A global industry report

BEYOND INTEGRATION

Three dynamics reshaping renewables and the grid

March 2015

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FOREWORD

by David Walker

It is an exciting time to work in the electricity sector, and the energy industry at large. The factors that define modern power systems are shifting. New technologies and existing systems must be made to work together; environmental concerns are far more important than they've been before; and electricity's role in underpinning and expanding prosperity is almost impossible to overstate.

This project started with the desire to understand how the transition to a largely decarbonised electricity system, with a large proportion of renewables, is changing the fundamentals of the electricity business. And so, because the transformation of electricity systems affects everybody with an interest in how electricity is made, transmitted or consumed, we asked the people on which the system depends what they think about the future and the transition ahead.

In a unique survey of more than 1600 professionals from all corners of the industry and world, we gathered information and opinions on the challenges and opportunities the electricity system may see in the future. To help interpret these findings, we spoke to senior industry executives from E.ON, TEPCO, DONG Energy and NYISO to understand what the energy transition means for them. We are very grateful to all survey respondents and interviewees who took the time to share their insights.

The results, reported here, are illuminating. There is agreement that change is upon us, but there are also some disagreements about what it means and how to respond. As we reveal in this report, moving to a system with a very high proportion of renewables demands more than simply 'integrating' new generation with existing infrastructure and processes. We need new models for doing business, for regulating the power sector and for thinking about electricity.

Alan Kay famously once said: "the best way to predict the future is to invent it." As we look to the future, we should remember that an electricity system is nothing more or less than the sum of the hard work and inventiveness of the people that work every day to create and maintain it.

A frank and open discussion about the future of electricity is needed. By publishing this report and demonstrating that the debate must move 'beyond integration', we are taking the broader view and opening that discussion. I hope that you find the report enlightening, useful, and perhaps even inspiring.

Chief Executive Officer
DNV GL – Energy

EXECUTIVE SUMMARY

Electricity systems around the world are changing. The challenge of combating climate change, maintaining secure energy supplies and protecting electricity consumers is proving transformative. Policy is struggling to keep up with technology. Business models are being created and destroyed.

One of the most profound changes to the power system is the expanding role of solar and wind. At DNV GL, we believe that a transition to a renewables-based electricity system is possible in a range of markets – but we have become increasingly concerned that the way in which this transition is presented underplays the extent of change required. Renewables are too often conceived as something to be 'integrated' into status quo arrangements. A smarter approach is needed.

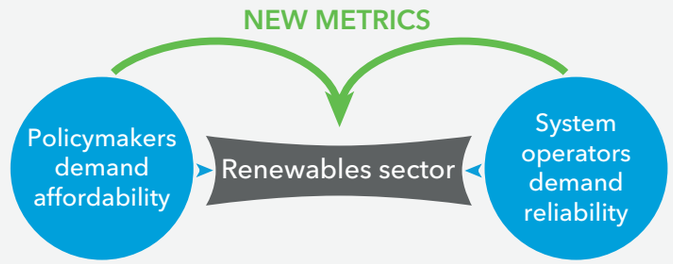
So we sought your insights. In a unique industry survey, over 1600 people from 71 countries provided views on a scenario in which renewables account for 70% of power sector generation. To help interpret these findings, we spoke to senior industry executives from E.ON, TEPCO, DONG Energy and NYISO to understand what the energy transition means for them. This landmark report presents the results of our research, shedding light on three dynamics shaping the energy transition underway.

> "The days of 'monopolized' power are coming to an end...get smarter or get out of the way."
>
> Energy Management Supervisor, Government, North America

Three dynamics reshaping renewables and the grid

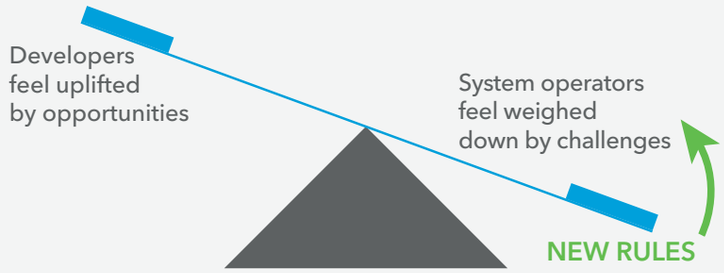
Convergence

New economic metrics will converge the needs of policymakers & system operators.



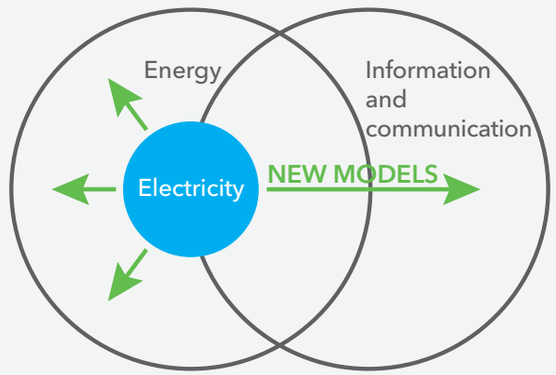
Rebalancing

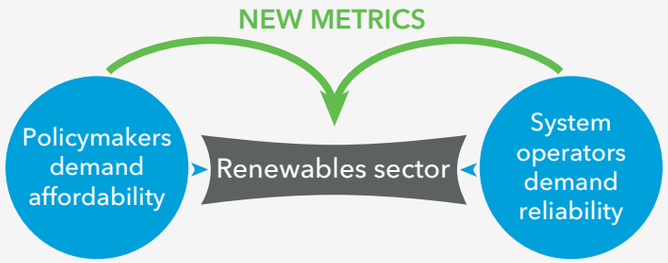
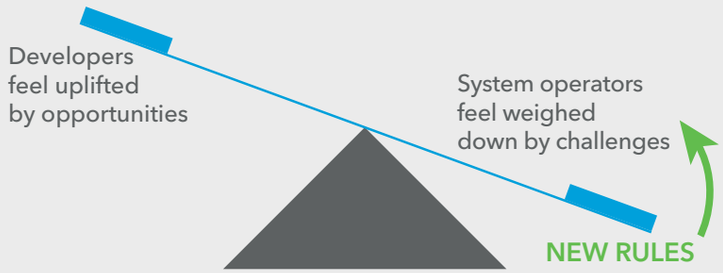
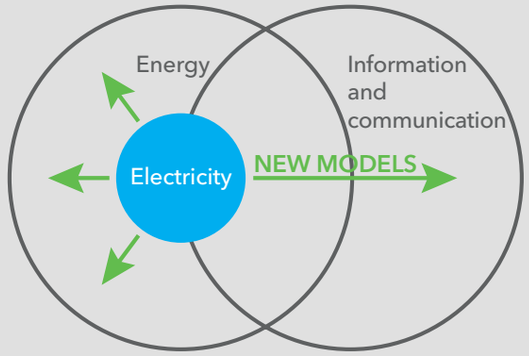
New rules will rebalance the opportunities & challenges for developers & system operators.



Expansion

New entrepreneurial models will expand the electricity business into the internet of energy.



	IN THE RENEWABLES SECTOR	IN THE POWER SECTOR	IN THE ENERGY SECTOR
CHALLENGES	**POLICYMAKERS AND SYSTEM OPERATORS PLACE DIVERGING DEMANDS ON RENEWABLES** Renewables developers are pulled in different directions. On the one hand, they must please policymakers: two-thirds of respondents list politicians and policymakers in their top three most vital players in the transition to a renewables-based electricity system, and qualitative data stresses that securing political will depends on affordability. On the other hand, in a high renewables future, developers must also engage with the increasing challenges of system operation.	**DEVELOPERS FEEL UPLIFTED BY OPPORTUNITIES AND SYSTEM OPERATORS FEEL WEIGHED DOWN BY CHALLENGES** Our survey shows that developers, independent power producers (IPPs) and original equipment manufacturers (OEMs) are relishing the opportunities brought by the move towards a high renewables system, while system operators and utilities identify themselves as being challenged by the transition. But the opportunities spotted by project developers, OEMs and IPPs to drive change can only be realized with the support, expertise and investment of utilities and network owners and operators.	**THE ENERGY TRILEMMA CANNOT BE EASILY SOLVED WITHIN CURRENT BOUNDARIES** Qualitative data hints that the electricity sector needs to become more interconnected with the wider energy system and with information and communications. Current high interest in energy storage, which 66% of respondents select as a top three lever for a high renewables future, is an example of the increasingly blurry lines between power, transport and heat. Meanwhile, respondents' emphasis on smart grids underscores the role for IT in helping to manage the variability of renewables.
DYNAMICS	 **Convergence** New economic metrics will converge the needs of policymakers & system operators.	 **Rebalancing** New rules will rebalance the opportunities & challenges for developers & system operators.	 **Expansion** New entrepreneurial models will expand the electricity business into the internet of energy.

DNV GL RECOMMENDATIONS

IN THE RENEWABLES SECTOR

A CONVERGENCE OF METRICS – LED BY POLICYMAKERS

New economic metrics will converge the needs of policymakers and system operators. Greater reliance on whole-system assessments of power system costs will allow a more representative picture of the affordability of decisions to be taken. The metric of market value, which encompasses revenue as well as cost, at a system level, will better converge developer incentives with the needs of system operators. Examples of implementing this include:

- Gradually exposing developers to stronger market signals on the timing and location of generation.
- Opening up ancillary services markets to renewables and other enabling technologies.
- Considering market value and system costs when planning technology mixes.

BEYOND OLD METRICS

IN THE POWER SECTOR

A REBALANCING OF RULES – LED BY SYSTEM OPERATORS AND REGULATORS, WITH DEVELOPERS' SUPPORT

New rules will rebalance the opportunities and challenges for developers and system operators. Grid code refinement to maximise the capabilities of renewables can often deliver substantial system benefit at minimal cost. This should be done carefully: a heavy-handed regulatory approach should be avoided, and market-based solutions – including the new metric of market value – remain an equally important part of the solution. Examples of implementing this include:

- Amending grid codes to make the most of sophisticated converter functionality of renewables.
- Updating regulation to allow more innovative approaches, such as microgrids.
- Increasing the emphasis on stakeholder engagement in the regulation of system operators.

