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World Energy
TRILEMMA | 2017

Changing Dynamics – Using Distributed Energy Resources to Meet the Trilemma Challenge

In Partnership with Oliver Wyman

ABOUT THE WORLD ENERGY COUNCIL

The World Energy Council is the principal impartial network of energy leaders and practitioners promoting an affordable, stable and environmentally sensitive energy system for the greatest benefit of all.

Formed in 1923, the Council is the UN-accredited global energy body, representing the entire energy spectrum, with over 3,000 member organisations in over 90 countries, drawn from governments, private and state corporations, academia, NGOs and energy stakeholders. We inform global, regional and national energy strategies by hosting high-level events including the World Energy Congress and publishing authoritative studies, and work through our extensive member network to facilitate the world's energy policy dialogue.

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ABOUT WORLD ENERGY TRILEMMA 2017

The World Energy Council's definition of energy sustainability is based on three core dimensions: energy security, energy equity, and environmental sustainability. Balancing these three goals constitutes a 'trilemma' and is the basis for the prosperity and competitiveness of individual countries.

The World Energy Trilemma Report 2017, prepared in partnership with global consultancy Oliver Wyman, along with the Global Risk Centre of its parent Marsh & McLennan Companies, tapped into the global insights of the traditional and emerging players in the electricity sector – including policymakers, regulators, traditional utilities, large consumer/ prosumers, and technology providers – to capture a wide range of views on the evolution of the energy sector.

The report identifies key focus areas for regulators and policymakers in the context of balancing the Energy Trilemma and driving forward progress on each dimension of the energy trilemma. This report will help further the dialogue by:

- Providing insights on the perspectives from across the evolving electricity sector to identify areas of convergence, divergence and lessons for policymakers
- Insights from global and regional energy sectors and countries at various stages of infrastructure development and Energy Trilemma challenges
- Examine the issues through the perspective of managing country level energy performance on the critical energy trilemma

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FOREWORD

Whether or not politics is behind or ahead of economics, there is no doubt that the energy sector worldwide is undergoing a dramatic transition in which governments, cities, companies, households, and individual consumers are all playing their part. Many attribute this transition to the need to prevent, or at least plan for the potential impact of, climate change whilst enabling access for billions more, new energy users. The drive to reduce greenhouse gas emissions has certainly been a stimulus to the development of new technologies such as solar and wind, which are becoming increasingly competitive with traditional energy systems based on fossil fuels and nuclear. Given the intermittency of energy from renewable sources, there has also been a new focus on improving the potential of electricity storage and smart management of the However, decarbonisation is only part of the transition story. There is also the increase in distributed generation. The renewable technologies it relies on can be deployed regionally or nationally, but the scope for deployment of renewables at a local level is clear, with concomitant new opportunities and challenges for solving the Energy Trilemma of providing secure, affordable and sustainable energy to organisations and to households. Decentralised energy systems may not always be the preferred option for governments and certainly not for traditional energy utilities initially; governments and energy monopolies may lose control and others gain from the decentralisation of energy. Provided regulations and regulators allow the transition to happen, decentralisation can empower local communities, organisations and individual consumers, particularly when energy consumers also produce energy - for example through wind and solar installations that they own. By diversifying potential sources of energy, these new sources of energy also open up opportunities for new entrants, large or small, who can compete to provide consumers with more competitive and reliable energy supplies and the associated supporting services, such as metering and storage which are needed to manage them effectively. In this sense, we may perhaps at last be seeing the emergence of markets for energy and energy services that enable consumers as well as suppliers to have an influence on the final results.

So the story of the energy transition is also about organising the energy market with new aggregating services around the consumer as well as the producer. In addition, if governments and regulators allow and plan for this transition, it will undoubtedly be accelerated by the rapid digitalisation of systems related to energy supply, energy networks and energy demand.

The research behind this year's Energy Trilemma report has attempted to gauge the potential impact of the energy transition, and in particular of decentralisation, on the wide range of energy systems that exist in different countries around the world. Its conclusions will obviously need to be interpreted differently in developed countries with established transmission infrastructures, compared with developing and emerging countries where access to energy is still a major obstacle to be overcome.

While many challenges remain, it is difficult not to be optimistic about the potential for change that has been opened up by decarbonisation, decentralisation and digitalisation in an overall context of electrification of final demand as outlined in the latest energy scenarios published by the Council. The recommendations of this report attempt to present policymakers with clear choices and potential solutions to the Energy Trilemma which are in the interests of society as a whole.

Philip Lowe
Chair, Trilemma | 2017

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EXECUTIVE SUMMARY

The global energy sector is being transformed by three trends that are impacting demand and supply at an unprecedented pace: decarbonisation, digitisation and decentralisation. These trends are reinforcing each other and helping to facilitate a new trend of empowered consumers. This is happening at a time when we are seeing a shift in final energy consumption with demand for electricity doubling globally by 2060. There will be new opportunities and challenges for policymakers to navigate the Energy Trilemma. This will require managing a greater diversity of market actors and technologies without fragmenting the energy system. Provided governments and regulators allow and plan for it, empowered consumers can play a key role in this transition. While the transmission system will remain important, the potential changes support the increasing significance of the distribution level to the optimal operation of energy systems.

KEY FINDINGS

Distributed energy resources are becoming increasingly important to the global energy system, particularly in the context of the energy transition. Improved efficiency and falling technology costs are expected to further accelerate this trend, with distributed generation, particularly renewables, playing a key role. In many countries, regulatory frameworks are trying to catch-up with technology options and shifting energy users demands. Policymakers must move quickly to seize new opportunities in meeting their countries energy needs.

More than 50% of energy leaders surveyed for this report expect a rapid increase in the share of installed distributed generation capacity in their country to 15% or higher by 2025. This represents a significant shift in the generating mix but there are large regional variations based on countries' current electricity structures and how their regulatory systems impact the pace of change. Policymakers, energy utilities[1], innovative new entrants and consumers are the driving forces behind the increase in distributed generation, pursuing electricity access, affordability and competitiveness as well environmental goals. Small-scale industry-level off-grid and household level on-grid are the most common forms of distributed generation in many countries.

Along with the increase in distributed generation, energy storage, including batteries, are becoming a key element of the grid of tomorrow, helping to support flexibility to enhance system efficiency and cost stability. Over the past decade, storage installation projects have sharply increased and that trend is expected to continue over the coming years. Global energy storage capacity along with revenues from utility-scale applications are expected to increase dramatically over the next 5-10 years[2]. But without dynamic policy frameworks this growth could stall.

As the decentralisation trend continues in many countries, four power system archetypes emerge. Each archetype represents a different combination of centralised and decentralised generation, including a centralised, two hybrids and a decentralised system. Recognising these emerging systems will be important in managing the complex transition from the infrastructure backbone of past to the grid of the future.

1 The word 'utility' is used more generally to cover the diverse range of companies involved in the provision of energy from traditional incumbents in non-liberalised markets to the different market operators in liberalised markets.

2 *Energy Storage Trends and Opportunities in Emerging Markets,* IFC, 2017

THE INTERVIEWS WITH ENERGY LEADERS HIGHLIGHTED FIVE KEY THEMES

1. Countries that do not take the necessary steps to integrate distributed energy resources will face heightened energy security risks, potential infrastructure redundancies and investment challenges that will adversely affect their Energy Trilemma performance.
2. Decentralisation not only adds new resources to the system, but can also create new actors on energy markets, provided governments and regulators are prepared to allow access to them. Market entrants such as large energy ‘prosumers’, energy service aggregators, and rural energy entrepreneurs offer new sources of generation, supply and demand management. As countries transition to hybrid systems, the policies and regulatory frameworks governing who can participate in the energy markets and how, need to evolve.
3. Maintaining system reliability will become increasingly complex and new approaches to system management, supported by enhanced information technology systems, will be required to ensure energy security. However, this also creates the opportunity to improve system resilience through greater diversity of supply and generation, together with improved grid management.
4. Distributed generation technologies and standalone micro-grid and off-grid systems can provide electricity access at a faster rate and lower cost than conventional grid connections. This could allow developing economies to consider ‘leap-frogging’ some degree of centralised generation infrastructure to increase electricity access and meet global sustainable development goals.
5. Energy access and use is being opened up as consumers (especially companies) take control of how their energy needs are met and managed, enabled by growing options for distributed energy resources. If regulations and regulators empower them, consumers have the option to generate power for their own consumption and sell their excess electricity back into the grid, to leave the grid completely, or only use grid supply to supplement their own generation. They can choose electricity providers and utilise new energy management technologies to determine how to use energy. New technologies, such as blockchain or predictive analytics, will support this trend. Policymakers must evolve regulatory frameworks to integrate new opportunities arising from distributed energy resources and, potentially more proactive consumers, to respond to rising and rapidly evolving demands and options for energy use.

IMPLICATIONS FOR THE ENERGY SECTOR

To achieve long-term energy goals and enable policy innovation, as well as reform, to play a part in navigating the Energy Trilemma, policymakers and regulators need urgently to focus on these emerging technologies. New opportunities can be created, but may be associated with the disruption of existing market frameworks, roles and responsibilities, leading to a reconsideration of the energy services provided and how the costs for energy services are recovered.

As countries transition from one archetype to another, the role of energy incumbents will change. This transition will need active management given the financial exposure of other economic sectors. Without coherent and predictable policy and regulatory frameworks in place, incumbents may refrain from making the necessary and new investments that may, in turn, affect system reliability and affordability. Energy incumbents need to work with regulators to develop effective and responsive tariff and pricing models to cover the cost for operating, upgrading and maintaining grids, as well as providing back-up capacity.

If consumers – residential, commercial and industrial – are enabled by regulators to exploit these new opportunities, regulators will also need to ensure equity for all consumers across the energy system. As distributed energy resources give consumers with financial capacity and empowered by suitable aggregation services the opportunity to manage energy cost and price volatility, it exposes those consumers without financial capacity to price increases.

Distributed energy resources could also offer scope to reduced carbon emissions and address localised pollution and some empowered consumers are already using them to meet their own environmental sustainability goals. Regulators will need to consider how their market frameworks can adapt to support suitably distributed energy resources while improving the environmental sustainability of their power systems.

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DISTRIBUTED GENERATION AND BALANCING THE ENERGY TRILEMMA

The electricity sector is undergoing change at an unprecedented pace, with the growth in distributed generation (DG) enhancing trends in decentralisation, decarbonisation, and digitisation. This is opening new opportunities and challenges for countries to balance the energy trilemma.

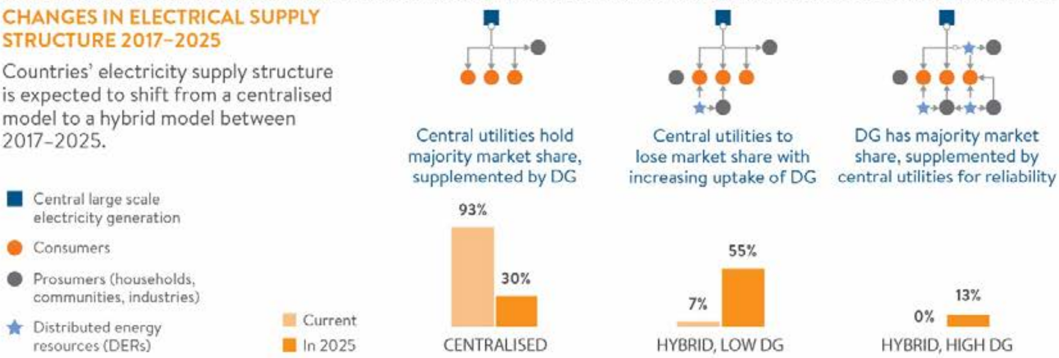
DG EXPECTED TO INCREASE RAPIDLY

Energy leaders are predicting a major increase in the amount of DG in their countries' installed electricity supply by 2025.

