place in the energy system?

What changes can we expect to happen in the operation of our power grids? And how will electricity grids need to adapt to support the transition to a cleaner energy system?

This six-part series will explore the role TSOs and DSOs play in the energy transition; how to make networks smarter; the impact of electrification on network operations; the impact of the offshore wind revolution on power networks and the levels of maturity in renewables integration.

In the first interview of our *Powering Tomorrow* series, former editor-in-chief and founder of Energy Post, Karel Beckman interviewed our experts about:

- The vital and active role TSOs and DSOs play in the transition to a low-carbon system
- The skills and resources needed to ensure reliability and safety in the power system throughout the energy transition
- The support needed from industry stakeholders, including policymakers and regulators.

Download the other articles in our series [here](#).

ARTICLE 1/6 - March 2020

COPING WITH RADICAL CHANGE IN TRANSMISSION AND DISTRIBUTION

How reliable is our power system?

Transmission and distribution system operators have become the linchpin of the energy transition. Their work is vital to making the efficient integration of variable renewables possible and at the same time to ensure the reliability and safety of the power system. Yet experts are concerned that the work of the network operators is being taken for granted by policymakers and the public.

TEXT: KAREL BECKMAN

INTERVIEWEES



Gunnar Heymann
Director Energy Advisory



Wessel Bakker
Business Director Power
Transmission



Matthias Müller-Mienack
Managing Consultant
Power System Planning

Remember the EU's Third Energy Package? Back in 2009, the EU adopted it primarily to unbundle the electricity networks from power generation and supply. The idea was that liberalized markets would be established allowing free network access, energy trading and competitive generation markets based on the state-of-the-art technology.

The network operators would serve as "facilitators" – the motorways on which the competitively generated and increasingly renewable power would freely flow.

Now, ten years later, Europe has a competitive market in generation, but the role of the networks is turning out to be very different from what was expected. It is becoming increasingly clear that the grid operators, far from being passive enablers, are playing a vital and active role in the emerging power system based on fluctuating renewable resources. They don't just facilitate the traffic – they direct it, connect it and balance it. Without them, the transition to a low-carbon system will come to a grinding halt.

This is one of the key insights that came out of a series of in-depth interviews held with three leading power experts from

DNV GL on the supercritical role of transmission and distribution system operators (TSOs and DSOs) in the power system. DNV GL's advisors are convinced that the grid companies have the skills to handle their immense responsibilities but are worried that they may not be getting enough support to handle all the energy transition challenges at the same time.

"The TSOs and DSOs are key to the energy transition", says Gunnar Heymann, Director Energy Advisory. He has summarized the position of the grid operators in a revealing chart which shows the wide range of challenges they have to deal with. "They not only have to build a lot of new capacity, but are also responsible for integrating growing amounts of variable renewable energy into the system, both new centralized sources, such as offshore wind farms and solar parks and decentralized sources, such as rooftop photovoltaics. At the same time, they have to implement the new digital technologies that can handle all this complexity, develop a new grid structure with new operational functions, prepare the system for intelligent EV charging, connect with storage and power-to-gas systems and deal with cost pressures. It's a pretty steep order."

TRENDS	CHALLENGES
ENERGY TRANSITION	■ Generation mix changes based on ten-year development plan (Europe) ■ Large utilities with restructuring ■ Fundamental change of business models ■ Smart grids including net metering ■ Microgrids/off-grid applications
RENEWABLES INTEGRATION	■ Europe leading in offshore (UK, Germany) ■ New markets NL, USA, Asia Pacific region ■ Cost decrease of PV and batteries ■ Levelized cost of energy competitive
ADVANCED ASSET MANAGEMENT	■ Cost pressure on grids ■ Risk-based asset management will be applied ■ More sensors at primary equipment ■ Aging workforce
DIGITALIZATION	■ Complexity of system operation increased ■ Interoperability needs to be ensured between IT systems ■ Application of new IT platforms ■ Verification of dynamic generation models ■ Blockchain enables peer to peer supply
NEW DISTRIBUTION REQUIREMENTS	■ Dichotomy between decentralization and strong transmission backbones ■ Sectoral coupling opportunities (power-to-gas, power-to-heat, storage, mobility) ■ Demand-side management including intelligent electric vehicle charging
NEW GRID TECHNOLOGY	■ HVDC, hybrid grid development ■ HVDC grids - interoperability of converters and necessity of DC breakers ■ 525 kV DC cables ■ Dynamic line rating ■ Large scale T&D investments

Figure 1 - Trends and challenges for grid operators
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What's more, they have to do all this in an extremely short time. We all know that the energy transition needs to speed up. "What all this means," says Heymann, "is that huge investments need to be made in T&D networks in the coming ten years against a fast-changing and uncertain background. That has never happened before." He adds: "The industry hasn't changed for a long time, but now the era of radical change is here".