BEYOND OLD RULES

IN THE ENERGY SECTOR

AN EXPANSION OF HORIZONS – LED BY THE ELECTRICITY BUSINESS, WITH NEW ENTRANTS

While policymakers often see energy in the holistic sense, industry thinking can still be too siloed, focused on the electricity sector. An expansion of horizons is needed, to go beyond old silos and into the 'internet of energy', where smarter, real-time operational controls are used to coordinate input from distributed sources of supply and demand, which span power, transport and heat. Examples of implementing this include:

- Seizing the opportunities of 'subsector arbitrage' with heat and transport.
- Partnering and upskilling in consumer engagement to stay relevant.
- Defining a minimal set of specifications for smart energy systems.

BEYOND OLD SILOS

BEYOND INTEGRATION

For each of these three dynamics, the solutions for a high renewables future demand a change in the way we think about the 'integration' of new technology. Ad-hoc changes to existing systems must give way to genuine systemic thinking, albeit that this systemic thinking should have a pragmatic flavour. We are prompted to take a broader view and to adopt more collaborative approaches as we move into an exciting electric future.

We need to go beyond old metrics, beyond old rules and beyond old silos. In short: beyond integration.

Introduction

The deployment of renewables is bringing profound changes to power systems across the world. It is striking that the two renewable energy technologies which are the least expensive and are available in volume – wind and solar PV – are also both highly variable in electricity production.

We believe that a transition to a largely renewables-based electricity system is possible in a range of markets – but we have become increasingly concerned that the way in which this transition is presented underplays the extent of change required. Renewables are too often conceived as something to be 'integrated' into status quo arrangements. A smarter approach is needed.

So we sought your insights. In a unique industry survey, over 1600 people from 71 countries provided views on a scenario in which renewables account for 70% of power sector generation. To help interpret these findings, we spoke to senior industry executives from DONG Energy, E.ON, NYISO and TEPCO to understand what the energy transition means for them. We are very grateful to all survey respondents and interviewees who took the time to share their insights.

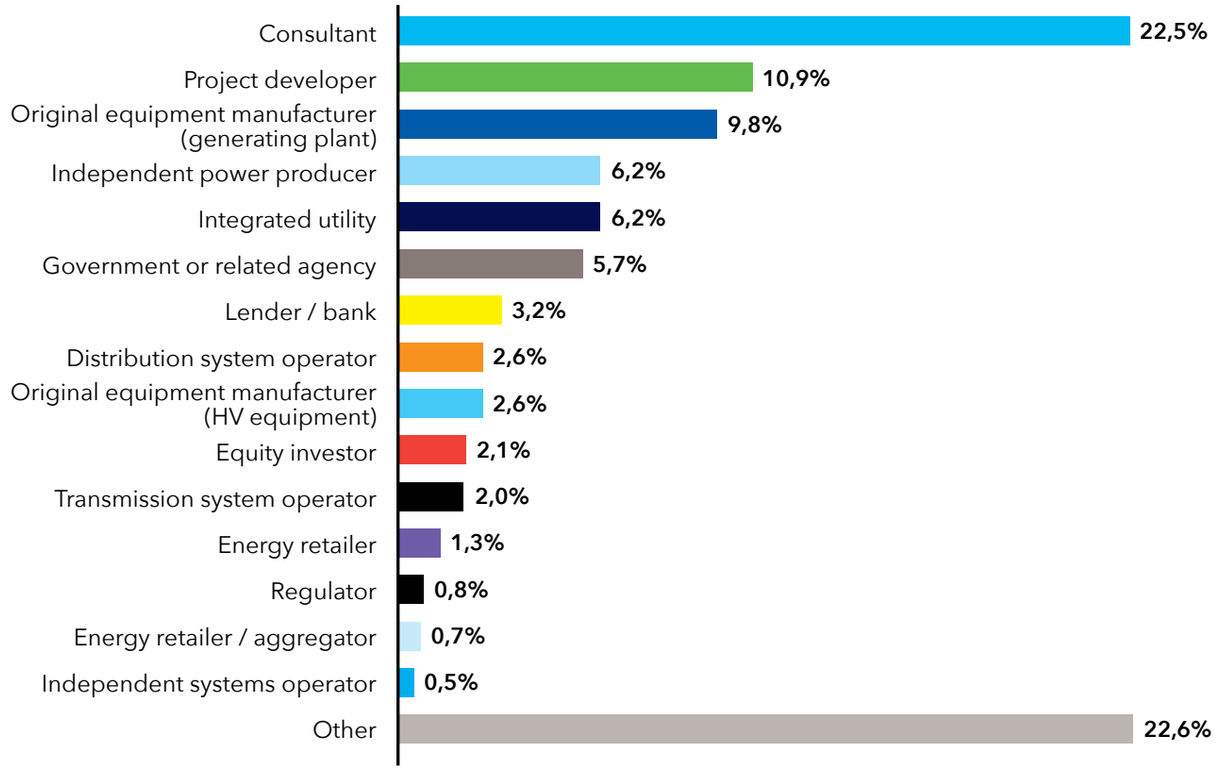
The survey was hosted online from December 2014 to February 2015, attracting responses from across the electricity industry. Three-fifths of respondents were senior/managerial level or above.

The results shed light on three dynamics shaping the energy transition underway:

- A convergence of metrics
- A rebalancing of rules
- An expansion of horizons

Respondent background

What type of organisation is your employer?



A CONVERGENCE OF METRICS

Dynamic 1

Overview: Policymakers and system operators place diverging demands on renewables. A convergence of metrics is needed.

Dynamic 1: A convergence of metrics

Survey findings

8 out of 10 respondents believe that 70% renewables can be achieved before 2050

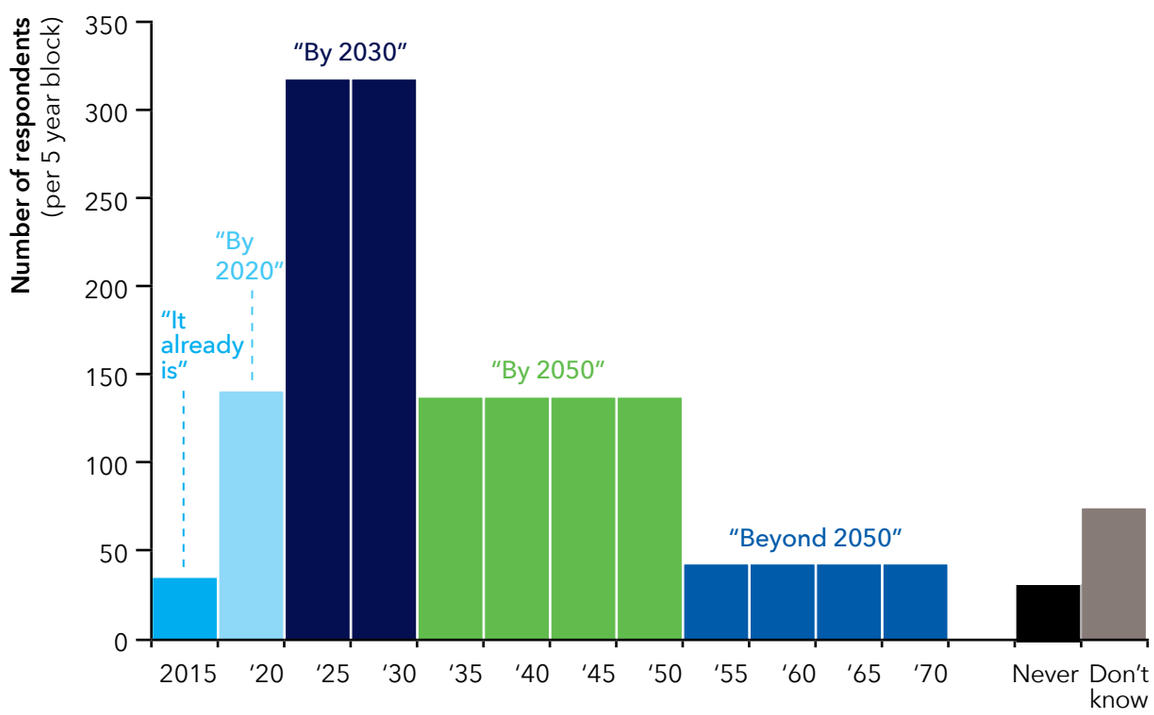
One striking result from our survey is the degree of consensus among respondents about the likelihood of significant change to the power sector and the timescale on which people believe it can happen. For example, nearly three-quarters of respondents said that they were convinced or confident that a smarter approach to the integration of renewables can lead to a clean and secure electricity system at no additional cost to consumers and tax-payers. Similarly, almost half of respondents believe that the electricity system they work in could make the transition to 70% renewable generation in the next 15 years. Even bearing in mind a potential selective bias of optimism amongst those who chose to reply to the survey, this finding is notable.

…but they stress that this is contingent on political leadership and affordability

However, closer inspection of the data indicates that this high renewables system is contingent upon political will. Two thirds of respondents selected politicians and policymakers in their top three most important groups to achieving a high renewables future - a theme which repeatedly reoccurred in qualitative data. To quote the Head of Offshore Wind at an OEM, **"a transition to a low carbon economy is entirely dependent on government support."**

The pace of transition to 70% renewables

How quickly can the transition be made to a high renewables electricity system (70% by generation) which is also secure and affordable in your market(s) of interest?