2017 **5% or less** → 2025 **25%-plus**

CHANGES IN ELECTRICAL SUPPLY STRUCTURE 2017–2025

Countries' electricity supply structure is expected to shift from a centralised model to a hybrid model between 2017–2025.



DG POSES SEVERAL CHALLENGES AND OPPORTUNITIES IN ACHIEVING ENERGY TRILEMMA GOALS

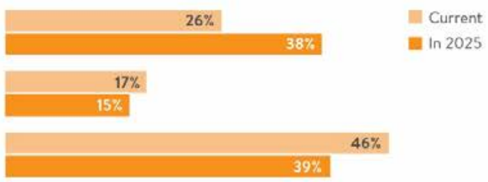
Perspectives on which energy dimension will be under greatest strain with increased DG.

44% ENERGY SECURITY

30% ENERGY EQUITY

19% ENVIRONMENTAL SUSTAINABILITY

Increasing energy access is current driver for DG but ensuring environmental sustainability and security will rise in importance by 2025



UNCERTAINTY WHETHER REGULATIONS CAN KEEP PACE WITH CHANGE

Increasing DG will require fundamental changes to regulations and who can participate in the energy market. Energy leaders worldwide are sceptical as to whether current regulatory frameworks can accommodate the shifting energy supply structure.

Can the current energy regulatory regime accomodate the shifting energy supply structure?

RECOMMENDATIONS

Evolving technology and customer demands are two key drivers of a transition of the electricity system at an unprecedented pace. Policymakers should develop their own in-depth analysis of the potential opportunities and challenges that may arise in their own countries or regions from adopting distributed energy resources. Regulatory frameworks must evolve to integrate new opportunities to balance the Energy Trilemma effectively. The 2017 World Energy Trilemma research has identified three key focus areas for policymakers and industry leaders to consider in order to build a resilient energy system of tomorrow:

- **Enable a dynamic and resilient market framework with the agility to adapt with the transitioning system.** The market framework must be responsive and resilient to the future changes that will arise from new consumers and evolving customer needs and technological advances, as well as changing roles and responsibilities of market participants. Within this dynamic environment, regulators will need to enable adaptable funding mechanisms for rates and charges to support the necessary continued investment in the energy system.

- **Establishing robust technology-neutral regulations supported by agreed standards with all stakeholders will be key to building a more dynamic and resilient market framework that supports transitioning energy systems.** This includes standards for project development and financing to reduce cost and inefficiencies. Technical interoperability and service harmonisation, as well as standards to promote uptake and integration of distributed generation and distributed energy resources, are critical.

- **Allow and plan for aggregator services to empower consumers to be more proactive by ensuring that the market framework can adapt to their evolving and shifting needs.** Technology will provide new options to access and consume energy so the framework design will need to enable consumers to make those choices. This will require a different approach of considering what consumers may want and ’reverse engineering’ a market framework to facilitate new market entrants while keeping the trilemma goals in balance.

The energy transition is an unstoppable phenomenon. There will be leaders, learners and laggards, and adapting to this new reality with innovative policy responses and new business models will require an enormous effort. The ability of companies and policymakers to respond rapidly, creatively and collaboratively will determine the pace and shape of the global transition and, in turn, affect the ability of societies across the world to navigate the Energy Trilemma of security, sustainability and equity successfully. Governments and regulators need to plan for the transitions and anticipate its likely impacts on energy systems and market actors.

Introduction

INTRODUCTION

The global energy system is being transformed by three reinforcing trends impacting the demand and supply of energy at an unprecedented pace: decarbonisation, decentralisation and digitalisation.

These trends affect all parts of the energy sector with a shift towards electricity in transportation and an increased role for combined heat and power (CHP) but will have a significant impact for the power sector, which is the focus of this report. But the trends also create new opportunities and challenges that allow policymakers to leverage a wider range of options to move forward on balancing the Energy Trilemma – the provision of secure, affordable and accessible, and environmentally sustainable energy. Responding to these new challenges and opportunities will require increased focus on managing the greater diversity of market actors and technologies without fragmenting the energy system. Furthermore, the emerging role of empowered consumers (particularly companies) is expected to be a driving factor of change, but only if the regulatory system allows sufficient empowerment of those consumers.

In this period of transition, energy industry leaders emphasized the need for energy policymakers and regulators across the globe to have clear long-term objectives that leverage all energy sources and technologies as well as the energy services that existing and new market players can offer. Coherent energy policy and market conditions that adapt with the transitioning system are key to attracting long-term investment, and driving progress on all three aspects of the Energy Trilemma while managing and optimizing the energy transition.

DEFINING THE THREE DIMENSIONS OF THE ENERGY TRILEMMA

ENERGY SECURITY
Effective management of primary energy supply from domestic and external sources, reliability of energy infrastructure, and ability of energy providers to meet current and future demand.

ENERGY EQUITY
Accessibility and affordability of energy supply across the population.

ENVIRONMENTAL SUSTAINABILITY
Encompasses achievement of supply- and demand-side energy efficiencies and development of energy supply from renewable and other low-carbon sources.

Distributed energy resources (DER), especially distributed generation (DG) and energy storage, are expected to play an increasingly larger role in the ‘Grand Transition’ of the future energy scenario (see Box A). This Transition will result in fundamental changes across all aspects of energy supply, demand and use. The power sector is already undergoing changes. The pace, impacts and specific consequences of the uptake of distributed energy resources and the transition of the energy system remain unclear and create a new uncertainty[3]. The rapid pace of change on many different fronts makes balancing the Energy Trilemma a more dynamic process for policymakers, regulators and market participants.

3 World Energy Council, *2016: World Energy Scenarios – The Grand Transition*

Box A: The Grand Transition

Since 1970, the world has seen rapid growth in energy demand, mainly satisfied by fossil fuels. The future will be different. Disruptive trends are emerging and the underlying drivers will create a fundamentally new world for energy industry. The uncertain journey into the new world of energy is called - The Grand Transition.

In looking forward, it is important to consider both inevitable changes and important yet uncertain, new developments. In the inevitable Grand Transition, predetermined factors include: the slowdown in global population growth, the accelerating convergence of digital and other technology developments, a greater appreciation of the planet's environmental boundaries, and a shift in economic and geopolitical power towards Asia. The global energy sector will also be shaped by the following key uncertainties: the pace of innovation and productivity, the shift in geo-politics and international governance, the priority given to equity, sustainability and climate change, and the selected tools for action - the balance between the use of markets and state directive policy.

Three alternative transition pathways

Of the many possible pathways, the WEC has identified three alternative scenarios which are plausible, relevant and challenging and avoid the normative trap of all good vs. all bad futures thinking. These three scenarios are not single trend forecasts but describe an interplay of inevitable and uncertain developments and the different configurations of energy ecosystems that emerge in each. The three scenarios are:

- Modern Jazz, which represents a digitally disrupted, innovative and market-driven world that;
- Unfinished Symphony, a world in which more intelligent and sustainable economic growth models emerge that internalise environmental costs and to a low carbon future; and a more fragmented scenario called
- Hard Rock, which explores the consequences of lower and slower global economic growth and a return to inward-looking, security policies.

These three scenarios present challenging and contrastable energy futures with a time horizon to 2060. They are designed to enable leadership dialogue about the future fitness of strategic decisions taken today as part of enterprise strategies and government policies.

The general contours of the world energy system in 2060

As a set, the three scenarios highlight that the world's primary energy demand will slow significantly and per capita energy demand will peak before 2030 due to unprecedented efficiencies created by new technologies and more stringent energy policies. Demand for electricity, however, will double by 2060. New cleaner electricity generation is needed to meet climate challenges and utility business models will be shaped by a combination of policy reform, rapidly shifting consumer demands and disruptive demand side technologies. The co-evolving diversity of regional energy systems will shape and be shaped by these new, fast and fundamental global shifts.

The implications for electricity grids – the new dynamics of centralisation and decentralisation

In Modern Jazz, the traditional utility model comes under pressure as the development of distributed energy systems accelerates and consumer demands have more direct influence of supply-side investments. In developing economies, such as India and Sub-Saharan Africa, modular systems that generate power close to where it is used provide new opportunities for electrifying rural regions. New energy technologies, non-traditional competitors, shifting societal expectations and new regulations on data and privacy, reshape energy systems. In response to these changes many utilities have to rethink conventional business models and address new risks. In Modern Jazz, three new models

emerge in response to the challenges of managing renewable energy penetration and distributed systems: low carbon energy producers; distribution platform optimisers; and, energy solution integrators.

In Unfinished Symphony, utilities must respond to a more globally coordinated and stringent national environmental policies and include increasingly variable sources of electricity into their supply mix. Intelligent infrastructure and smarter grids enable utilities to better manage distributed renewable resources. The increasing complexity of connections between energy infrastructure, communications networks, and other infrastructures such as water and wastewater systems presents new challenges. Energy leaders rethink traditional, linear security paradigms of energy system planning and operation, and develop adaptive and dynamically resilient energy systems that address network effects and balance benefits and risks of centralisation and decentralisation. High integrated business models and funding mechanisms emerge that allocate the system cost of renewables to avoid the zero-marginal cost effect distorts energy markets.

In Hard Rock, utility companies encounter a tipping point in consumer demand as prices for renewable energy fall with the accelerating pace of clean energy technology adoption. However, a structural slowdown in global economic growth forces governments to enhance performance and extend the lifetime of existing energy infrastructures. Utilities struggle to navigate demand-side disruptions and to effectively engage with regulators who demand energy productivity improvements that enhance national energy security. Regions spawn a variety of new energy security policies and energy productivity models and a common feature is less regional integration. Large, integrated utilities work best in some regions, such as China and Europe, while in others, such as India and Sub-Saharan Africa, distributed energy solutions dominate urban and rural communities. There is no one-size fits all energy security model, but the most successful companies nimbly adjust to the different needs of urban and rural communities.

The 2017 World Energy Trilemma report, prepared in partnership with global consultancy Oliver Wyman, along with the Global Risk Centre of its parent Marsh & McLennan Companies, tapped into the global insights of the traditional and emerging players in the energy sector - including policymakers, regulators, utilities, large consumer/ prosumers, and energy sector technology providers – to capture a wide range of views on the evolution of the energy sector.

The report's primary focus is on the impacts and challenges of the expansion and integration of distributed energy resources, in particular distributed generation, into existing power and electricity systems. It identifies key focus areas for policymakers and regulators using the framework of the Energy Trilemma to develop a path to greater energy sustainability.

This report furthers the dialogue by:

- **Providing insights on the perspectives from across the evolving energy sector** to identify areas of convergence, divergence and lessons for policymakers and regulators
- **Sharing lessons from countries across the world** at various stages of energy system and electricity infrastructure development as they manage the decentralization trend
- **Examining implication of the development of distributed energy resources on the Energy Trilemma** by identifying opportunities and challenges countries may face as they manage the greater diversity of market actors, technologies and empowered consumers

The report methodology included desk research, interviews, workshops, and an on-line survey and the aggregated perspectives of this research is presented in the report.

- **Interviews** were conducted with close to 40 energy leaders (including utilities, prosumers, energy entrepreneurs) around the world.

- **Workshops** were conducted in Africa, North America and in Europe.
- **An on-line survey** was widely distributed by the World Energy Council in partnership with Oliver Wyman and Marsh & McLennan Companies to members, clients and energy sector participants. The survey consisted of ten closed ended questions and received close to 200 responses from respondents around the world.
- **Desk research** was conducted to ensure all prior research, publications and work on the current energy landscape was understood and not duplicated. This report leverages prior discussions and continues the dialogue.