Building new grids should be a no-brainer

How can the grid operators cope with these unprecedented challenges? According to Wessel Bakker, Business Director Power Transmission, the companies have to work along two main tracks. "First, they need to build more transmission and distribution capacity. Much more. The buildout of the grid is not going fast enough." As an example, Bakker points to the situation in the Northern Netherlands, where solar parks

have to wait for months or years to get a grid connection. The delays in the buildout of the German transmission grid are also a well-known problem. "This is putting the whole energy transition in danger", says Bakker.

He argues that building new grids should be a no-brainer. "Despite all the uncertainty that the energy transition brings, there is one thing we do know for certain: the demand for electricity will shoot up".

“The TSOs and DSOs operators are key to the energy transition. The industry hasn't changed for a long time, but now the era of radical change is here.

"We want to have more decentralized renewable power, we want to heat with electricity, we want to drive on electricity. Our models show global demand for power will grow three-fold and installed capacity six-fold while grid extensions take a long time to realize. So, what are we waiting for?"

The second track that the grid operators must follow, says Bakker, is operating their existing assets more smartly and efficiently. "I know this sounds obvious, but in practice it is far from simple. If we just take one challenge, that of securely operating the grid, we see that there is a wide range of new and existing technologies available that operators have to choose from: voltage regulation, fast frequency response, congestion management, dynamic rating, load frequency control processes, flexibility platforms. Taking all the challenges together, clearly requires a very good overview of the available options and a vision on how the system will develop."



On the edge: review conventional dimensioning criteria

Heymann agrees that the grid operators need “to have profound scenario planning skills” to choose the right strategy and make the right investment decisions. If they get it wrong, the energy transition may fail. Renewable energy production may become stranded. Or we may see outages.”

Let’s not forget: the network operators are responsible for maintaining the balance of the power system, which is becoming more and more difficult as a result of the growing supply of volatile energy sources. “The number of critical moments in the German grid for example has risen drastically”, says Heymann. “Ten years ago, we had maybe 30 critical days in a year, when there was a risk of coming close to design limits. Now almost every day is a critical day.”

Yet, the DNV GL specialist point out, society will have to accept more risks if we want to realize the network expansion that is needed efficiently. “We cannot afford to keep designing all our systems without consideration of proven measures for operational grid optimization”, says Heymann. “That would make the buildout far too expensive.” He says the regulators will have to be prepared to give the grid operators more freedom to overcome conventional dimensioning criteria for the electricity grids. “We need to give up applying the classical N-1 safety standard in all cases.”

The basic principle of N-1 security in network planning states that if a component – e.g. a transformer or circuit – should fail or be shut down in a network operating at the maximum forecast load levels, the network security must still be guaranteed. But, notes Heymann, “thanks to IT we are now able to realize fast curative measures (e.g. wind farm curtailment within a few minutes) to reduce the element loading after loss of a critical element and thus to prevent a thermal overloading. This kind of technology could be incorporated in our security guidelines.”

“ We have to ask whether the right regulation is in place in Europe at this moment. Unbundling was good to open the market. But we need more cooperation between TSOs and DSOs.

Bakker agrees that grid operators will increasingly have to work “on the edge”. That’s acceptable, he says, but it does imply that it becomes more important that they work to the highest quality standards and use fail-safe equipment and technologies. “We must get it right the first time. This is not always the case today. I see too many things going wrong that could have been prevented if best practices had been followed and if a proper risk assessment had been in place.”

As an example, he mentions the problems with some offshore wind farms, which have been built under strong cost pressures. “There has been too much focus in some projects on building as cheaply as possible. As a result, we see an increasing number of damage claims in this sector. And 80% of the claims pertain to the grid connections, not the turbines, although the connections form just 20% of the cost of the projects.

Renewed focus on grids

The DNV GL experts all praise the efforts that are being made by the T&D operators. “They are working very hard to make the transition work”, says Heymann. “They are getting a lot of things right.”

But they also agree that the grid companies can’t do it alone. “Many of the solutions need to come from others”, says Heymann. “Storage solutions must be developed. Links must be made with the gas grid, when green electricity is turned into hydrogen, for example. This kind of sector coupling must be part of the solution. Market players are expected to come up with flexibility products, such as virtual power plants. Policymakers will have to provide incentives to electrify the heating sector.”

In Europe, we will also need to look at the regulatory framework, says Matthias Müller-Mienack, Managing Consultant Power System Planning. “We have to ask whether the right regulation is in place in Europe at this moment. Unbundling was good to open the market. But we need more cooperation between TSOs and DSOs. They need to be able to share data and work together, for example, to operate joint IT-based flexibility platforms such as developed within the German funding programme *Smart Energy Showcases - Digital Agenda for the Energy Transition*. In other parts of the world they can’t always understand the choices we made in the European system.”