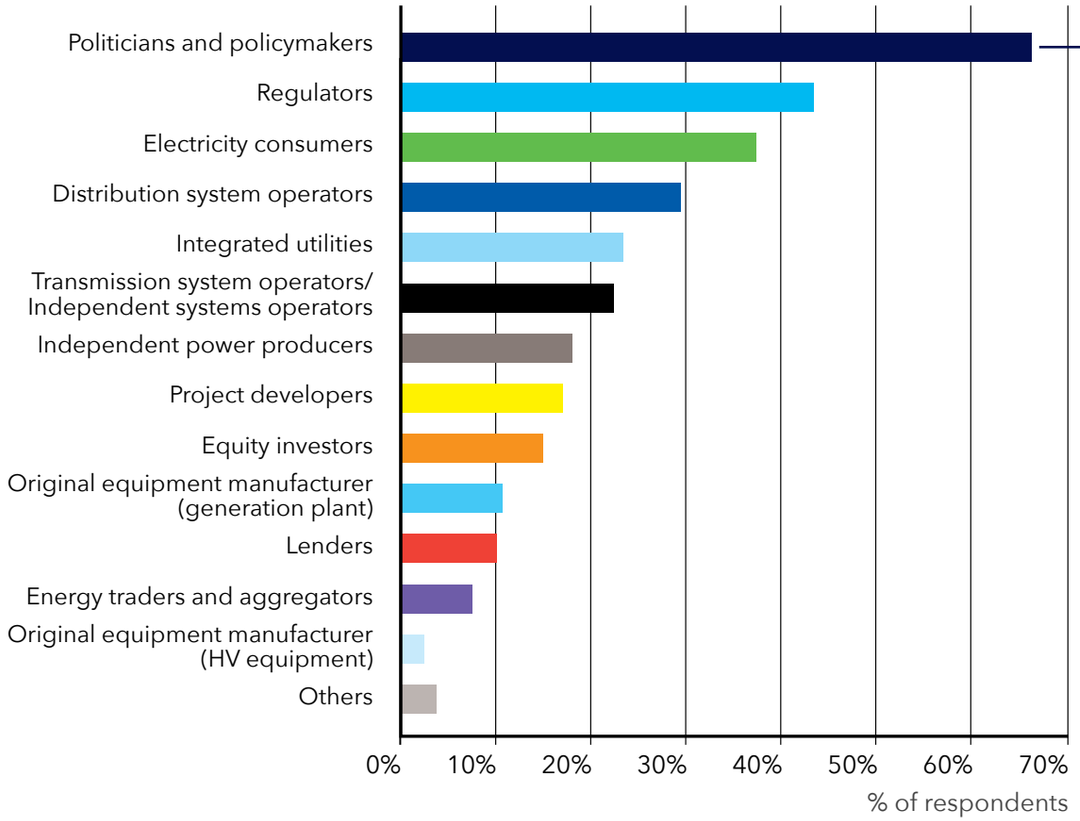


There is a consensus that a high renewables future is achievable within our lifetime.

Notes: 'Beyond 2050' graphically presented as between 2050 and 2070. Percentages are presented through averaged 5-year blocks.

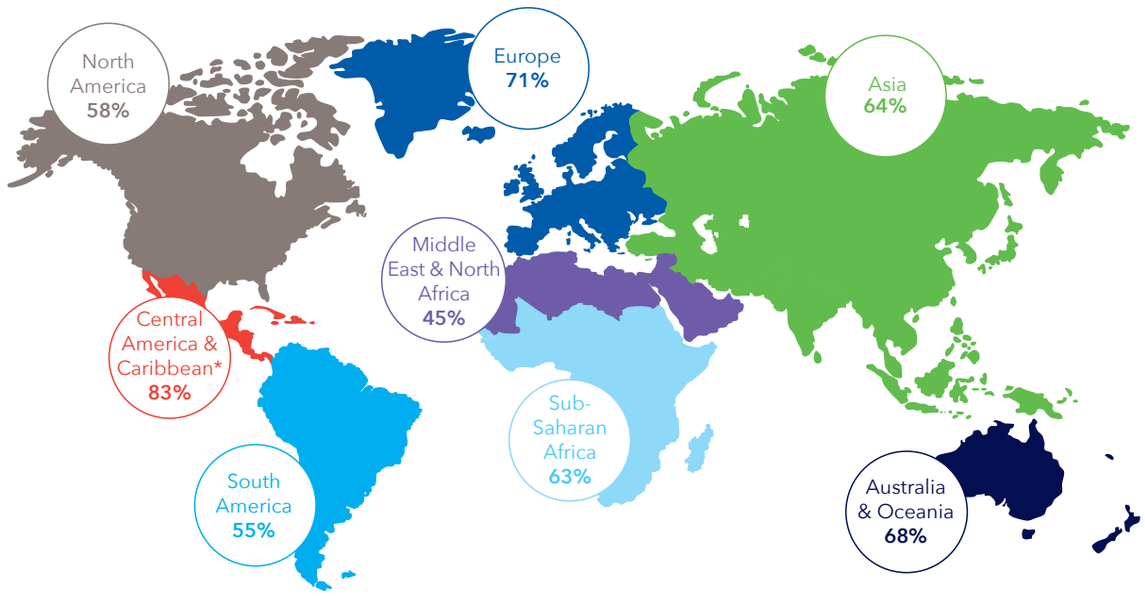
The most vital actors

Whose involvement do you think is most vital to the transition to a renewables-based electricity system (70% by generation) in your market(s) of interest? (Choose up to 3 answers)



Regional breakdown: politicians and policymakers

% of respondents by region who selected 'politicians and policymakers'



*Central America & Carribbean sample size is <10.

Politicians and policymakers are seen as vital to the transition.

Respondents expounded in written answers that political will is contingent upon a clear pathway towards improved affordability of renewables, to satisfy voters and bill-payers. As a European Business Development Director put it, **"The whole industry is about consumers, politics and finance."**

Many were critical of policymakers' narrow focus on levelised cost of energy (LCOE), partly because it ignores externalities such as reduced carbon emissions, but also because it excludes consideration of the market **value** of generating electricity at different times:

- **On externalities: "The current focus on LCOE typically ignores damage costs associated with fossil fuels."** Technical Services Manager, Consultancy, Australia and Oceania

- **On market value: "Most times only comparisons on LCOE are done and [the] main benefits for the electricity system are not taken into account. Most decisions are made in [the] short term and do not regard the long term possibilities of technologies like, which technology would fit best in the long run."**
  Professor, Academia, Sub-saharan Africa

> "The technology is already there. The political will is what will drive the change."
>
> Team Leader, Transmission System Operator, Europe

…whilst at the same time ensuring system reliability

But whilst the political focus may be on the metric of affordability, through the imperfect proxy of levelised cost, written responses stressed that system reliability could not be compromised.

- **"Make sure that reliabilty is the focus. We have a very reliable system and consumers are not used to seeing any brown outs or power failure."**
  Vice President and Chief Engineer, Government or related agency, North America

A minority saw the threat to reliability as a showstopper for a 70% renewables system, whereas others were more nuanced, emphasizing complexity instead. The reliability issue seemed particularly common amongst North American respondents:

- **"I see 70% as a pipe dream primarily because of the reliability issue."**
  Consultant, North America

- **"Intermittent resources only add complexity and cost."**
  Senior Engineer, Integrated Utility, North America

Discussion

Challenge: Policymakers and system operators place diverging demands on renewables.

The survey results show that the achievement of a high renewables system depends on political leadership, dependent in turn on affordability, measured through the proxy metric of levelised cost. This levelised cost metric presents the cost of generation from alternative technologies in isolation, and has historically been the dominant form of assessment. But as renewables penetrations increase, so does the complexity of system and network planning and operations. Measuring generation costs becomes a less robust basis for making decisions about the optimal mix of technologies, and the metric of reliability becomes more important. Thus, in a high renewables system, developers are torn between diverging demands – between levelised cost and reliability.

*Market value is suggested as a pragmatic proxy or second-best metric for true system/economic value.

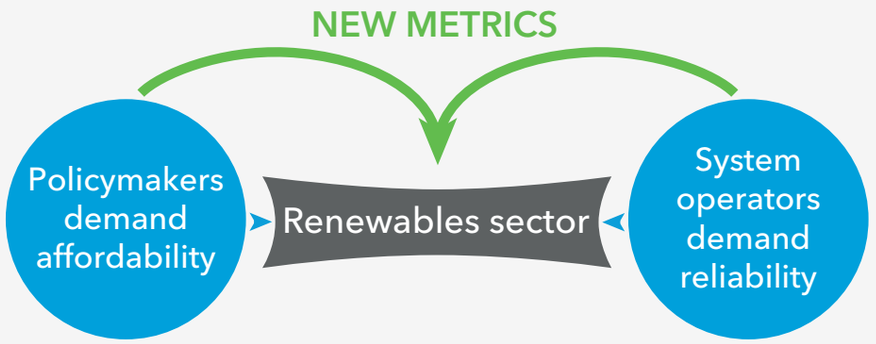
Recommendation: A convergence of metrics

Greater reliance on whole-system assessments of power system costs will allow a more representative picture of the affordability of decisions to be taken. The metric of market value*, which encompasses revenue as well as cost, at a system level, will better converge developer incentives with the needs of system operators. This metric is admittedly complex and location-dependent, varying, for instance, on the local energy mix and market structures. Yet as renewables penetrations increase, it is precisely this kind of holistic approach that is needed. Examples of implementing this metric include:

- **Gradually exposing developers to stronger market signals on the timing and location of generation.** Under high renewables scenarios, the market value of kWh at specific times and locations matters as well as the mere quantity of generation. The metric of *differential kWh* value should be captured through refining renewables support mechanisms. Some countries are already close to achieving this; others still rely on more simplistic mechanisms. The goal should be for more mature renewables technologies to be increasingly exposed to market signals on the scarcity or abundance of generation. Similarly, locational charging reflecting location-based transmission and distribution costs should be phased in. This will encourage developers to optimise generation timing and location at the system level, rather than at the individual project level.

- **Opening up ancillary services markets to renewables and other enabling technologies:** As renewables penetrations increase, it becomes more important for renewables technologies to support system operation, rather than simply maximising total generation. This wider role should be reflected through market design. System operators should review the design of ancillary markets, to enable the full participation of renewables, an example being the provision of synthetic inertia by wind turbines. A key guiding principle of market redesign should be technology neutrality to ensure that the most cost-effective options are selected; in some cases this will be renewables, in others it may be other enabling technologies such as batteries.

- **Considering market value and system costs when planning technology mixes:** Given the long-term consequences of the energy mix, policy roadmaps are crucial – and they must be informed by an understanding of how generation technologies fit together, rather than their narrow levelised costs. This can be achieved through using system models, including an assessment of costs, revenues and risk.



Beyond old metrics: new economic metrics will converge the needs of policymakers and system operators

Sven Utermöhlen
Director Construction & Engineering, E.ON

Headquartered in Germany, E.ON SE has been at the heart of that nation's energy transition or 'Energiewende'. A major investor-owned energy supplier, it has 35 million customers and operates 61 GW of generation capacity.

In November 2014 E.ON unveiled its new strategy. In a landmark move, it announced that it would focus on renewables, distribution networks and customer solutions. E.ON's conventional generation, global energy trading and exploration and production businesses will be combined in a new independent company.

Is this a sign of things to come? What is E.ON's vision of the future of electricity? We asked *Sven Utermöhlen, Director Construction & Engineering, in Global Unit Next Generation* to tell us more.

> "70% renewables is not mainly a technical or commercial discussion. It is mainly a political question."

DNV GL: Our polling of the electricity industry suggests that most respondents are confident or convinced that a power sector with 70% renewables will be achieved, though a substantial minority remains sceptical. How does E.ON see the future of the energy mix?