The report is divided into three sections:

1. Section 1 examines how distributed generation as part of an evolving array of distributed energy resources presents challenges and opportunities for policymakers to consider in structuring energy frameworks to meet the Energy Trilemma – ensuring secure, affordable and environmentally sustainable energy.
2. Section 2 outlines the components and actors in an electricity system as countries move from centralised systems to hybrid archetypes and highlights the key issues for policymakers to consider in optimizing these components.
3. Section 3 presents guidelines for policymakers and regulators as they evolve regulatory frameworks in response to energy technology changes.

1

The Evolving Energy System and the Energy Trilemma

1.1 THREE TRENDS DRIVING TRANSITION IN GLOBAL ENERGY SECTOR

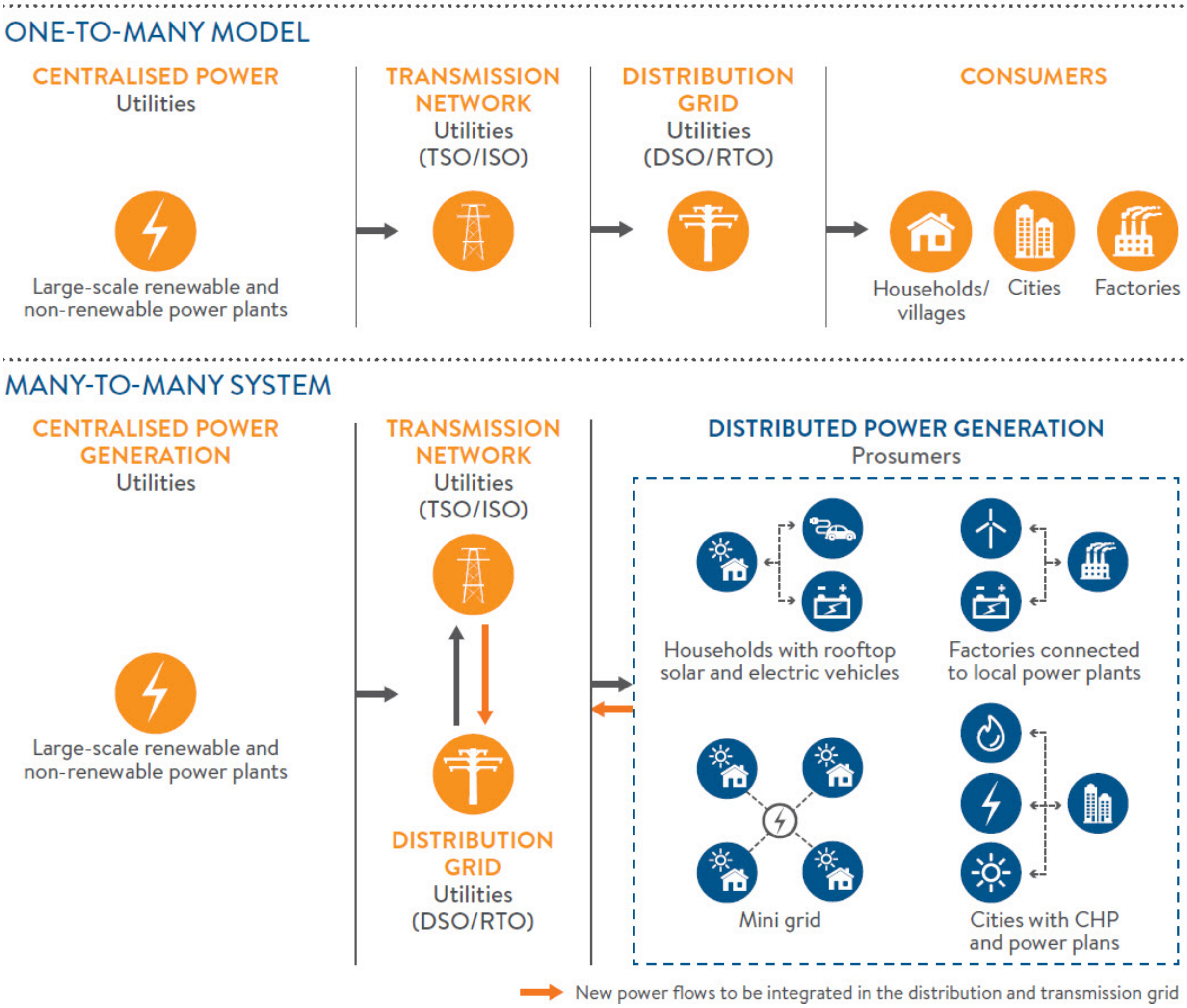
The global electricity sector is undergoing a large-scale transition, marked by three inter-related and reinforcing trends impacting demand and supply of energy:

- **Decarbonisation** with the shift towards lower-carbon energy generation and use. This is marked by a growth in natural gas (playing a bridging role), and renewables in energy supply and generation, particularly in distributed generation, as well as electrification of the mobility sector.
- **Digitalisation** supported by the increase in information and communication technologies and the overall shift to an 'internet of things' that enables smart grids and optimized energy use and storage, greater efficiency and the integration of distributed energy resources, especially distributed generation.
- **Decentralisation** marked by the greater adoption and availability of a distributed energy resources including new distributed generation sources, developments in energy storage, new market entrants and shifting consumer preferences.

Decentralisation is marked by the growth of distributed energy resources including distributed generation. There is uncertainty about the extent of decentralisation of the electricity system as transmission and distribution grids are likely to continue to be at the centre of power systems for many decades in much of the world. This will be particularly true for developed countries with infrastructure and networks already in place where more variable renewable generation, together with more diverse electricity uses (electric vehicles, heat pumps, etc.) will require the network to average out the generation and demand variability. In developing countries, decentralised generation can be an effective solution to enhance energy access, but it is uncertain if distributed generation will allow countries to leap-frog a centralised approach, or if distributed generation may be a first step on a path to develop the grid with more centralised generation to meet rising consumption.

These trends are enabling a re-design of electricity systems. Systems can shift from a one-to-many model in which utilities with large-scale generation assets provide energy, to a many-to-many model, with multiple actors providing energy into the system through a variety of assets and services. The evolution provides opportunities for new service providers and energy integrators to enter the system and potentially disrupt incumbent energy actors (see Figure 1).

FIGURE 1: Evolution of the electricity system



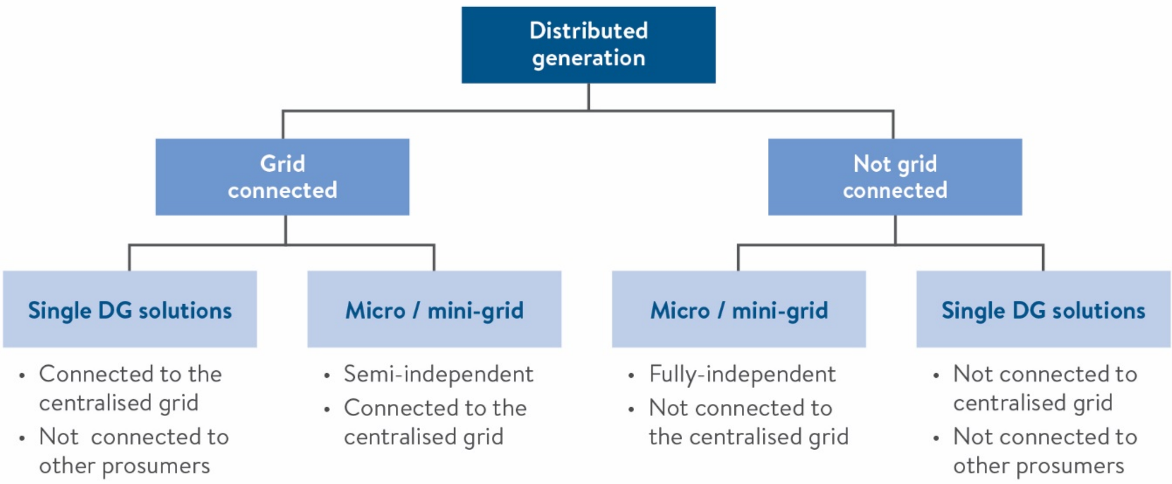
Source: Oliver Wyman/ World Energy Council.

The evolution of the electricity system offers challenges and opportunities for both developed countries that are in the process of modernising and decarbonising aging infrastructure, as well as developing countries that are in the process of building and expanding their energy systems.

A common denominator of the three trends outlined above is the growing importance of distributed energy resources across the world. Improved efficiency and falling technology costs are expected to further accelerate this trend. **Distributed energy resources** are at or near customer loads that generate or store energy or reduce energy consumption. They can include distributed generation technologies such as solar PV systems and emergency backup generators, electric energy storage such as batteries and behind the meter storage, and smart appliances or other controllable loads, including e-vehicles that can communicate with the grid.

Distributed generation is one element of distributed energy resources and can be defined as electricity generated from small-scale generation units (usually less than 50 MW) that are located close to or at the consumer's site. Distributed generation can use renewable energy, such as solar or PV, or other generation sources such as hydro or natural gas. It can be implemented with a national or regional grid connection, or without grid connection and with or without micro-grid connection (see Figure 2). Depending on site- and country-specific contexts, the general definition of distributed generation finds different implementation patterns, correlated to the level of energy access, stages of electricity infrastructure development, percentage of renewable generation, environmental/energy policies etc.

FIGURE 2: Forms of distributed generation



Source: World Energy Council, Oliver Wyman, 2017.

1.1.1 THE GROWTH OF DISTRIBUTED GENERATION AND FUTURE TRENDS

Distributed generation has been a component of the energy landscape for a long time but is becoming increasingly important in the context of the energy transition and country's strategies to meet their Energy Trilemma goals. Improved efficiency and falling technology costs are the main drivers of the increasing pace and extent of distributed generation growth, particularly renewable, in recent years.

While data for current and predicted growth of distributed generation is unavailable for many countries, our research in surveying energy leaders across the world, as well as selected country examples highlight that the pace of growth will continue to accelerate, and have significant impacts within the next ten years.

Indeed, more than 50% of energy leaders surveyed anticipate that distributed generation will represent in excess of 15% - 35% of installed generation capacity by 2025 compared with an estimated 5% of current installed generation capacity. This represents a significant shift in the generating mix and a notable increase in the anticipated pace of change. Indeed, as many energy executives agreed: "From a historical perspective this transition of the energy sector is happening at light speed."

The changes are occurring worldwide. For example, in Germany, distributed generation accounted for roughly 50% of the total installed generation capacity in 2016, up from 42% in 2011. While in 2011 this accounted for 24% of electricity generation, in 2016 it accounted for 30% of electricity generation[4]. Looking to the US, in 2016, 3.4GW of distributed solar photovoltaic capacity (i.e. rooftop systems) were added and there was a doubling in megawatt capacity of PV from small scale facilities between 2014 and mid-2017[5]. In New Zealand, between July 2014 and July 2017, the number of distributed generation installation connection points at residential, commercial and industrial sites – including below and over 10 kW - rose from just over 4,000 to more than 15,000, with the vast majority being solar (PV and thermal)[6].

If current trends hold, research suggest that the amount of power generated by utilities' residential and commercial customers in Europe and North America will rise by more than 60% within the next five years, reaching a record amount of approximately 400 terawatt hours per year. While that represents but a small portion of the entire power universe (the United States alone generates 10 times that amount of electricity), this amount is steadily growing. By 2050, customers in Europe and North America will generate the equivalent of US$104 billion worth of electricity, up from about US$44 billion today, provided energy prices stay close to their present level, supportive regulations remain in place and low-cost technologies become even more commonplace[7] (see Figure 3).