Heymann agrees that the market design needs to be critically looked at.

"In Germany, we have chosen an energy-only market system, which only compensates electricity that is produced while establishing more and more capacity instruments for the sake of grid stability without market base."

We have to ask whether we should add market-based capacity elements which would compensate power producers for keeping generation available when it's needed, ideally with minimal impact on the market."

"Traditionally, transmission and distribution has been taken pretty much for granted by policymakers and the wider society", notes Bakker. "The energy debate is all about solar and wind power, storage, EVs. Relatively little attention is paid to grids. That has to change. We need a renewed focus on transmission and distribution."

“ We will need to spend much more money on the networks, but this is compensated by lower generation costs. Total costs for society will go down. We have to communicate this better.

If the required support is forthcoming, say the DNV GL experts, the energy transition will become a success. "I am confident we will be able to manage it", says Müller-Mienack. "Ten years ago, we could not have imagined where we are today. Prices have come down. IT is advancing.

Grid operators have enormously improved their processes. In some countries, we have over 50% renewables integration. And our engineers will keep on pushing forward. Although we can't see yet very concretely what the future system will look like, we are on our way there." Bakker adds: "We will need to spend much more money on the networks, but this is compensated by lower generation costs. Total costs for society will go down. We have to communicate this better. Furthermore, we should not be afraid to build new grids. In my career I have never seen an investment in a grid that proved unnecessary." ■

Managing the energy transition: What can grid operators expect from tomorrow's energy landscape?

DNV GL's [Energy Transition Outlook \(ETO 2019\)](#) offers an overview of the "big shift" taking place and discusses the many options available to grid operators to manage the transition. Integrating variable renewable energy sources will require large-scale investment in network extensions. The greater complexity in system operation will include increased application of newer technologies such as high-voltage direct current (HVDC) in so called hybrid alternating and direct current (AC/DC) grids. In view of the costs and acceptance issues connected with grid investments, grids will have to be operated closer to their thermal and stability limits. In Europe, interconnectors between large market areas will add to this complexity. Elsewhere, such as Latin America, the increasing share of variable renewable energy allied with market coupling opportunities will lead to interconnectors between countries which have hitherto operated as 'electrical islands.'

Here are the key trends changing the grid landscape in the next few years.

1. VARIABLE RENEWABLES WILL CHALLENGE TRANSMISSION SYSTEM OPERATORS, BUT DIGITALIZATION WILL ENABLE RELIABLE SYSTEM OPERATION

The increased use of markets for flexibility and ancillary services to support system operations, for example, balancing markets, have already led to a significant increase of market liquidity and lower costs. Capacity elements will play an increasing role in maintaining reliability. With greater variability of generation, some power plants will be needed only during power system extremes. Decision-making tools will be increasingly automated. We expect more use of flexibility platforms for accessing decentralized flexibility; automatic optimization of load flow-controlling assets; active management for operation closer to thermal limits; and dynamic weather-dependent line rating. Better operational planning and more accurate forecasting of energy demand and supply will be needed for efficient grid operation based on minimum costs for system balancing. Efficiently integrating variable renewable energy will also require improved system services such as balancing, voltage regulation, fast frequency response (FFR), and congestion management. The national and especially supranational regulatory framework needs to facilitate this transition to a more and more decentralized system.



2. INTERCONNECTIONS AND SUPER GRIDS WILL PLAY A KEY ROLE IN MANAGING SUPPLY AND DEMAND

The completion and continued development of current and new interconnector projects is needed to manage supply and demand over supply regions as variable renewable energy sources capture an increasing share of interconnected power markets. Projects such as the Northeast Asian supergrid, interconnectors in Southern Europe, and Northern Europe's new Hansa PowerBridge, combined with Germany's HVDC corridors, will form overlay grids on top of the existing high-voltage alternating current (HVAC) grid topology. Such overlays will enable seamless trading of electricity, and further market coupling, helping to integrate renewable energy based on competitive principles. They will also have an impact on geopolitics, as reliance on fossil fuels (often imported) decreases and the value of renewable resources increases. Wind and solar PV plants will have to assist their own integration by providing synthetic inertia in combination with storage elements. They can add further value to power systems by supporting grid restoration following blackouts. Renewable energy generators will increasingly provide ancillary services under the condition that they comply with grid codes as well as balancing market and product requirements. State-of-the-art load-frequency control processes will be required for operating highly reliable power systems.