Sven Utermöhlen: 70 percent renewables is not mainly a technical or commercial discussion. It is mainly a political question. It is clear that a renewables-based electricity system is technically and commercially possible, perhaps by the middle of this century; but only if backed up by political support. We expect renewables to substantially increase their market share, albeit at different paces in different countries. The key political risks endangering this remain the cost of energy supply, and sustainability slipping down the agenda.

The exact make-up of the energy mix depends on the framing of the political objective. Is the goal to decarbonize? Or it is to go renewable? If the former, then nuclear and carbon capture and storage (CCS) may have a role to play. But we often see policymaker preference for renewables in particular due to their additional benefits – such as reduced reliance on fuel imports and safety.

DNV GL: Tell us more about the role you see for gas, nuclear and CCS.
Sven Utermöhlen: The need for a certain amount of dispatchable generation on the way to a 70% renewable future means that, in Europe at least, gas will be the most important of the three. You could say that gas has 'matchmaking potential' with renewables, because of its ability to provide the short term backup capacity to the fluctuating supply from renewables.

DNV GL: The survey tells us that energy storage technologies are rapidly escalating up the agenda. Does E.ON agree with this assessment?
Sven Utermöhlen: Advances in storage technology will be massively important. However, another key innovation will be the 'flexibilisation' of demand. The demand profile will certainly change – for example from technologies which can shift demand into the night or into high supply times, although the impact is still difficult to forecast because it is unclear where exactly this demand response will come from.
The potential for radical change from technologies such as e-mobility is clear.

DNV GL: E.ON's decision to separate conventional and nuclear generation from the renewables and distribution business made headlines last year. Your Chief Executive Johannes Teyssen described it as 'a bold new beginning'. Can you tell us about the factors that led to the decision?
Sven Utermöhlen: Renewables and distribution have very different needs and business dynamics than conventional generation. European and global energy markets have undergone a dramatic transformation with the emergence of a new energy world which is markedly different from the conventional energy world. The new energy world is not centered on the system but on the consumer. Key success factors are a sustainable and clean brand, rapid product development, innovative solutions, digital integration and smart distribution. In the conventional energy world, the key aim is to deliver security of supply. To deliver simultaneously in both the new energy world and the conventional energy world in a single integrated company will become increasingly difficult. Both energy worlds do have their own logics like different value drivers, opportunities, capabilities, cultures, potential partners and ways of thinking. That's why both have their own development and growth opportunities. We're convinced that energy companies will have to make a choice and focus on one of the two energy worlds if they want to be successful in the future.

DNV GL: We've talked a bit about the long term prospects for the power sector. Looking to the year ahead, what does 2015 hold for the energy transition?
Sven Utermöhlen: 2015 will continue the series of ongoing steps towards the electricity transition. It's important to keep a sense of perspective. We are in the process of a long-term transition of the energy landscape, in the way we generate, transport and consume electricity. The transition may not be as quick as many people expect – but it is happening.

REBALANCING OF RULES

Dynamic 2

Overview: Developers see the opportunity, and system operators see the challenge. A rebalancing of rules is needed.

Dynamic 2: Rebalancing of rules

Survey findings

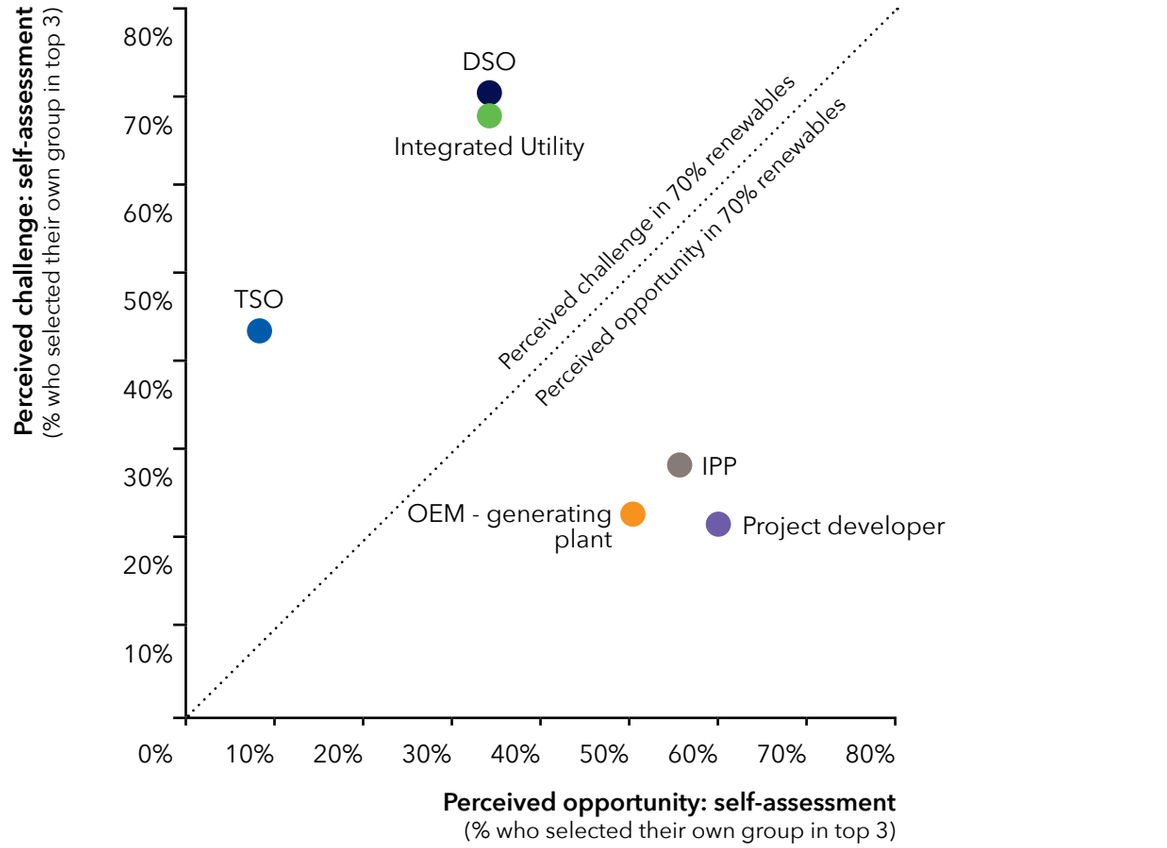
Network owners and operators feel challenged by a high renewables scenario…

The analysis shows an interesting and potentially worrying split between those who build and own new power generation capacity and those who own and operate the networks essential to the functioning of the system. System and network operators are more likely than average to feel challenged by a high renewables scenario. One utility representative commented that clean energy has **'taken on the attributes of a religious cult'**, whilst an employee of a distribution system operator fears that **'there will be a revolt'** due to the possible cost implications. Others recognized the technical challenge, and showed appetite to take it on.

> "I think my utility and others will sit back and do nothing while the 'future' is shaped around them…we seem to think if we bury our head in the sand and not react, maybe it will all go away."
>
> Project Manager, Integrated Utility, North America

Perceived impact of a 70% renewables electricity system

The transition to a renewables-based electricity system (70% by generation) poses the greatest challenges/opportunities to which stakeholders in your market(s) of interest? (Choose up to 3 answers)



Bridging the gap: developers, OEMs and IPPs see the opportunities, but network owners and operators feel challenged.

Note: For simplicity, the graph presents only a subset of datapoints for this survey question, namely the self-assessments of six respondent groups.

The finding that network owners and operators feel challenged by the renewable energy transition is significant, because these players are typically seen as vital to the transition and are highly aware of their powerful role.

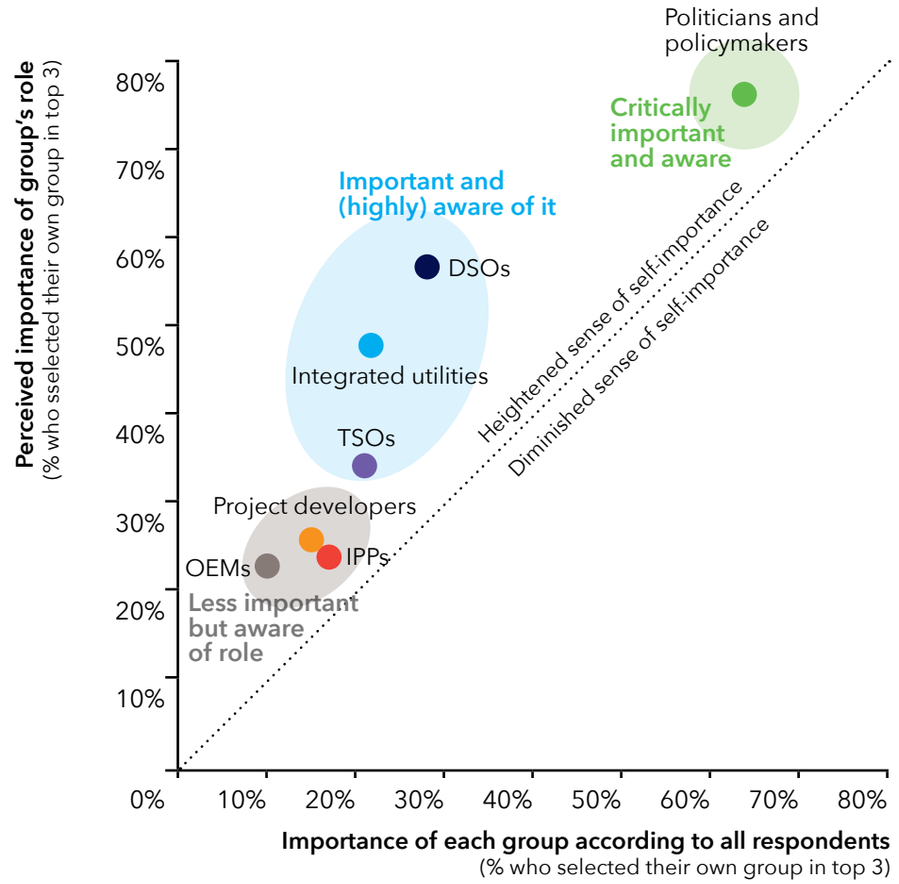
> "Incumbents have a lot to lose."
>
> Anon, Australia & Oceania

…but those involved in development see the opportunity

Meanwhile, developers, manufacturers and IPPs see opportunities in a high renewables system albeit that the nature of those opportunities are changing, challenging traditional business models. One director of a global smart grid company commented that **"The economies of scale most important to the future of electricity are no longer the result of centralization and scale, but rather decentralization and mass manufacturing."**

Importance of each group in transition to renewables-based system

Question: Whose involvement do you think is most vital to the transition to a renewables-based electricity system (70% by generation) in your market(s) of interest? (Choose up to 3 answers)



Grid becomes king: Players involved in system operation are generally seen as important to the transition and are highly aware of their vital role.