4 Weltenergierat Deutschland (2012), Energie für Deutschland 2012; Weltenergierat Deutschland (2017), Energie für Deutschland 2017; BDEW Bundesverband der Energie- und Wasserwirtschaft e.V.

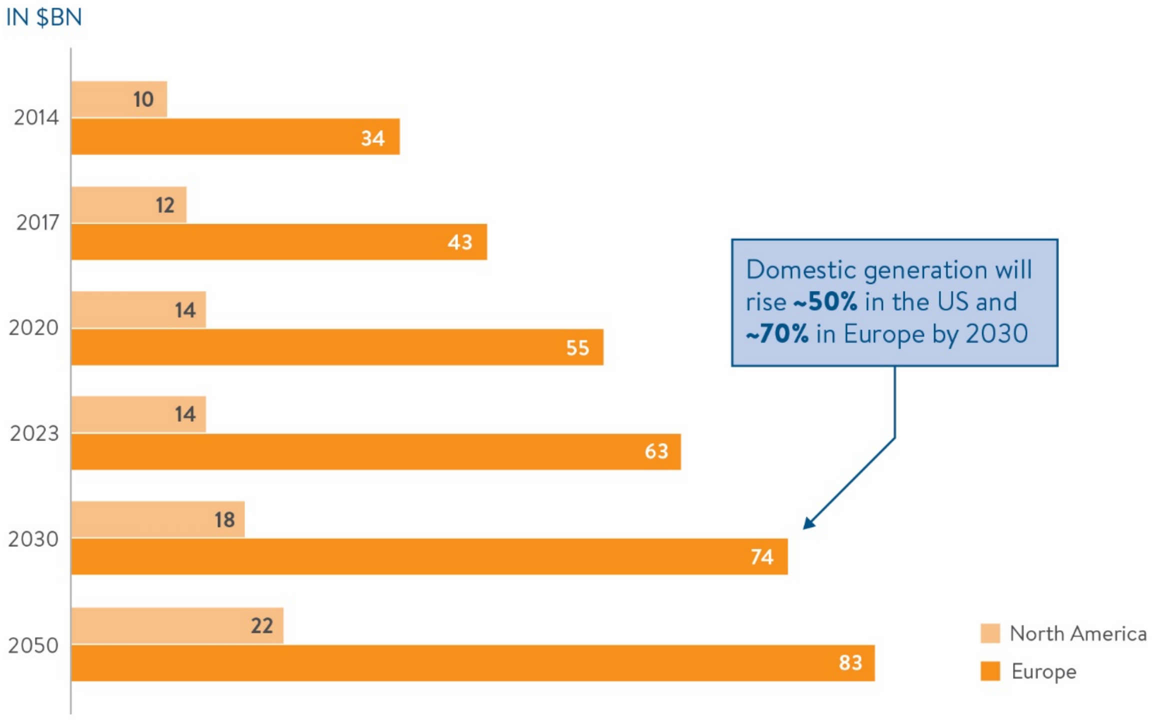
5 Electric Power Monthly, Data for July 2017, EIA

6 Electricity Market Information (EMI), Installed distributed generation trends: New Zealand https://www.emi.ea.govt.nz/Reports/Retail/Chart/GUEHMT?Show=ICP_Count&FuelType=All_Total

7 The New Make vs. Buy Calculus: How Utilities Can Remain Relevant To Customers Who Produce Their Own

Power, James Basden, Adam Witkowski, Tim Wright, Oliver Wyman, 2017

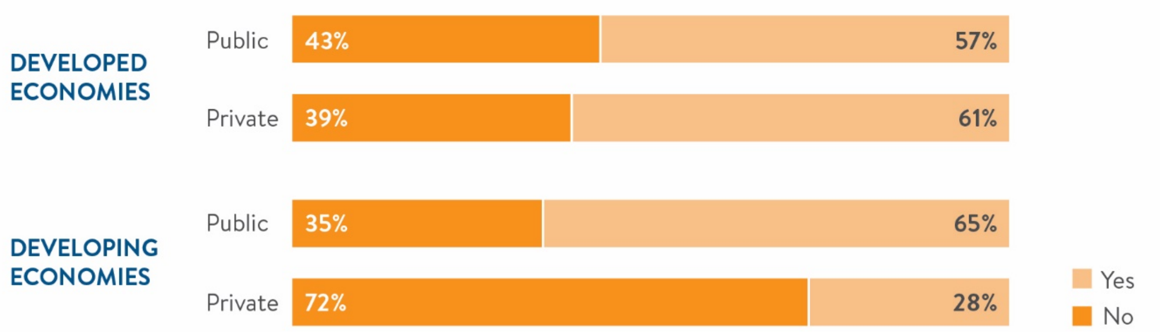
FIGURE 3: Market value forecast of residential and commercial power generation



Source: "The New Make or Buy Calculus", Oliver Wyman

Energy sector participants surveyed widely agree that the global energy system will be more decentralised within the next ten years, but there are diverse views on whether regulatory regimes can evolve at the same pace as technological developments and evolving consumer preferences (see Figure 4).

FIGURE 4: Perspectives on whether current regulatory regime can accommodate the shifting energy structure



Source: World Energy Council, Oliver Wyman, 2017.

Policymakers, energy suppliers, innovative services providers and consumers are viewed as the driving forces behind the increase in distributed generation, as countries focus on increasing electricity access, improving affordability and competitiveness as well meeting decarbonisation goals.

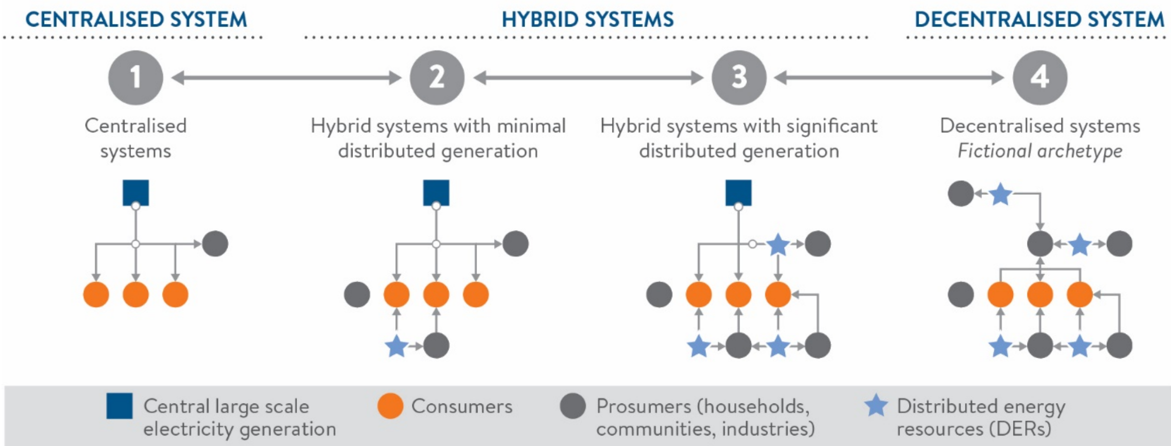
For policymakers, increased distributed generation, particularly renewable, and other distributed energy resources are core tools to achieve decarbonisation targets set out in the Paris Climate Agreement. Initial support schemes, improved efficiency and falling technology costs have supported increased adoption of distributed generation by residential and industrial consumers and this is expected to accelerate as the efficiency and cost of storage continues to decrease. For example, in parts of the US, corporate renewable energy development and purchasing is one of the key driving factors behind the growth of renewable energy and distributed generation.

Survey respondents noted other factors that are stimulating the update of distributed generation, including improving the diversity of electricity supply, easier access to finance, and improved system resilience.

1.1.2 ENERGY SYSTEM ARCHETYPES

As the decentralisation trend continues in many countries, four electric power system archetypes are becoming apparent. Each archetype represents a different combination of centralised and decentralised generation, including centralised, low hybrid, high hybrid, and decentralised system (see Figure 5). Recognising these existing and emerging systems will be important in managing the Energy Trilemma in the complex transition to the archetype of tomorrow.

FIGURE 5: Emerging energy system archetypes



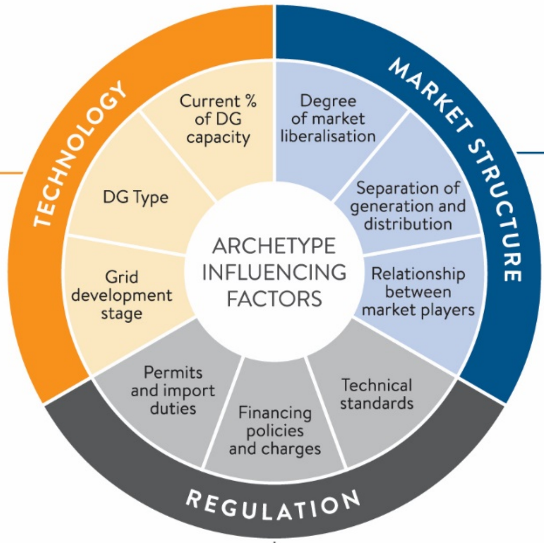
Source: World Energy Council, Oliver Wyman, 2017.

Archetypes are defined according to the amount of distributed generation present in the system, as well as a comprehensive set of factors that contribute to the transition from one archetype to another. These include: technology, market structure and regulation (see Figure 6). Although the decentralised archetype completes the analysis framework, it does not represent any existing power system at a national scale and is not discussed further in this report[8]. For additional details on each archetype and their characteristics, please see Appendix A.

8 At a sub-national scale or regional scale, countries may have a mixture of energy archetypes depending on regional or state regulations. In addition, cities or regions are implementing pilots to better understand the feasibility and operational issues associated with decentralised archetypes. For example, the world's first "plug and play" micro-grid powered by solar PV and hydrogen-based storage in Chile, operated by Enel.

FIGURE 6: Characteristics in three areas contribute to the archetype definition

- The higher the DG capacity, the more likely a system is decentralised.
- The introduction of DG in the grid requires changes in the whole system: the transition to a smart grid is fundamental to accommodate higher DG capacity. The more the system has evolved in this direction, the higher the degree of decentralisation.
- In case of off-grid DG, the system can be decentralised even without a smart grid.



- Centralised systems can work with any market structure.
- Decentralised systems can only work in open market characterised by legal unbundling between grid infrastructures and generation.
- The degree of market decentralisation is determined by the relationship between market payers: distributed generation is limited in centralised systems, supplements central utilities in hybrid systems with minimal DG and substantially contributes to power generation or has majority market share in hybrid systems with significant DG.

- Centralised systems do not need any regulation on distributed generation.
- Systems transitioning towards decentralisation are usually characterised by the presence of subsidies to encourage the up-take of low-carbon technologies.
- In decentralised systems, regulation is well established (both technical standards and feed-in tariffs).
- Use-of-system charges have been introduced to share grid maintenance costs and avoid free-riding.
- Subsidies are no longer necessary to encourage low-carbon DG. Approval processes for DG are low-cost and efficient.

Source: World Energy Council, Oliver Wyman, 2017

1.2 ACHIEVING TRILEMMA BALANCE IN A DYNAMIC ENVIRONMENT

The transition from one archetype to another involves changes in all aspects of a country's energy system. Ultimately, it is the ability of energy sector participants to manage these opportunities and challenges, and the regulatory framework governing energy sector participation that will determine a country's ability to provide a sustainable energy system.

The interconnected dimensions of the Energy Trilemma (see Figure 7) provide a useful framework to understand the challenges and opportunities. As countries transition from one archetype to another, the complexity and dynamics in managing the three trilemma dimensions increases.