3. DIGITALIZATION AND SMART TECHNOLOGIES WILL LEAD TO AUTOMATION OF NETWORK OPERATIONS

We will see more automation of network operation, and full automation of energy billing and accounting processes. IT platforms will grant access and open the market to new distributed energy and flexibility providers. Sensors and data analytics will mature and enable smart asset management and better utilization of main system elements. This will include new Internet of Things (IoT) sensors; improved monitoring of lifetime consumption indicators; enablement of a decentralized generation structure; and, more sophisticated Supervisory Control and Data Acquisition (SCADA) and related grid-operation tools. Much of this progress will depend on adequate data sharing by grid companies to facilitate combined data harvesting and data hubs to improve performance.

4. A MORE DECENTRALIZED SYSTEM OPERATION WILL DRIVE A NEED FOR HIGHER LEVELS OF REGULATION TO DEFINE ROLES AND INTERFACES BETWEEN PLAYERS

In Europe, ENTSO-E, the association for TSOs, is cooperating closely with EDSO, the association for DSOs. Distribution networks were originally designed to distribute electrical energy top down from transmission systems to consumers. Many distribution systems already operate nowadays with 'reversed' power flows, a trend set to continue as penetration of distributed generation from variable renewable energy and the resulting regional imbalance between supply and demand increases. As system operation becomes more complex, digitalization will play a crucial role and have a big impact through better monitoring and control. This concerns both, transmission and distribution. Better and new security tools, including cyber security, will be needed to manage renewable sources connected to distribution networks. For example, 95% of variable renewable energy sources in Germany are connected to DSOs. We expect greater use of 'digital twins', data-driven virtual representations of physical assets and processes, to predict and test condition management for optimizing renewal and maintenance strategies.

5. AS THE VOLUME OF VARIABLE RENEWABLE ENERGY GROWS, STORAGE WILL PLAY AN IMPORTANT ROLE IN MANAGING SUPPLY AND DEMAND

We will likely see increasing trade-offs between technological solutions for future power systems, such as: massive distribution grid reinforcement; flexibility options such as intelligent charging of EVs; storage; demand response; and sector coupling. The European Ten-Year Network Development Plan predicts that up to 10% of system load in 2040 will be from EV battery storage and large-scale batteries. Storage has a dual role to play both, in the electrification of transport (deployment of batteries in the large fleet of EVs), and the need for static batteries to support weaker grid infrastructures.

6. NEW BUSINESS MODELS WILL EMERGE BY 2025 AS RENEWABLE ENERGY STARTS TO PROVIDE MORE THAN A QUARTER OF OUR POWER NEEDS

At the heart of these models will be a more low-price generation market based on a majority of renewable generation. But for the grid operators we need to enable maintaining a reliable grid infrastructure in both, transmission and distribution. Flexibility markets enable local ancillary services, EVs and their associated demands, and behind-the-meter services. New aggregator roles will enable prosumers to benefit from wholesale price signals. Consumers transforming into prosumers will also increase direct energy transfers and shift the power balance between providers and consumers as the two roles merge. Digitalization will give rise to new digitally-based energy demand response solutions for industries, commercial businesses and households.

7. MICROGRIDS WILL PLAY LARGER ROLES IN THE FUTURE

Examples include the following:

- Isolated very small electricity grids, e.g. for islands or remote villages, usually because low population density or low economic activity makes traditional network extension unaffordable
- Isolated very small electricity grids, driven by economics of fuel supply, such as for mines, offshore oil installations, remote telecommunications, scientific installations or military use
- Commercial, industrial or residential electricity microgrids will be established which have a connection to a larger network, but which, for reasons of reliability, are intended to be run disconnected if necessary.
- Commercial, industrial or residential electricity microgrids will be established, which have never been intended to be autonomous, but managing their own 'behind-the-meter' generation, storage and demand to minimize costs and/or manage grid-connection limitations. We will see more small-scale local microgrids in communities taking advantage of decentralized



power generation opportunities, such as community solar farms. As vRES are integrated into the grid, microgrids can provide a reliable and resilient solution in times of main-grid instability or outages. Lower-cost energy storage equipment enables remote microgrids with vRES in two ways. First, in regions where delivered fuel is expensive, battery storage can reduce the amount of fuel consumed, which in turn reduces the levelized cost of electricity. Second, using less fuel reduces related greenhouse gas emissions.

Coming next...

Next in our *Powering Tomorrow* series, journalist Sonja Van Renssen interviews DNV GL's experts about reinventing grid management for a new age.

The article will explore:

- Grid stability with the mass roll-out of power electronics
- Grid reliability with aging assets
- Sector coupling for flexibility and storage opportunities

You can download and pre-order our series for free by going to www.dnvgl.com/poweringtomorrow

To discuss any of the issues raised in this article please contact our experts on contact.energy@dnvgl.com.