Discussion

Challenge: Developers see the opportunity, and system operators see the challenge.

Developers, IPPs and OEMs identify themselves as reaping the opportunities of a high renewables system, whereas those involved in system operation identify themselves as being challenged by it. The implications of this polarized view of the future are far reaching: the opportunities spotted by project developers, OEMs and IPPs to drive change can only be realized with the support, expertise and investment of utilities and network owners and operators.

Clearly, the importance of the grid will increase, to deliver the right quantity at the right moment at the right place and the right quality – bringing significant complexity and challenges. This appears to represent a shift from 'generation is king' to 'grid is king'.

For the orderly transition of the electricity system, all players need to pull together. The polarization of views between those developing new technologies and projects, and those who operate the system is alarming and must be addressed.

*The **'50.2 Hz problem'** refers to a grid-related challenge experienced in Germany resulting from the substantial deployment of PV. Historically, there was a requirement for generators connected to the low voltage distribution network in Germany to shut down when the mains frequency exceeded 50.2 Hz. This requirement was appropriate when the penetration of decentralized generators was low, but posed risks as PV installed capacity rapidly grew. It was recognized that the aggregate effect of potential simultaneous shutdown (and subsequent reconnection) of GWs of PV endangered system stability. A programme of mass technical retrofit was introduced to address this risk.

Recommendation: A rebalancing of rules

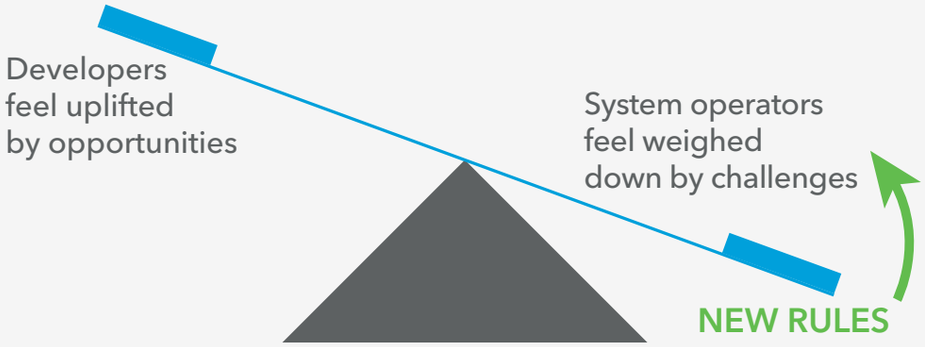
The solution to this challenge partly lies in refining market mechanisms – realigning economic incentives to align with broader metrics that fairly reflect whole-system value, as discussed in Dynamic 1. But regulatory innovation also has a role to play in closing the gap between development and operation. System operators should revise grid and technical codes in preparation for a high renewables system, to ensure that developers, IPPs and OEMs face the right requirements to aid system operation. Regulators have a role to play in nudging system operators in the right direction, and the renewables industry should engage with this process too. Example actions include:

- **Amending grid codes to make the most of sophisticated converter functionality of renewables:** Renewables have different power electronic interfaces to conventional generators. If controller settings are chosen cleverly, some system operation challenges can be avoided, and beneficial services can be provided such as provision of reactive power and selective curtailment. Although such smart converter functionality may not be required at low penetrations of renewables, it will prove helpful as the proportion of variable renewables grows. Bearing in mind the long lifespan of renewables projects (often 25 years), it is important for system operators to plan ahead, whilst retaining a sense of proportionality to avoid unduly onerous requirements. The '50.2 Hz problem'* in Germany provides a case study in the importance of planning: mass retrofit of PV systems was required when it was recognised that frequency settings posed a risk to system stability.

- **Updating regulation to allow more innovative approaches, such as microgrids:** In some cases, particularly in more sparsely located areas or in countries with lower electricity access, a modular microgrid system, or other similar innovations, may bring benefits. Regulatory barriers should be removed to enable exploration of such approaches. Lessons may be learned, for instance, from significant microgrid experience in many developing countries where industrial zones and manufacturing sites often have their own power system due to lack of grid reliability.

- **Increasing the emphasis on stakeholder engagement in the regulation of system operators:** Effective regulation is required to ensure that system operators set the right forward-looking rules. In doing so, it is important that regulators promote stakeholder engagement so that the full breadth of technical options and commercial viewpoints are considered. An example is the Stakeholder Engagement Incentive within the UK's price control regime. This Incentive encourages distribution network operations and transmission operators to engage with a wide range of actors and use the outputs from this process to inform how they plan and run their own businesses.

It should be stressed that whilst a rebalancing of rules may in some instances bring near-term costs to the renewables industry, it is critical for the long-term sustainability of its business – both in terms of ensuring a market, and in avoiding expensive retrofits. If done smartly, there is large potential for the benefit to system operators to be much greater than the cost to developers – meaning that this goes beyond a mere rebalancing effect to delivering mutual benefits to all.



Beyond old rules: New rules will rebalance opportunities and challenges for developers and system operators

Hiroshi Okamoto
General Manager, TEPCO

Tokyo Electric Power Company (TEPCO) has 29 million customers and a peak demand of 51 GW. As the largest electric utility in Japan, it has been engaged in debates about the future energy mix following the 2011 Fukushima Daiichi nuclear accident. It's been a time of great change – with a solar boom, new habits in energy usage and the seeds of market liberalization taking root.

Having witnessed this change, what is TEPCO's vision of the future of electricity? We asked *Dr. Hiroshi Okamoto, General Manager, Engineering R&D Department and Inter-regional Power Exchange Promotion Office* to tell us more.

"We need to strengthen the power markets to introduce more renewable energy."

DNV GL: Japan has a strong nuclear legacy. Can and will Japan move to a high renewables electricity system?

Hiroshi Okamoto: Before the great earthquake of 2011, the government aimed for 50% nuclear and renewables. After the earthquake, this central aim remains unchanged – we need more than 50% non-fossil energy, in a combination of nuclear and renewables, by 2030.

Looking longer term, there is great uncertainty to 2050, but a 60-70% non-fossil fuel mix is expected. It is important for Japan to consider energy security, so we need to decrease dependence on fossil fuel imports.

DNV GL: What role do you see for gas in a future with higher proportions of renewables in Japan?

Hiroshi Okamoto: Japan will conclude discussions on the generation mix for 2030 by summer/autumn 2015. The first driver for gas is decarbonisation: we need to consider the diversification of fossil fuels up to 2030, but within this, gas remains essential to reduce CO_2 emissions (due to lower emissions than other fossil fuels). The second driver for gas is the need for flexible combined cycle gas turbines to balance the grid when larger amounts of renewable energy are introduced.

DNV GL: What innovations do you see as being most important in a future with more renewables?

Hiroshi Okamoto: Many areas will be important – including storage, strengthening the national grid and more advanced metering and control.

The introduction of power markets is particularly important in Japan. We have good technologies for storage and grid technology, and very advanced IT systems. However, from an economic viewpoint, we do not have a well-functioning wholesale power market, so we need to strengthen the power markets to introduce more renewable energy.

DNV GL: What new entrants will appear in the Japanese electricity system in future?

Hiroshi Okamoto: In the near future we will see many new entrants from telecommunications, plus gas companies, steel manufacturers and other players from the heavy industries. There will be a wide range of new entrants on both the seller and buyer side. In particular, on consumption we will see more effective pricing and service packages – telecommunication companies are particularly good at this.

DNV GL: What will be the impact on TEPCO of a greater proportion of renewables? How is TEPCO preparing?

Hiroshi Okamoto: We are now studying the impact of greater integration of renewables. Our service area is not yet ready for renewable energy penetration above around 10-15%. In some rural areas transmission capacity constraints will drive a need to strengthen our grid. On the eastern side of Japan (Hokkaido and Tohoku) we expect very high penetrations of renewable energy. In that case we'll have to consider wider area grid operation and a wide area ancillary services market. We will need some combined systems for ancillary services.

TEPCO's portfolio includes 10% pumped hydro, which is very valuable to aid the integration of renewable energy in the eastern part of Japan. We need to consider the enhancement of interconnection of Tohoku and Tokyo, and the interconnection of Tohoku and Hokkaido. We will also need to consider enhancement of the 50/60 Hz divide.

DNV GL: We've talked a bit about the long term prospects for the power sector. Looking to the year ahead, what does 2015 hold for the energy transition and how is TEPCO preparing?

Hiroshi Okamoto: This year is a very important year for TEPCO. The government will start the energy mix discussion, and then may review and change the feed-in tariff (FIT) system. In doing so, we expect the government will discuss the role of nuclear energy.

Next year the electricity retail market will be fully liberalized, and TEPCO will change from a corporate system to a holding company system to compete in the new market. The change in the electricity market brings challenges. We will need a very good customer management system, and also perhaps to seek alliances with other players.

AN EXPANSION OF HORIZONS

Dynamic 3

Overview: The energy trilemma cannot be easily solved within current boundaries. An expansion of horizons is needed.

Dynamic 3: An expansion of horizons

Survey findings

Qualitative data suggests the importance of seeing electricity in the wider energy system context.

Qualitative data emphasizes that 'the future of electricity' is best seen within 'the future of energy', that the renewables debate should be framed within the energy trilemma of delivering clean, reliable and affordable energy. One respondent expressed this through a succinct imperative: **"Think, plan, design, optimize beyond electricity."**

> "The future of electricity should be put in context with 'the future of energy' in general."
>
> Researcher, Transmission System Operator, Cross-regional

Energy storage is part of this wider energy thinking

Sixty six percent of respondents listed energy storage in their top three most important levers to integrating high shares of renewables.

Yet digging more deeply into the answers to the open-ended question, it seems that although most people agree that energy storage is important there is a lack of clarity on what actually defines storage. While some storage applications lie wholly within the power sector – for instance, dedicated battery storage – the lines soon become blurred with other parts of the energy sector. It seems that some respondents may include electrification of heat and transport within their conceptualisation of energy storage. Some respondents discussed charging electric vehicles at night. As another example, one respondent discussed **"households with electric storage heaters as 'grid batteries' to store renewable energy whenever it is available."**

The intense industry focus on energy storage, then, is opening the door from beyond the power sector and into wider energy system thinking.