Figure 7: The three dimensions of the Energy Trilemma

Source: World Energy Council, Oliver Wyman, 2017

As indicated by survey results and recent energy investment trends, the energy system of 2025 will be more decentralised. Gains on the Trilemma's energy equity dimension are perceived to hold the greatest opportunities, while ensuring secure and reliable energy supply is expected to pose the greatest challenges. Figure 8 summarizes the impacts on the Trilemma dimensions associated with a move towards a hybrid system with increased share of distributed generation.

FIGURE 8: Trilemma challenges and opportunities associated with a move towards a hybrid system with increased presence of distributed generation

	OPPORTUNITIES	CHALLENGES
ENERGY SECURITY	Diversification and decentralisation of energy sources can make system less vulnerable to energy supply shocks due to improved system resilience	Increased system complexity and technology requirements can increase challenges to system management and the likelihood of system failure
ENERGY EQUITY	The range of energy supply models provide opportunities for improved rural electrification and enable the democratisation of energy supply	Increased system complexity and technology requirements can result in increased system costs and changes to established cost structures
ENVIRONMENTAL SUSTAINABILITY	Changes to the energy mix have the potential to contribute towards de-carbonisation, reduce local environmental degradation and reduce life cycle impacts associated with certain energy sources	Changes to the energy mix have the potential to increase carbon emissions and create life cycle impacts associated with certain energy sources

Source: World Energy Council, Oliver Wyman, 2017

1.2.1 ENERGY SECURITY

Over 40% of survey participants anticipate that increased decentralisation will challenge the reliability and security of energy supply. This is related to concerns that maintaining system reliability will become increasingly complex and new approaches to system management, supported by enhanced information technology systems, including smart grids, will be required to manage energy security challenges. This should present opportunities to improve system resilience. Countries at all performance levels in the Energy Trilemma Index are exploring how distributed energy resources can serve to increase energy security over the mid-to-long term as technology continues to evolve.

Challenges: With the increase in distributed energy resources, no single entity has control over all generation, transmission and distribution activities. Moreover, intermittency of renewable installations may vary in terms of seasonality and daily variation may make supply forecasting more difficult. Reliability and security of supply are at risk if the necessary steps to integrate distributed energy resources, robust system management and the active addressing of the interdependence between networks are not taken.

For example, the failure of nodes in one network may lead to the failure of nodes in dependent networks. If this happens recursively, it can lead to a cascade of failures and lead to the system collapsing[9]. In fact, a cascade of failures (‘concurrent malfunction’) led to an electrical blackout that affected much of Italy on 28

9 http://bit.ly/2tw6EWh

September 2003. The shutdown of power stations directly led to the failure of nodes in the internet communication network, which in turn, caused further breakdown of power stations[10.]

If a grid is not adequately prepared for an increase in penetration of distributed generation, there could be adverse effects on the quality of power supply. The effects of voltage fluctuations can be pronounced on businesses that rely on a continuous and stable supply, such as heavy industrial manufacturing. Micro-fluctuations in supply can trigger equipment shut-downs leading to material spoilage or equipment damage.

Unless the integration is well-planned and managed, infrastructure redundancies may become an issue. Put simply: who is responsible for this and how are they compensated? The role and responsibility of energy incumbents is changing. Distributed energy resources allow new market entrants including consumers, large prosumers and energy aggregators to participate in the energy sector. This is raising concerns about the flow of investments to maintain and expand new and existing infrastructure. Incumbents are facing declining market share and uncertainties in tariff and pricing models to cover cost of operating, upgrading and maintaining the grid as well as being requiring the utility to provide back-up capacity. As an example of the costs to be covered, in the USA, the New York Independent System Operator estimates that that almost 5,000 miles of high-voltage transmission lines will have to be replaced in the next 30 years at a cost of about US$25 billion to bring its transmission grid up to date[11].

Opportunities: The diversification and decentralisation of energy resources can make energy and electrical systems more resilient. With a wider array of resources, distributed energy resources can reduce vulnerability to energy supply shocks, extreme weather events or cyber-attacks. Distributed generation usually features flexible technologies, such as small hydro, solar, wind or geothermal power installations. While the capacity of these systems is comparatively low they can function separately from the main grid and some can do so during, or in the aftermath of, an extreme weather event. Similar to distributed generation systems, microgrids continue operating while the main grid is down and function as a grid resource for faster system response and recovery[12]. For example, as Superstorm Sandy hit New York in 2012, the force of the storm shut down most of the region's electricity networks, apart from a few small communities that could leverage microgrids. For example, Princeton University's microgrid used a cogeneration system powered by natural gas and solar to produce sufficient heat and electricity for 12,000 people and was able to run for two days entirely disconnected from the grid[13]. Co-op City in the Bronx was able to use its 40 MW combined heat and power plant to provide power for 14,000 apartment units, 35 high rise buildings, eight parking garages, three shopping centres and six schools[14]. Experiences such as these are prompting a new focus on distributed generation in the future energy system as a means to strengthen resilience, for example, New York State has established a US$40 MM grant to create at least 10 microgrids as business model templates[15].

10 Rosato, V. et al. *Modelling interdependent infrastructures using interacting dynamical models.* Int. J. Crit. Infrastruct. 4, 63–79 (2008) and http://bit.ly/2tvrlBY

11 See, http://www.nyiso.com

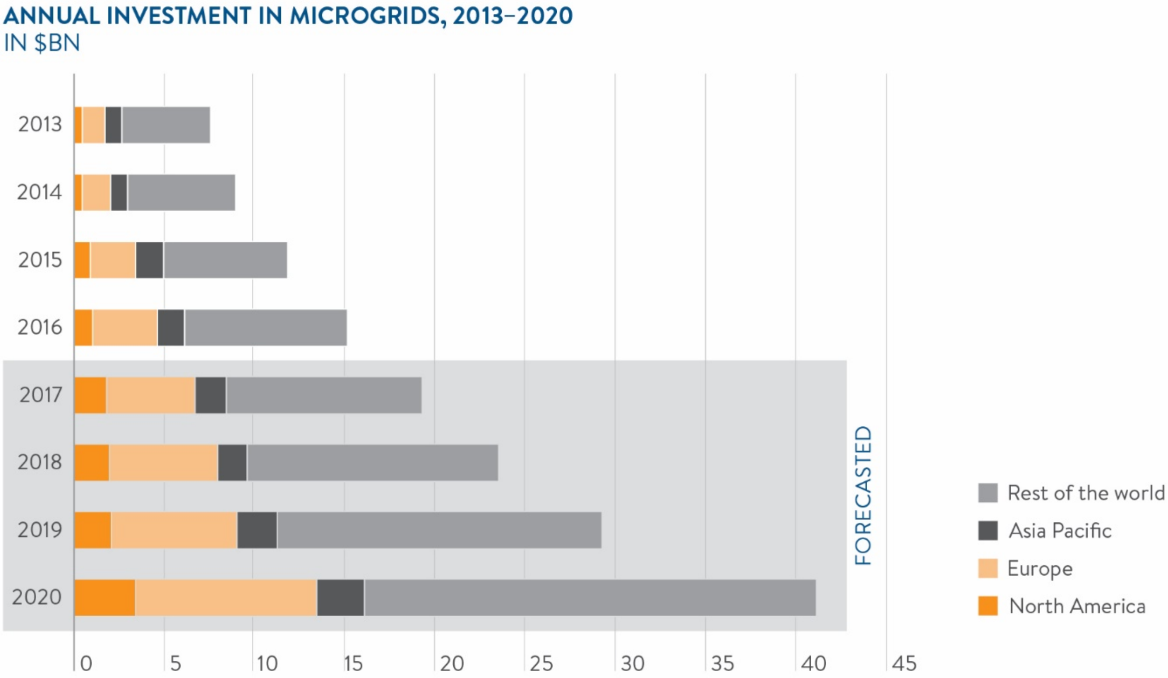
12 World Energy Council, 2015: *The road to resilience – managing and financing extreme weather risks*

13 https://www.princeton.edu/news/2014/10/23/two-years-after-hurricane-sandy-recognition-princetons-microgrid-still-surges

14 *Lessons From Where The Lights Stayed On During Sandy,* Forbes, October 31, 2012

15 See: www. rev.ny.gov/ which provides details on New York State's "Reforming the Energy Vision (REV)" which includes a focus on distributed energy resources. See also, Microgrid Momentum: Building Efficient, Resilient Power, Center for Climate and Energy Solutions, March 2017.

FIGURE 9: Annual investment in microgrids, 2013-2020



Sources: Navigant Microgrid Market Data, MD Task Force Presentation, SNL articles, Oliver Wyman analysis

Moreover, the integration of distributed generation in a transmission and distribution system can help increase resiliency through improved black start[16] capabilities of the system, if the distributed generator is used as a black start unit when a general or localised blackout occurs.

16 Black Start is the procedure to recover from a total or partial shutdown of the national electricity transmission system which has caused an extensive loss of supplies. This entails isolated power stations being started individually and gradually being reconnected to other power stations and substations in order to restore the interconnected system. (www.nationalgrid.com)

1.2.2 ENERGY EQUITY

Distributed energy resources, especially distributed generation, is perceived to be a key opportunity to improve energy access. Survey respondents from developing countries view electricity access for consumers as the driving factor behind increasing distributed generation. Most of the countries in the lower rankings of the Energy Trilemma Index have low energy access and distributed generation, especially renewable, is viewed as key tool to improve overall performance on the Energy Trilemma.

At the same time, 30% of all survey respondents anticipate that as consumers increasingly take more control of their energy needs, it will become difficult to ensure energy affordability, for all consumers across the energy system.

Challenges: The adoption of distributed energy resources could enable some consumers – residential, commercial and industrial – to become more empowered with new technologies changing the way they can consume electricity. However, ensuring equity for all consumers becomes a challenging task. Distributed energy resources give consumers with financial capacity the opportunity to manage energy cost and price volatility, but can also expose those consumers without financial capacity to price increases. Moreover, lower-income consumers may not be able to participate in community programmes to reduce energy costs or net-metering programmes. In this scenario, under the rate structure of many current electric systems, a smaller percentage of consumers could end up paying more to build and maintain transmission wires and equipment.

Regulators, incumbents and consumers must manage the balance between effective and responsive tariff and pricing models to cover the cost for operating, upgrading and maintaining grid as well as the benefits of the utility providing back-up capacity, and meeting goals to decarbonise the energy system and meet renewable energy targets. There is a concern that if too many customers defect from the grid to adopt distributed generation, electricity prices will increase for the remaining customers, leading to additional customers leaving the grid (creating to what many commentators refer to as a “death spiral” for utilities).

Indeed, in Australia, reports have warned that without policy and regulatory reform “…the future energy market will create a two-tiered system that favours those who can access and afford distributive energy resources (such as rooftop solar panels) and those who cannot, further widening the gap between the haves and the have-nots”[17]. In addition, in the UK, balancing supply and demand across a system with a greater number of generators as well as intermittent supply has resulted in higher, more volatile balancing services use of system charges. While at the beginning of 2012 balancing costs were at approximately £1 per MWh, at the end of 2013 the costs had doubled[18].

Developing countries also face the challenge of a two-tier energy system. For example, many local governments use electricity revenue to cross subsidise other services and low income households. Often, the local government’s electricity pricing structures make distributed generation an attractive option for those that can afford it. However, the availability of distributed generation can create an ‘every person for themselves’ situation reducing the options for local governments to cross subsidise. In addition, many

17 *Empowering disadvantaged households to access affordable, clean energy*, Australian Council of Social Service, Brotherhood of St Laurence, The Climate Institute 2017

18 https://www.eonenergy.com/for-your-business/large-energy-users/understand-energy/~/media/PDFs/For-your-business/Large-Energy-Users/3rd%20Party%20Charges/BSUoS%20charge.pdf

entrepreneurs are using pay-as-you-go models for lower income households to buy distributed generation technologies and appliances. However, there are still many that cannot afford these modest monthly payments and cannot access capital or a loan to purchase the technology.

In developing countries, distributed generation and grid expansion can be two competing alternatives discouraging investments to increase electricity access. While grid expansion in rural areas is a key risk faced by entrepreneurs and mini-grid developers, the increase in distributed generation adds complexity to central transmission and distribution infrastructure planning and expansion. Without clear regulation, uncertainty may deter or limit investment.

Opportunities: Providing electricity through distributed generation presents an opportunity to meet global electrification goals. Across the world, an estimated 1.2 billion people, 16% of the global population, were without access to electricity in 2016[19]. Providing initial access to electricity through a standalone off-grid system is often much cheaper and faster than connecting households to the grids.

Many developing countries, especially in Sub-Saharan Africa but also in Asia, are challenged by the lack of transmission infrastructure outside of urban areas. Currently 20-30% of households are electrified in Africa with the majority living in urban centres[20]. It is estimated that the cost of grid extension in developing countries ranges from US$6.3 thousand per kilometre in densely populated areas to as much as US$19.1 thousand per kilometre in regions with dispersed populations[21]. Furthermore, the cost of connecting a household to the grid can range from US$1,200 to US$4,000 per connection.

By contrast, costs for an off-grid standalone distributed generation system can range from US$500-600 per household. Consequently, in these circumstances, the overall system costs are often smaller than for fossil fuel based household systems or grid connections.

As one energy leader noted, “The off-grid electrification approach is much cheaper on a capex basis than extending grid lines.” Others noted that the development from a first off-grid standalone household solar system to an interconnected community (mini-grid) to a mini-grid that is connected to the grid may take three years. Indeed, Colombia is looking to use distributed energy resources to help meet 100% access targets using a combination of off-grid, micro-grid, and PV solar with storage[22].

In mature energy markets, the influx of distributed generation and the shift to a hybrid energy system archetype enables new service opportunities to empower consumers’ energy supply options. If enabled by the regulators, as consumers become more empowered, they have the option to generate power for their own consumption and sell their excess electricity back into the grid, to leave the grid completely or only use grid supply to supplement their own generation. New aggregator services could enable consumers to can choose electricity providers and utilise new energy management technologies to manage energy consumption, energy cost and price volatility.

19 IEA, World Energy Outlook, http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/

20 *Tracking Africa’s Progress in Figures*, African Development Bank Group, https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Tracking_Africa%E2%80%99s_Progress_in_Figures_-_Infrastructure_Development.pdf

21 *Power for All Fact Sheet: Making Energy Access Affordable*, September 2016 (http://www.powerforall.org/blog/2016/9/13/fact-sheet-making-energy-access-affordable)

22 Based on interview

Box 1: Advancing energy equity through local empowerment

In 2012 a micro hydro interconnected mini grid project was commissioned in Nepal with the assistance of the United Nations Development Programme, the alternative energy department of the national government as well as private loans and resident contributions. The project integrated six nearby micro hydro mini grids with a total power output of 107 kW, through the construction of an 8 km long, 11 kV transmission line that serves approximately 1,200 households. A cooperative was formed as a new entity, in which all six micro hydro mini grids act as independent power producers and sell their electricity to the cooperative. The cooperative then distributes electricity, purchasing electricity from the independent power producers at US$ 0.045 per kWh and selling to consumers at US$ 0.07 per kWh upwards, using the remainder to maintain the network. The cost of electricity to consumers is lower than that compared with if connected to the Nepalese grid, and reliability is also substantially increased since the national grid can be prone to load shedding. Excess electricity also enabled the development of a stone crusher that provides productive end-use benefits to local businesses.[23]

1.2.3 ENVIRONMENTAL SUSTAINABILITY

The adoption of distributed energy resources, especially renewables, is viewed as a means for all countries to make progress on the environmental sustainability dimension of the Energy Trilemma and improve rankings on the Energy Trilemma. This report primarily focuses on emissions reduction although the broader aspects of environmental sustainability such as resource productivity also need to be considered.

Challenges: Distributed generation from non-renewable energy sources, including gas oil and diesel generators, can produce the same types of localised environmental impact as larger fossil-fuelled power plants. While these impacts are likely to be smaller in scale, the generators are likely to be located closer to populated areas.

Without appropriate integration of distributed energy sources, there is also a risk of unintended changes to the energy mix, leading to a short-term shift towards fossil fuels, rather than renewable energy sources. For example, the uptake of renewable distributed generation and the associated intermittency may lead to maintaining, or possibly increasing, the residual fossil-fuelled generation capacity to balance and provide base loads and ensure energy security and reliability.

Lastly, while the benefits of distributed energy resources may be apparent, it is important to bear in mind that end-of-life management of equipment is fundamental to sustain environmental gains made, including the recovery of scarce materials, proper treatment of hazardous materials, and recycling of components (for example, recovery rates for some PVs is 98%)[24]. Cost effectiveness is a key challenge for the energy transition, trying to ensure the best environmental impact at lowest cost.

Opportunities: Distributed energy resources, especially renewable distributed generation, help countries to reduce dependence on carbon-intensive generation sources, reduce greenhouse gas emissions, and

23 http://aepc.gov.np/docs/resource/subreport/20130818074830_Final%20Report%20on%20Techno-Socio-economic%20Study%20on%20Baglung%20Mini%20Grid.pdf; http://apvi.org.au/solar-research-conference/wp-content/uploads/2016/02/B-Shakya_Peer-Reviewed_FINAL-1.pdf; p. 36,

24 http://earth911.com/eco-tech/recycle-solar-panels/; http://www.irena.org/DocumentDownloads/Publications/IRENA_IEAPVPS_End-of-Life_Solar_PV_Panels_2016.pdf

reduce local environmental degradation and lifecycle impacts associated with certain energy sources. For example, many large industrial and commercial prosumers, such as those that have signed on to the "RE100", are turning to distributed generation from renewables as a means to meet sustainability goals and to manage volatility in energy costs.

Moreover, because distributed generation and distributed energy resources are usually physically nearer consumers, they can provide the opportunity to reduce the inefficiency of the existing large-scale electrical transmission and distribution network (between 7-15% of energy can be lost in transmission), increase energy efficiency of grid connected applies and support enhanced demand management. Distributed generation also enables harnessing of energy that might otherwise be wasted; for example, through a combined heat and power system.

1.3 IMPLICATIONS FOR THE ENERGY SECTOR

The energy sector around the world is being transformed by three reinforcing trends that are impacting demand and supply at an unprecedented pace: decarbonisation, digitisation and decentralisation. This is happening at a time when we are seeing a shift in final energy consumption with demand for electricity doubling by 2060. The transition to a hybrid energy system marked by a greater use of distributed generation is supported by new technologies, additional energy services and new actors including technology providers, energy integrators and entrepreneurs focussed on increasing access to energy.

To achieve long-term energy goals and balance the Energy Trilemma, policymakers and regulators need to urgently focus on these emerging technologies which can create new opportunities but also potentially disrupt existing market frameworks, roles and responsibilities. This may include a reconsideration of the services provided and how the costs for such services are recovered.

Policymakers and regulators are faced with three key challenges that need to be addressed during this 'Grand Transition' and ensure progress on the Energy Trilemma:

1. Providing clarity on long-term energy goals;
2. Enabling diversity without fragmentation;
3. Establishing clear roles and responsibilities for all market players.

2
Managing the Energy Trilemma challenges in a transition

2.1 PROVIDING CLARITY ON LONG-TERM OBJECTIVES

The trends of decentralisation and digitalisation are both enabling and enabled by new entrants into the energy systems which are offering new sources of energy generation, supply and use management. At the same time, the emergence of new technologies, the bi-directional power flows, the increased number of actors in the emerging energy system, different roles and the need to bring all parties together, increase the complexity of the energy system. To reduce uncertainty for all market participants and ensure a secure and reliable energy supply at affordable prices, it is more critical than ever that policymakers clarify their country's long-term energy goals. Clear goals provide policymakers with a guide to evaluate different options and their consequences, and develop effective energy policy framework.

Developing a long-term energy plan requires the systematic analysis of all the factors that influence the evolution of energy systems. A clear plan must enable a framework for the effective and efficient deployment of distributed generation technologies and other distributed energy resources, while taking into account the long-term energy infrastructure considerations. This is particularly important as countries move between archetypes, for example, moving from a centralised energy system towards a hybrid system with a low or high shares of distributed generation.

In practice, the integration of distributed energy resources typically requires active system management that connects separate components of a smart grid, including DERs, to monitor and control the operation of these components through the use of communication and data processing technology[25]. The rise of digitalisation and communication technology allows aggregated DERs to be used as energy resources to balance the system in real time as well as capacity resources used in the planning process and to maintain reliability by assuring that loads will not exceed supply during the system peak.

Energy system management challenges will become inevitable as decarbonisation, decentralisation and digitalisation together with empowered consumers drive the transition from one energy system archetype to another. Similarly, for developing countries, choosing a preferred energy system archetype from the onset allows an active management of the energy system.

Well-managed integration of distributed generation, along with distributed energy resources, is critical to avoid fragmentation of the energy system, infrastructure gaps and overall reduced system reliability. Coherent and predictable policies and regulation are more important than ever given the rapid pace of change in the energy sector.

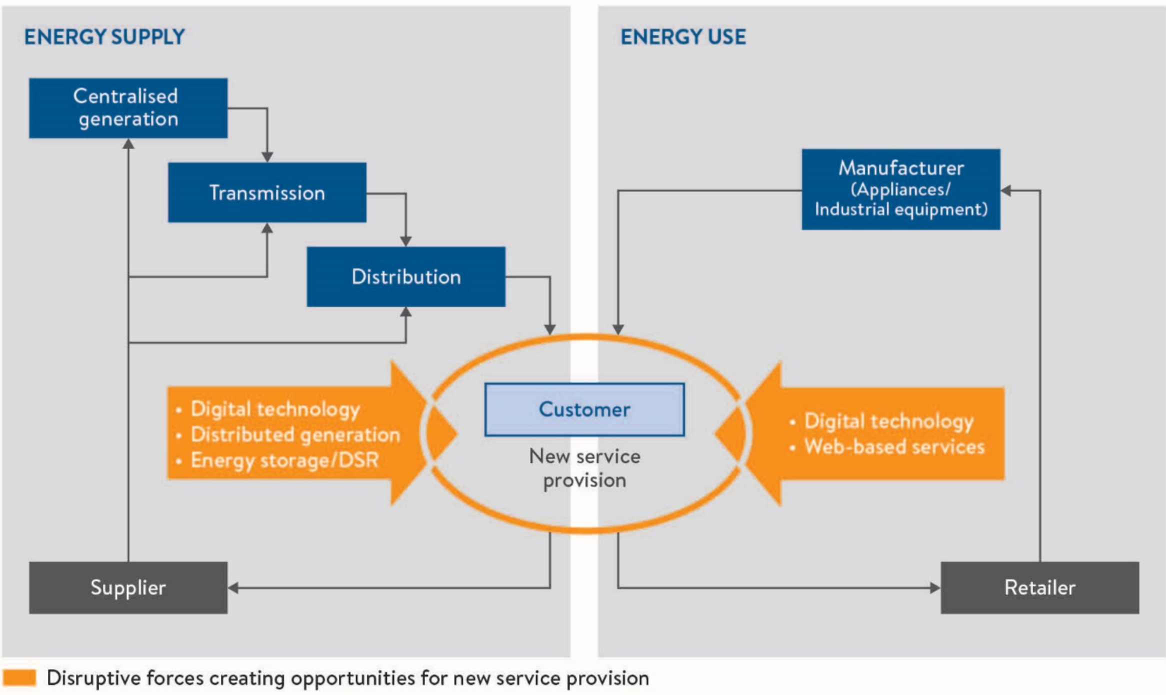
25 https://www.ninessmartgrid.co.uk/our-trials/active-network-management/what-is-active-network-management/ and https://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/Project-Documents/LCL%20Learning%20Report%20-%20A7%20-%20Distributed%20Generation%20and%20Demand%20Side%20Response%20services%20for%20smart%20Distribution%20Networks.pdf

2.2 MANAGING A COMPLEX WEB OF ENERGY SYSTEM ACTORS

As energy systems evolve to increasingly hybrid models with more distributed energy resources deployed, the number of actors in the energy system will increase. The system will include emerging new market players, energy services providers and empowered consumers. The power system will be particularly affected and will broaden from the current cast of incumbents, transmission and distribution operators, and consumers, into a complex matrix of generators, transmission and distribution operators, “prosumers” (and potentially owners of e-vehicles), electricity storage providers, energy aggregators, and others (Figure 10 below). In addition, roles can fluctuate within the system as energy consumers can switch to producers as their energy use varies during the day; storage providers can switch from storing energy to injecting electricity back into the system; utilities can provide more energy management services and not just energy generation.