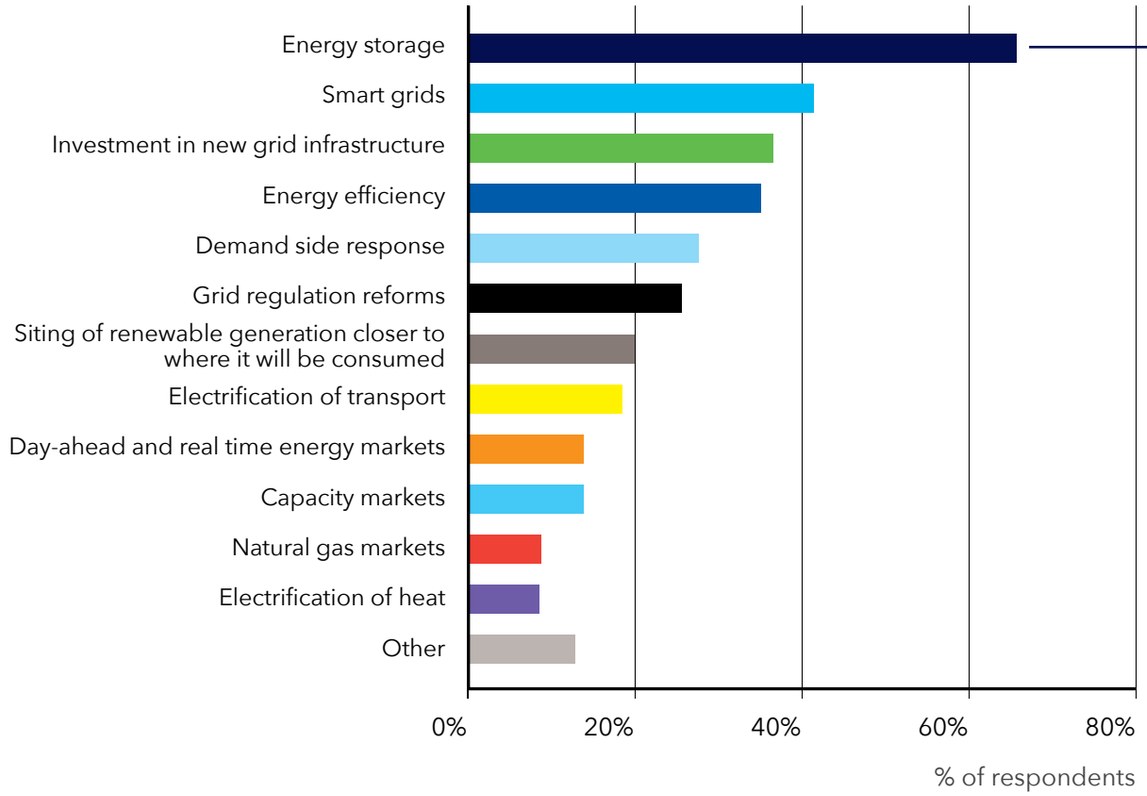
…and horizons are being broadened even beyond energy

Some participants are thinking even more broadly, beyond the immediate energy sector. When asked whose involvement is most vital to the transition, the written responses to the 'Other' option included 'Silicon Valley', 'IT industry', 'Big Data' and 'innovative startups'. This message is reinforced by the finding that 41% of respondents think that smart grids (which are associated with IT innovation) are important to integrating high shares of renewables, the second most popular answer after storage. Consumers are expected to play a key role in this smart grid: 37% of respondents selected electricity consumers in their top three most vital players in achieving 70% renewables, with discussion of demand response appearing in written responses.

> "My money is on Silicon Valley."
>
> Engineer, OEM (Generating plant), Global

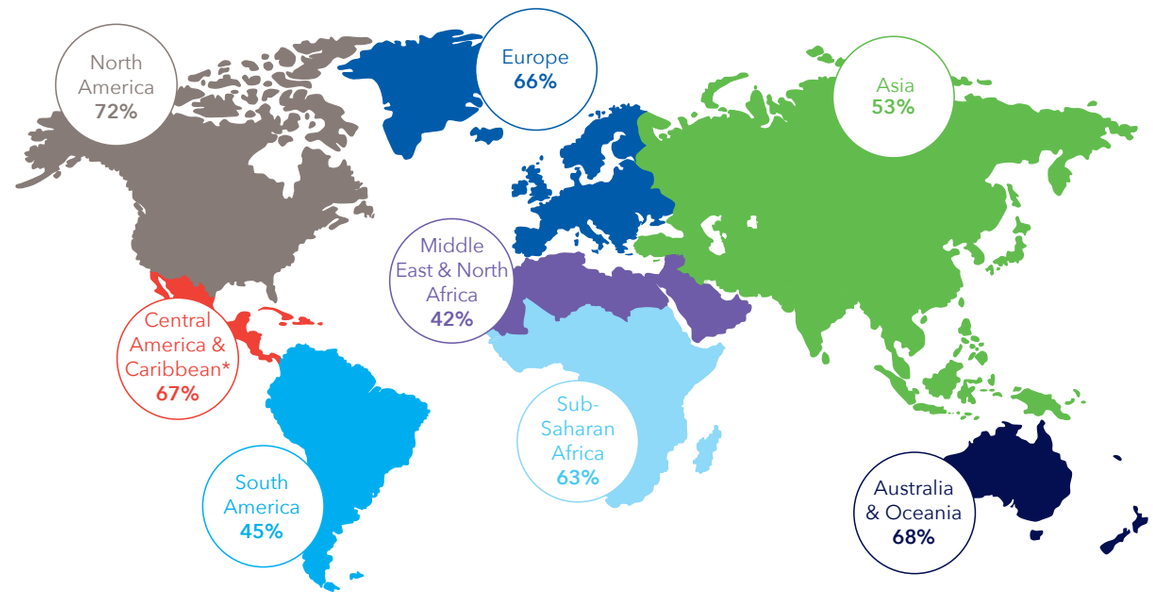
The most important levers

Which changes to technology, markets, behaviour and regulation do you believe are most important in your market(s) of interest for integrating a high share of renewables (70% by generation) in a cost-effective and secure way? (Choose up to 3 answers)



Regional breakdown: energy storage

% of respondents by region who selected 'Energy storage'



*Central America & Carribbean sample size is <10.

Two-thirds of respondents see storage as crucial to integrating high shares of renewables.

Discussion

Challenge: The energy trilemma cannot be easily solved within current boundaries.

The electricity sector is becoming more interconnected with the wider energy system, and also with newer sectors such as IT. Current high interest in storage is an example of the blurry lines between power, heat and transport, whilst the emphasis on smart grids signals the role for information and communications technology. Taken together, this wider energy system thinking and emphasis on smart asset utilization suggest that many of the technical solutions enabling a high renewables electricity system lie outside traditional industry boundaries.

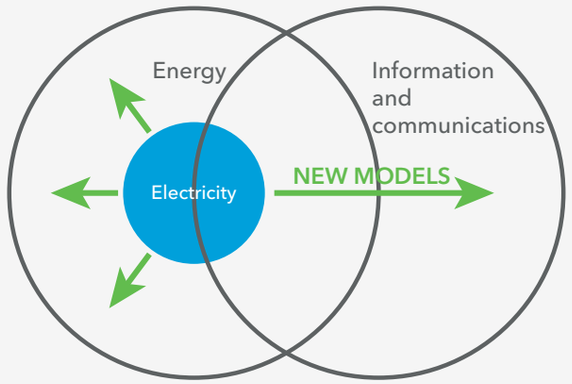
Recommendation: An expansion of horizons

While policymakers often see energy in the holistic sense, industry thinking can still be too siloed. An expansion of horizons is needed, to go beyond silos and into the 'internet of energy', where smarter, real-time operational controls are used to coordinate input from distributed sources of supply and demand, power, transport and heat. The key to deriving benefits often lies in a strategic shift away from development and hardware, to operations and software. Examples of implementing this include:

- **Seizing the opportunities of 'subsector arbitrage' with heat and transport:** Competitive advantage may be obtained through a wider system perspective. Companies which operate across different energy sectors – e.g., electricity and heat – may be able to derive the benefits of 'subsector arbitrage' and taking the broader view within the energy system. Examples could include TSOs owning electric vehicles and leasing them to customers in return for control of charging profiles, or perhaps owning batteries in electric trains and short-run ferries for similar purposes.

- **Partnering and upskilling in consumer engagement to stay relevant:** Forging new partnerships beyond the electricity industry's immediate comfort zone is required to provide new flexibility solutions. An example is the need for utilities to improve capabilities in data analytics and digital engagement to make better use of smart meter data and maximise demand response.

- **Defining a minimal set of specifications for smart energy systems:** This will ensure that products and services for smart grids become 'interoperable'. An example is the Universal Smart Energy Framework (USEF), an industry initiative with the aim to design an open framework to accelerate the development of smart energy products, services and solutions for the large scale implementation of smart grids.



Beyond old silos: New entrepreneurial partnerships will expand the electricity business into the internet of energy

Brent Cheshire
UK Country Chairman, DONG Energy

Whilst its legacy is in oil and gas, *DONG Energy* seeks to 'move energy forward', through the construction and operation of offshore wind farms, and the use of biomass in electricity and heat generation. DONG has built more than one third of the total offshore wind capacity globally. By 2020, it aims to have installed 6.5 GW – representing a quadrupling of its 2012 capacity.

With these strong growth ambitions, what is DONG's vision of the future of electricity? We asked *Brent Cheshire, UK Country Chairman* to tell us more.

> "There is a continued need for large renewables projects, even with a strong focus on distributed generation. "

DNV GL: Can and will we move to a high renewables electricity system, defined as 70% by generation?

Brent Cheshire: DONG Energy aspires to help lead the green transformation of the electricity sector. The challenge is that discussion of specific percentages, targets and dates can leave people fixated on the numbers and forgetting the bigger picture. Whilst people might debate the timelines, certainly over the last decade there has been a huge growth in renewables, including offshore wind, and we expect this to continue in future.

DNV GL: Visions of a high renewables future are often characterized by distributed generation and the empowerment of prosumers. How does offshore wind fit into this?

Brent Cheshire: Offshore wind plant are effectively large power stations. DONG Energy is already building projects that are >500 MW with >40% load factors, and future projects will be around 1 GW with load factors of 50-60%. There is room for substantial growth in distributed generation – but we need to be realistic about how much this can penetrate. For instance, there is a limit to how much prosumers can generate in densely populated cities. There is a continued need for large renewables projects, even with a strong focus on distributed

generation. The reality is that a diversity of supply is required – both in terms of technology, and in terms of scale.