Establishing a suitable framework to include the evolving number of actors from the broader context of distributed energy resources will be essential to leveraging the opportunities of distributed generation. As one energy leader noted, “the technology for a new electricity system exists but it depends on the regulatory framework and whether and how regulations enables change. It is easy to talk about the system changes, but how you bill for electricity, how to account for it, how to set the market price for the power drawn out of the battery… the devil is in the details.”

FIGURE 10: A complex matrix of incumbent and new energy system actors



Source: Oliver Wyman

Maintaining a balance on the Energy Trilemma will depend on the type and availability of distributed energy resources, the current and potential energy infrastructure, and the appropriate market framework. For example, the high-growth rates and decreasing costs associated with storage and e-mobility[26] will become critical elements of many future energy systems and will influence meeting Energy Trilemma goals. As one executive noted: "All distributed energy resources are relevant in the energy transition. Energy storage and batteries [are] becoming a key element of the grid, and their role is expected to take off over the next years. Energy storage is fundamental to increase efficiency and to guarantee constant flow on the grid, in particular if linked to renewable energy, and price stability." Indeed, it was widely noted by those interviewed for this report that "The pace of innovation on batteries and re-charging has increased much faster than expected."

Box 2: The challenge of considering a diverse array of technologies and their impact in the energy transition:

The shift from centralised to hybrid energy system requires a long-term view of all components of a future energy system and a greater number of diverse actors in the system. For example, as one energy leader noted, the potential growth of e-vehicles (EVs) in the UK from 90,000 today to 9 million in 2030 could exceed the capacity of the Hinkley Point nuclear power station by 2030. The number of EVs could add as much as 8 GW of additional demand if they are not charged smartly[27]. Meeting this increased electricity demand efficiently and effectively will require an energy policy that factors in all forms of distributed energy resources and will require greater coordination between energy, transportation, urban and city planning, and infrastructure policies. This level of coordination will be critical to ensuring that the shift to e-mobility does not simply move greenhouse gas emissions from tailpipes to generating assets and potentially adversely impacts the Energy Trilemma.

Dynamic system management is increasingly important to optimise an array of distributed energy resources. In addition, countries will need to consider how these fundamental changes to their power systems will impact the role of key existing actors and how the different actors in the emerging energy system can be integrated successfully. A key question will be to determine the real value of new services from new players and how they can be incorporated and remunerated.

Regulators and policymakers need to consider the optimal role for each to ensure that their systems continue to provide secure, affordable and environmentally sustainable energy. The new roles and relationships between power sector actors are adding a complexity to the power system that did not exist before. Policymakers are faced with questions such as what type of services (storage, demand management, or electricity generation) can be provided to the electricity systems as part of an active system management approach. Also to be considered is how to price the services (e.g., just offer energy into the grid when additional is needed from storage, or two-way provision of electricity generation services)[28].

Indeed, policymakers are faced with the tension of enacting policies that both support necessary existing or future infrastructure, and support new and emerging technologies and services that are required as countries transition towards new energy system archetypes. As one large energy user noted: "All parties have [their] own stakeholders to address and it is hard for the regulators to mandate something that would

26 While not covered in this report, there are considerable uncertainties about the future penetration of e-vehicles and their associated charging requirements.
27*Will the power grid handle amped demand from EVs?* RP Siegel, GreenBiz.com (Tuesday, July 25, 2017)
28 *Distribution System Pricing With Distributed Energy Resources,* Berkley Lab, Report No. 4, May 2016

cause one party to erode its value. Every group has legitimate challenges and points. Policymakers can help bring all concerns to the table to create a roadmap to optimize the future energy system.

The following section discusses the impacts of increased distributed generation on key players in the energy system, and also highlights how distributed energy resources such as e-vehicles and storage will affect the uptake of distribution generation.

UTILITIES

The current and future role of the utility in managing energy generation and supply varies across the energy archetypes and also whether the utility is operating in a regulated or liberalised market. Currently, many developed countries are moving from a centralised system to a more hybrid system. This trend is expected to continue with significant evolution over the next eight years as indicated by survey respondents.

In this context, regulators and policymakers need to determine what role utilities should play or need to fulfil, in order to ensure the overall electricity system supports a balanced Energy Trilemma.

The energy transition is, and will continue to impact the utility business models in both liberalised and non-liberalised markets. In liberalised markets, utilities are expected to lose market share in terms of providing electricity but have a potentially bigger role in providing energy services and energy management services. In mature and well-developed power systems, the combination of large loads being taken off the grid with an increased in DG, and the flattening of demand in many countries due to increased energy efficiency, and an increase in intermittent renewable generation, could challenge energy security and reliability if the role of the utility is not well managed. For example, vertically integrated utilities face the double impact of declining energy sales revenue and increased network costs to support reliable energy delivery. There are concerns that traditional utilities will refrain from making investments into the system in the face of earnings decline. For example, traditional energy suppliers in Germany are already facing significant falls in their earnings that could still decline further[29].

This could have knock-on effects on the stability and reliability of energy and also affordability. As one utility leader suggested: “When looking at the Trilemma, it is quite clear that the environmental dimension is being taken care of - at the expense of cost and security of supply. A decarbonised future in the energy market is possible, but it will be very expensive, and will require significant action to guarantee security of supply.”

Featured Interview: Leo Birnbaum, Chief Operating Officer – Networks & Renewables, Eon

“The future energy system will be much more influenced by customers than in the past”

The largest consumers - companies - are creating long term climate plans for the future and they will not care what the market is like since they will do whatever it takes to achieve these commitments. Therefore we could see investment based on long-term arrangements on the customer side, meaning that market design just becomes an optimisation signal for whatever asset base they have built around the customer business.

The key players that can take responsibility for system stability are the TSOs and Distributed System Operators (DSOs), and in a complex world with lots of prosumers it should primarily be the DSOs. If you decentralise everything, then you have local actors so this should be the area to optimise first. Also sector coupling can only really be done on a local level. This can’t be done with a central, master plan.

29 https://global.handelsblatt.com/companies-markets/e-on-reports-record-e16-billion-loss-for-2016-726611

We actually might get into a world where the wholesale market is only a dispatch signal, and actually somehow we get the investment signals by other means, such as large customer groups.

In this context, in deregulated mature systems, regulators may need to consider some degree of increased regulation in order encourage the appropriate investment. Incumbents may be unwilling to invest within the current energy market framework but could be able to access capital to secure investment with a more regulated market. As one energy leader noted: “We are moving towards a new market design that has much more regulated elements. The free electricity market may be a relic of the past.”

Regulated utilities also face challenges in responding to rising customer demands for distributed generation – especially renewable distributed generation. Large industrial consumers are driving utilities to make changes in their energy mix, the services provided and the charges for these services. As another energy leader noted, “Utilities must have a vision on what their business could look like in the future with technological change. If they want to hold on to older business models, they would need to be subsidized. Utilities need to understand what will be the energy system of the future and to create a new business model. They have to make the decision now that change is coming, because if they don’t manage the change, change will take them away.”

For example, the increased use of storage raises questions for utilities. Widespread adoption of storage could reduce revenue from demand charges, which are based on the amount of electricity used during times of peak usage and, in some markets, can represent as much as 80% of a commercial customer’s monthly bill.

Responding at the pace of technological and customer change can be difficult for large incumbent utilities due to their traditional business models but also from cultural barriers to fast-paced commercial innovation. Nonetheless, utilities are recognizing that industrial and commercial customer preferences will be more significant drivers of change over the next decade rather than regulation. Along with this, revised and more sophisticated pricing structures that reflect the cost structure of the business are viewed as essential to enabling regulated utilities to effectively meet shifting consumer demand.

Box 3: Utilities adopting business models to meet future consumer energy demand – but face competition

Overall, utilities are shifting business models to be much more consumer-centric and also offer more energy services management and not just electricity. As indicated by survey data, currently, regulators and policymakers are seen as the primary drivers of DG, followed by consumers. However, this is expected to change with utilities taking a driving role over the coming years.

Utilities are evolving their business models and offerings in the emerging power system marked by digitalisation, decentralisation and decarbonisation.

Utilities in Germany, Italy, USA, and the UK are increasingly branching-out into energy management service and 'smart-home' services that can include energy management, home security, and entertainment. One survey indicated that bundled energy solutions – such as a domestic heating package, intelligent tariffs, and energy consultation – all influence more than 30% of respondents in their choice of utility[30]. The smart-home business sector is expected to grow at 14% a year between 2016 and 2022 and preliminary market analyses indicate that smart-home services could increase utilities' operating margins substantially, with estimates anywhere from 11- 18%. Looking further out, utilities are considering other options, for example, a battery charging service if behind-the-grid storage becomes ubiquitous by 2040. However, utilities need to move fast. New entrants, especially global technology players, are moving into the business with packages that leverage their digital technology. Utilities could face customer attrition that could be between 3-5%.

Energy utilities have an advantage over newcomers through their connections to people's homes and the vast quantities of data they collect on consumer power use. However, to offer attractive packages, they will need to team-up with firms that provide complementary skillsets, such as telecoms, automated building firms, software designers, and data analytics providers. If utilities wish to remain as the key connection point with customers, they must take care to retain control over the new offerings, by acting as the main orchestrators and first movers[31].

Many utilities in mature markets also view the expected rapid growth in e-vehicles and overall electrification of mobility as an opportunity to stimulate electricity demand growth. The expansion of electric vehicles raises questions as to who will develop the charging infrastructure along with setting up clear processes and services such as billing, etc. In regulated markets, utilities are expected to play a larger role in the development of e-vehicle infrastructure. How electricity is priced and the underlying source of utility revenue (e.g., demand charges) can impact how utilities participate in the e-vehicle infrastructure market. As one energy leader noted: "As we go into the early 2020s, we do not know which happens faster: the growth of EV adoption on grid demand or the increasing use of solar that will reduce grid demand. "

However, to capture the e-vehicle opportunity fully, both utilities and regulators will need to ensure a simple changing and payment system for car drivers. For example, traditional utilities are focused on meeting the need of customers in a specific geographic area but not necessarily for mobile energy use. This can result in a patchwork of charging rates for consumers as each utility may implement an e-mobility policy and rates independently. For example, one utility may offer night-time rates for charging but other players may offer different rates and methodologies for charging. "The biggest challenge is a very inconsistent charging

30 *For Utilities Under Pressure, Smart-Home Services Offer a Way Forward,* www. Brinknews, May 22, 2017 Sandro Melis, Partner and Angelo Rosiello, Principal, Oliver Wyman (http://www.brinknews.com/for-utilities-under-pressure-smart-home-services-offer-a-way-forward/)

31 *The New Make vs. Buy Calculus: How Utilities Can Remain Relevant To Customers Who Produce Their Own Power*, James Basden, Adam Witkowski, Tim Wright, Oliver Wyman, 2017

approach." In this scenario of a patchwork of networks and mobile customers, utilities need to consider that third party smart phone applications or even the automaker-installed apps on vehicles will guide the customer to the best rates and actively manage the vehicle to optimize charging behaviour at the lowest cost to the consumer.