DNV GL: What is the role of DONG in the journey towards a 70% renewables electricity system?

Brent Cheshire: DONG Energy are passionate about the energy transformation. As a company, we aim to reduce our own emissions from electricity production from 640g CO_2/kWh to 230g CO_2 /kWh by 2020, and so are keen to contribute to the renewables transition. Offshore wind has a big role to play in this, and we have a clear strategic target to deliver 6.5GW by 2020 - something we are well on the way to achieving. To maximize the potential of offshore wind, we also need to consider how it can be integrated into the system. Offshore wind has many of the right technical characteristics to deliver ancillary services, and we are in discussion with various grid companies about how to bring this forward. One issue is that the current subsidy regime makes offshore wind seem expensive relative to alternative providers of ancillary services.
The technical potential is there, but market and policy issues need to be resolved to deliver on it.

DNV GL: What do you see as the main challenges to achieving 70% renewables?

Brent Cheshire: Offshore wind technology is developing and costs are coming down. We have been fortunate to have a very supportive regime in the UK, in terms of subsidy and a clear direction from the public and government on what needs to be delivered.

What we need to see in the future is continued support for growth in renewables. This cannot be automatically assumed – due to concerns about the impact on consumer bills, and a rise in scepticism around the climate change agenda. We have been hugely successful as an industry, and we need to continue to deliver - at the same time, becoming better at what we do, so we reduce costs and demonstrate the benefits we bring.

DNV GL: What should we watch out for in 2015?

Brent Cheshire: We are excited about bringing some of our biggest projects to date online, such as London Array and West of Duddon Sands. But the sector won't make a step-change to renewables in a year. This is an evolution. We're on a journey, and in 2015 we'll see the continued evolution of the system adapting to this.

Rana Mukerji
Senior Vice President, NYISO

The *New York Independent System Operator (NYISO)* is at the heart of New York State's electric system, operating the high-voltage transmission network, administering and monitoring the wholesale electricity markets and planning for the state's energy future.

What is NYISO's vision of the future of electricity? We asked *Rana Mukerji, Senior Vice President – Market Structures,* to tell us more.

"We may need to design new market structures… the rate schedule will need to move away from MWh-based compensation."

DNV GL: Let's start with the fundamentals: is a future with 70% renewables possible in New York? Will it happen?

Rana Mukerji: It is technically possible, but low gas prices represent a challenge to the cost-competitiveness of renewables, and storage costs may have implications in the future, too. Political leadership is needed to overcome the cost challenge – for example by addressing uncertainty over the PTC [Production Tax Credit] for wind.

DNV GL: You mentioned storage. What is the role of storage in the future?

Rana Mukerji: It's important to distinguish between two different types of storage. First, there is large-scale storage storing power from hour-to-hour and day-to-day. The economics for this are not currently attractive; gas turbines are often more appropriate. Second, there is storage that helps to match supply and demand on a second-by-second timeframe for regulation services; for example, through flywheels. The latter is already operating commercially and is much more promising.

DNV GL: Many of the services provided by gas and storage could also be provided by a smarter grid in which load is more responsive to price. How do you see this evolving?

Rana Mukerji: Again, the technology is there. The primary barrier

holding back smart grids and demand response is regulation. And here, the New York Public Service Commission's new Reforming the Energy Vision (REV) initiative represents a paradigm shift, unlocking the potential for load to follow generation.

Work has already been done in New York to increase the sensitivity of commercial and industrial consumers to wholesale prices – the next stage is moving towards real-time signals rather than referring to day-ahead pricing. The residential sector still uses fixed rates, although a segment of the population is already installing monitoring devices without any price signal. Some pilots with time-varying rates have been successful; others less so. We need to make sure that time-of-use programs are fair for all and do not lead to the disadvantaged paying more.

DNV GL: What impact will the energy transition have on NYISO?

Rana Mukerji: The impacts will be significant: our job becomes more challenging and interesting as we manage more distributed resources and dynamic loads. We need to prepare for increasing complexity in forecasting loads in both the short and long-term; and may need to adapt to a situation of negative load growth. It is a challenge, but a good challenge.

We're working with others to take concrete steps to adjust to this transition. REV is proceeding, with implications for distributed generation. There will be a Distributed Service Provider (DSP) effectively acting as an Independent System Operator (ISO) for the distribution system to coordinate and manage behind-the-meter resources such as solar and storage. Forecasting mechanisms for wind and solar energy will be refined. And we may need to design new market structures to integrate renewable and distributed energy resources. The rate schedule for ISO/RTO services will need to move away from MWh-based compensation.

DNV GL: Where do the opportunities lie for new entrants?

Rana Mukerji: There are lots of opportunities. Smart home software and appliances are a big growth area – as signaled by Google's decision to pay $3.2 billion for Nest Labs last year. Associated with this growth is an increasing need for expertise on data security and personal privacy protection – another major opportunity. There is also a role for companies that can use data analytic techniques to reduce the acquisition cost of residential customers; at the moment, this acquisition cost is a big hurdle.

DNV GL: In the nearer term, what does 2015 hold for the energy transition?

Rana Mukerji: In New York, I'm keeping my eye on two things: first, how the regulatory regime will evolve to handle behind-the-meter generation; and second, the roll-out of solar across the state.

DNV GL: Any final thoughts?

Rana Mukerji: The electricity industry is on the brink of a sea change. The world is moving to more distributed energy, and this will be helped further by smarter grids and big data. This change is global, important and incredibly interesting – and we're making the planet more sustainable.

"The electricity industry is on the brink of a sea change."

NEXT STEPS: BEYOND INTEGRATION

The survey findings and interviews in this report point to a broad global consensus that a renewables based electricity system can be achieved. But the nature of the electricity transition is contingent upon three dynamics, acting at different levels of the power sector.

These dynamics will play out differently in different regions, shaped by local electricity systems, renewables resources, business models and political cultures. For instance, achieving 70% renewables will generally be easier in areas with hydro, geothermal and/or biomass resource.

But it is clear that for each of these three dynamics, the solutions for a high renewables future demand a change in the way we think about integration of new technology. To unlock the potential, we must shift away from a mindset in which renewables are considered a nuisance to be grudgingly accommodated, and instead adopt a broader view.

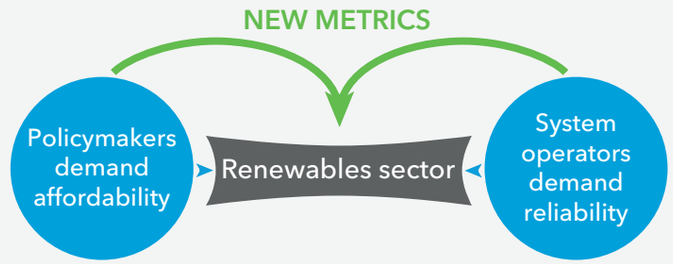
Ad-hoc changes to existing systems must give way to genuinely systemic thinking. This systemic thinking should retain a pragmatic flavour, to mitigate the risk that the search for perfect solutions is used as a blocking tactic.

We need to go beyond old metrics, beyond old rules and beyond old silos. In short: beyond integration.

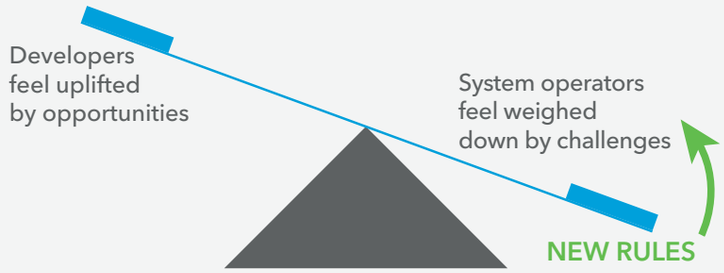
> "[70% renewables] requires a connected joined-up approach with multiple stakeholders acting in concert"
>
> Head of Strategy, Lender/Bank, Europe

Three dynamics reshaping renewables and the grid

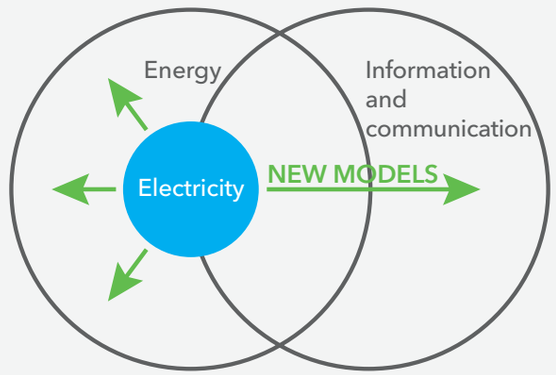
Convergence
New economic metrics will converge the needs of policymakers & system operators.



Rebalancing
New rules will rebalance the opportunities & challenges for developers & system operators.



Expansion
New entrepreneurial models will expand the electricity business into the internet of energy.



Survey details

Survey overview

The survey was hosted online, from December 2014 to February 2015, with DNV GL actively inviting the industry to participate via an e-mail campaign and social media channels. Industry spotlight interviews were conducted by phone or in person, from January to February 2015.

Participants were asked ten questions. These consisted of three profiling questions followed by seven questions on a high renewables scenario:

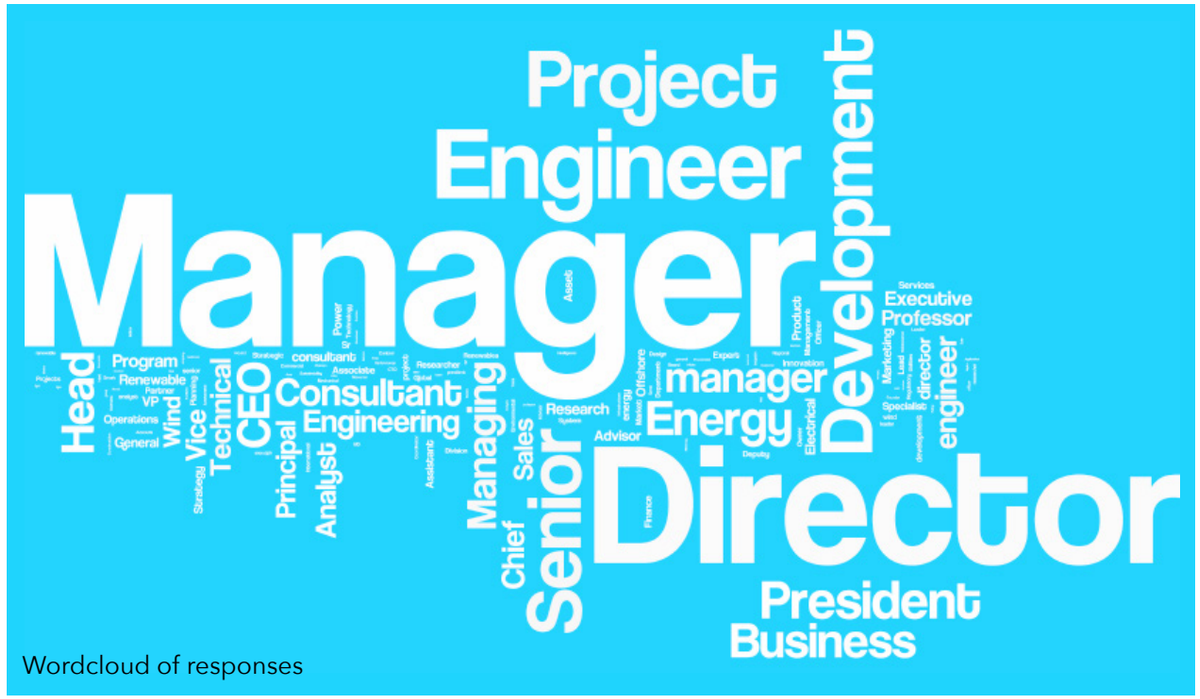
1. What type of organization is your employer?
2. Which global region contains the national electricity market(s) which your job is concerned with? (Choose all that apply)
3. What is your job title?
4. How certain are you that, by 2050, a smarter approach to the integration of renewables can lead to a clean and secure electricity system at no additional cost to consumers and tax-payers, compared to a fossil fuel based alternative in your market(s) of interest?
5. Which changes to technology, markets, behaviour and regulation do you believe are most important in your market(s) of interest for integrating a high share of renewables (70% by generation) in a cost-effective and secure way? (Choose up to 3 answers)
6. Whose involvement do you think is most vital to the transition to a renewables-based electricity system (70% by generation) in your market(s) of interest? (Choose up to 3 answers)
7. To which stakeholders does the transition to a renewables-based electricity system (70% by generation) bring the greatest opportunities in your market(s) of interest? (Choose up to 3 answers)
8. The transition to a renewables-based electricity system (70% by generation) poses the greatest challenges to which stakeholders in your market(s) of interest? (Choose up to 3 answers)
9. How quickly can the transition be made to a high renewables electricity system (70% by generation) which is also secure and affordable, in your market(s) of interest?
10. Please contribute your comments and additional insights in the box below.

70% by generation was provided as an indicative quantification to characterize a renewables-based electricity system. This percentage was selected to focus respondents' minds on a specific scenario that is challenging yet technically possible in a range of markets globally. DNV GL purposively avoided picking a specific existing national/regional target, to avoid introducing regional framing bias into a global survey.

Participant profile

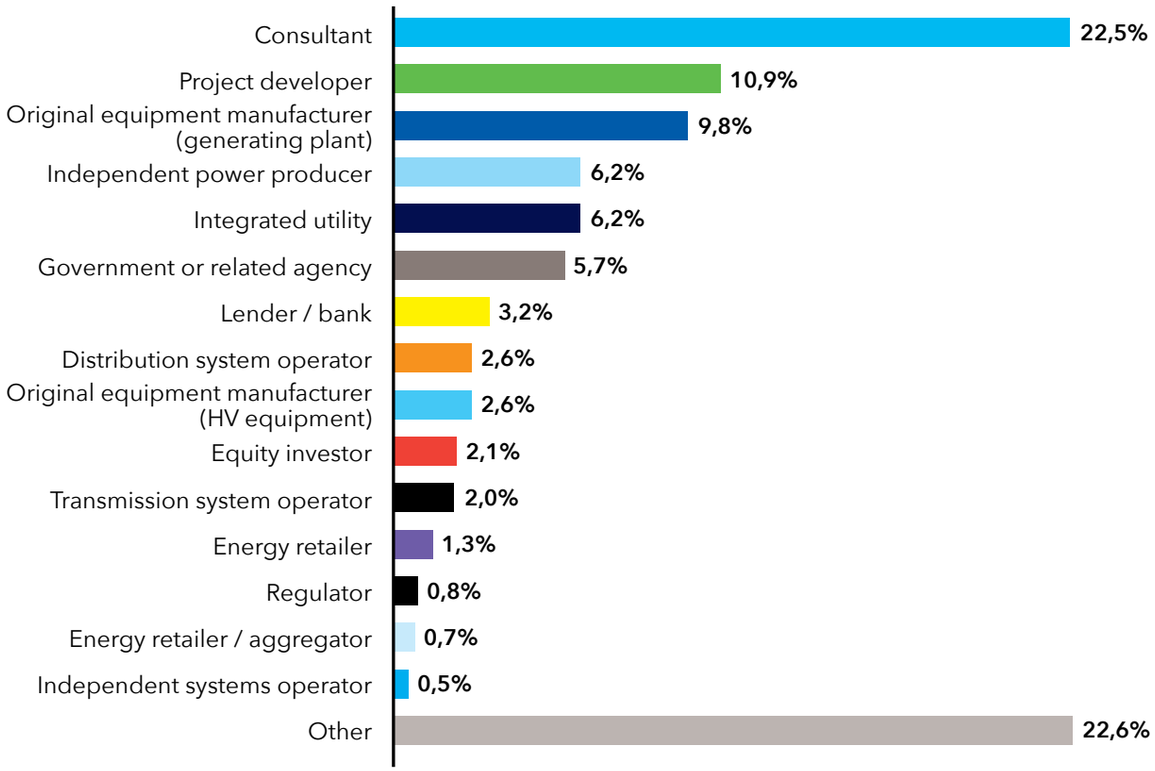
1665 complete survey responses were received. Incomplete survey responses were excluded from the analysis.
60% of respondents were of senior/managerial level or above, where this is defined as their job title, including one of the following words: CEO, President, Director, Executive, Senior/Sr, Head or Manager.

What is your job title?



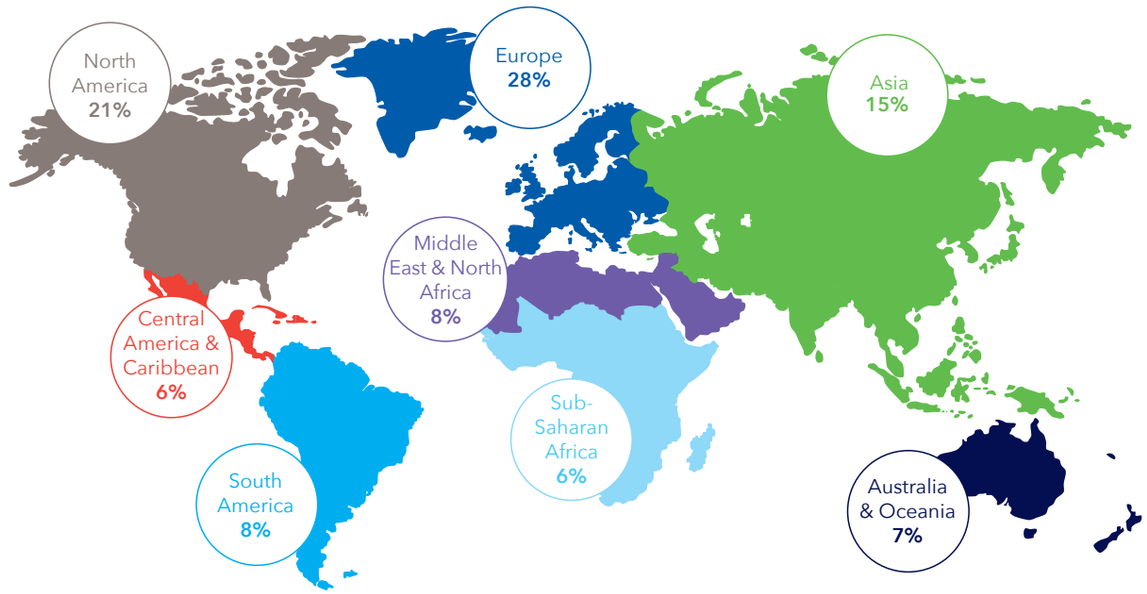
Wordcloud of responses

What type of organisation is your employer?



Which global region contains the national electricity market(s) which your job is concerned with?

Note that the statistics in the map below exclude the respondents who ticked multiple regions, to enable total percentages to add up to 100%.



Respondents came from a broad range of organisations across the energy sector, with the four organization types of consultancies, project developers, OEMs and IPPs together accounting for around half of participants.

There may be selective bias amongst those who chose to respond to the survey. It is possible that those who are more optimistic about a high renewables future may have felt more interested in participating in the survey.

Respondents work in electricity markets across the globe, with responses from the mature markets of Europe and North America being particularly common. 487 respondents indicated that their job was associated with two or more regions, highlighting the global nature of the energy sector.

Presentation of data

- Quantitative data labels have been rounded, meaning that some labels may not add up to 100%.
- Qualitative data presented in the report is mostly taken from freeform answers to the final question, supplemented by answers to the 'Other' category of other questions. Spelling and grammar errors in respondents' qualitative responses have been corrected.
- The profiling information provided after respondents' quotations in the report is based on their answers to the first three survey questions.

Acknowledgements: DNV GL is grateful for the time and insights provided by all survey respondents and interviewed executives from DONG Energy, E.On, NYISO and TEPCO.

Authorship: The principal author is Felicity Jones, Senior Consultant who has lived and worked in the UK, Singapore and Norway, leading strategy and policy projects in renewables. Significant editorial contributions and insights were provided by other DNV GL experts: Oscar Fitch-Roy, Joe Phillips, Ali Nourai and Peter Vaessen.

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In the Energy industry

In DNV GL we unite the strengths of DNV, KEMA, Garrad Hassan, and GL Renewables Certification. DNV GL's 2,500 energy experts support customers around the globe in delivering a safe, reliable, efficient, and sustainable energy supply. We deliver world-renowned testing, certification and advisory services to the energy value chain including renewables and energy efficiency. Our expertise spans onshore and offshore wind power, solar, conventional generation, transmission and distribution, smart grids, and sustainable energy use, as well as energy markets and regulations. Our testing, certification and advisory services are delivered independent from each other.
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