For developing power systems, faced with the challenges of building and expanding energy infrastructure, regulators need to consider the right balance between a central utility and distributed generation supply. A "traditional" utility model may be most effective for urban areas while distributed generation along with energy entrepreneurs may be more effective for serving rural areas.

The increase in distributed generation and the potential role of energy entrepreneurs and new entrants (in both in developing and developed countries) in providing distributed generation can also challenge the business model and attractiveness of the traditional utility concept which relies on a large transmission and distribution system to function. The right balance of utility generation and supply and distributed generation will be necessary to ensure that the utility can secure investments. In this scenario, it may be easier for utilities to secure investments if the regulators have flexibility in how to meet rural energy demands.

One energy entrepreneur described the shift facing the traditional energy delivery model in developing countries: "Donors [are realizing] that the utilities and the grid does not provide the services required or demanded by consumers." For example, the World Bank has invested US$570 million over ten years into Tanzania, resulting in 33,000 households connected to the grid at an estimated US$90,000 per household. In this context, "relatively speaking, the utilities are losing on market share as there is limited grid expansion. It is bound to happen that there will be a future where off-grid providers dominate and the central utility will play a secondary role[32]."

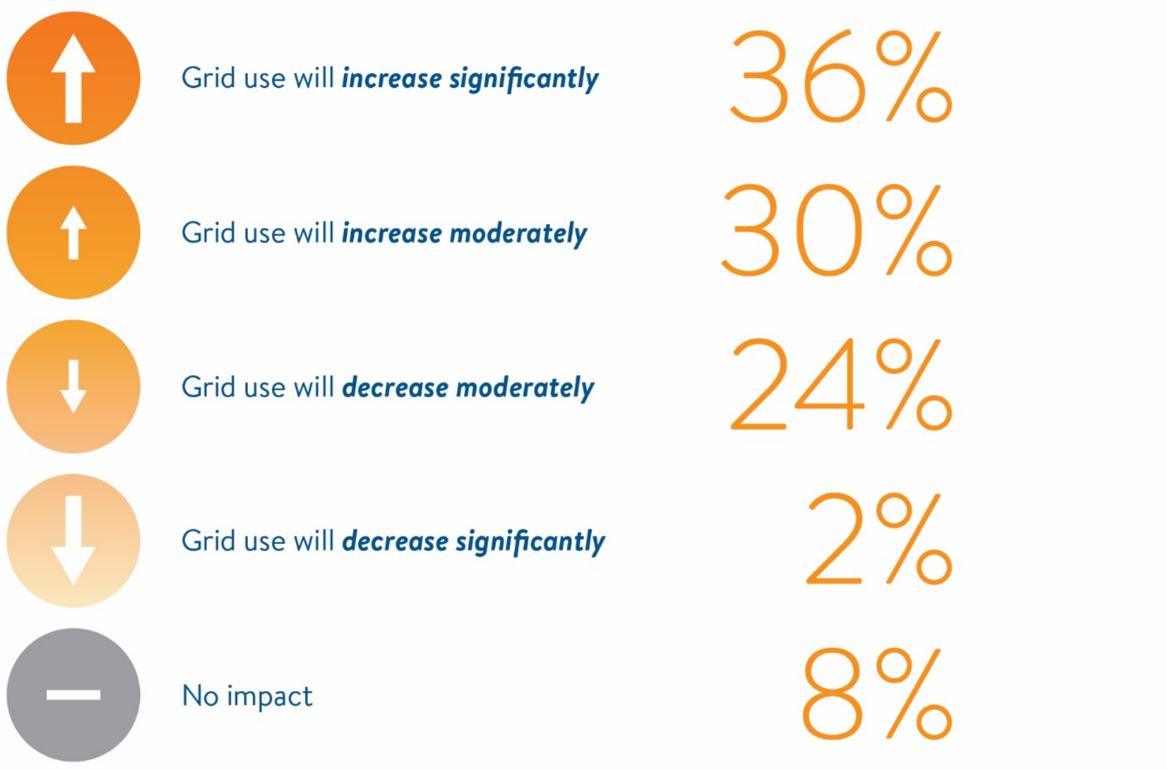
THE GRID

Distribution systems have traditionally played a passive role in managing electricity systems in centralised energy systems with a unidirectional flow of power. The real-time balancing of the electricity system is often managed by the Transmission System Operator, who operates on the higher voltage network, although the system is evolving[33]. As countries move towards hybrid energy systems with increasing shares of distributed generation and intermittent renewables, dynamic grid management to provide reliable electricity will be necessary. In established markets, changes in customer behaviour, combined with the increasing challenges associated with the increase of distributed generation and renewables, will require more dynamic system operation models where data and smart technologies are deployed for improved system management. Most survey respondents predict that grid use will increase over the next eight years (see Figure 11).

32 Based on interview

33 http://baringakentico.itssystems.co.uk/getmedia/9174062a-ecc8-4032-9129-04b5573e44f8/The-future-role-of-network-operators-the-emerging-active-DSO-model/

FIGURE 11: Expected grid use in 2025 compared to 2017



Source: World Energy Council, Oliver Wyman, 2017

The increase in distributed energy resources together with the emerging smart control technologies provide new opportunities for system operators to deploy new flexible options for frequency and voltage control as well as congestion management. As one energy leader noted: "Leveraging digital resources to better understand grid operations would allow to optimize and to smooth the grid. This is very important in a system in which the share of renewable resources is increasing and also with the uptake of distributed generation. Focusing on digital transformation and grid operations would enable real-time calculation and real-time pricing."

Featured Interview: Alison Andrew, CEO, Transpower

"Our role could evolve from providing 24/7 reliability and real-time balancing to providing a resilient battery-charging service."

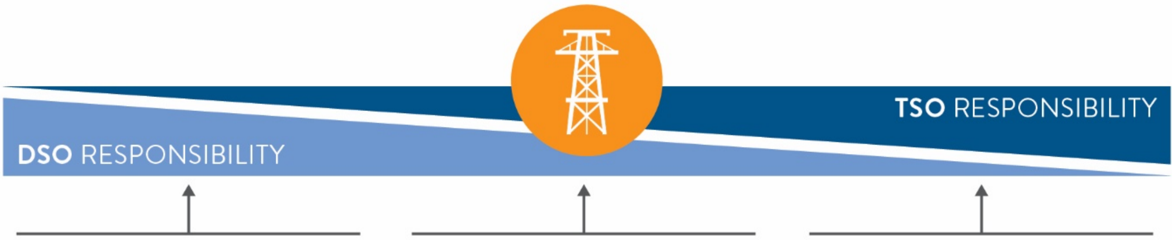
Consumers have new options for making, storing, and controlling electricity, and their impact on the energy outlook is a challenging factor to accommodate. For example, by the 2020s, we expect there will be more battery storage in the system. Looking beyond that, we are asking questions around how energy will be used, such as will people still demand electricity as they do now, in what form, and what role will the grid play, etc.?

Looking forward, we expect to see more behind-the-meter technology such as interconnected appliances, behind the grid storage and consumers using batteries for their e-vehicles. Taken as a whole, this creates challenges such as managing seven-way power flows and growing cybersecurity concerns. As distributed storage becomes extensive, our role could evolve from providing 24/7 reliability and real-time balancing to providing a resilient battery-charging service.

It is an exciting future and some form of interconnection is key to providing reliable energy. Policy regulation will have to adapt, and be prepared to change fast. Often regulation is developed after a technological or market shift, however it is important for regulators to keep up-to-date with how the market is progressing.

Greater flexibility and clarity in responsibilities between transmission and distribution network operators will become key determinants for grid reliability during the transition. Under a model of one-to-many energy generation and supply, transmission system operators (TSO) were able to manage the capacity and demand fluctuations easily. As more distributed generation is connected to the distribution grid, the pool of resources for ancillary system services that are required to balance the system increases at the distribution system operator (DSO) level. Concurrently, the available resources available for ancillary services at the TSO level decreases. This shifting availability of resources for system services necessitates new operational arrangements between TSOs and DSOs to unlock the capabilities of distributed generation and DER to plug the shortfall in these services (see Figure 12).

FIGURE 12: New operational arrangements between TSOs and DSOs emerge as the availability of resources for system services shifts



LOCAL AS MARKET MODEL

- A separate local market managed by the DSO
- Resources from the DSO grid can only be offered to TSO via DSO/local market and after DSO has selected resources needed to solve local congestion
- DSO aggregates and transfers bids to the AS market, operated by the TSO
- DSO assures that only bids respecting the DSO grid constraints can take part in the AS market

COMMON DSO-TSO AS MARKET MODEL

- A common market with flexibilities for both TSO and DSO with both resources connected at transmission level and connected at distribution level
- TSO and DSO are both responsible for the organization and operation of the market
- DSO constraints are integrated in the market clearing process

CENTRALISED AS MARKET MODEL

- There is one common market for ancillary services, operated by the TSO, for both resources connected at transmission and distribution level.
- There is no separate local market

Source: Adopted from Smartnet and http://www.gridwiseac.org/pdfs/workshop_091014/kristov_091114_pres.pdf

By contrast, in emerging markets with limited energy infrastructure, the increase in affordable distributed generation solutions presents new opportunities for improving energy access, security and reliability without having to invest into large-scale infrastructure projects, which can challenge the role of the utility and the grid in providing electricity access.

As one energy leader noted: “In Africa, over the long-term, the grid will be essential at connecting communities over longer distances. But distributed generation can get delivered much faster in an optimal pattern in specific areas than getting the grid out and getting the additional capacity at the other end of the grid to deal with the increased demand.”

In emerging markets, it is the new electrification strategies that embrace a top-down grid extension, as well as a bottom-up off-grid, electrification process, which are challenging the role of the grid as a provider of electricity access. The key challenge in determining the appropriate model arises in: (a) uncertainties of how electrification will be delivered; and (b) to what extent regional interconnection projects will be developed further.

The role of the transmission system operator is expected to become ever more important in connecting local demand and supply centres over longer distances. In addition, regional interconnection projects are also expected to remain important, for which transmission systems will remain critical.

NEW MARKET ENTRANTS

The trends of decentralisation and digitalisation are both enabling and enabled by new entrants into the power systems which are offering new sources of energy generation, supply and demand management. As energy systems move from a centralised archetype to a hybrid archetype, regulators, policymakers and all players in the power system need to consider changing roles and responsibilities to ensure a balance on the Energy Trilemma.

Digitalisation is lowering the barriers to entry for services that may have previously been provided solely by utilities and technologies such as storage are creating opportunities for new entrants and new partnerships for energy provision and management[34]. For example: Ford built a number of homes with "MyEnergi Lifestyle[35]" with time of use rates. They partnered with Whirlpool and other companies[36] to demonstrate how connected appliances, storage and smart energy systems can make a significant impact to the CO^2 emissions of a home (reductions of up to 60%) and provide significant economic benefits.

Policymakers and utilities need to consider the impact of these trends on the overall system. As one utility leader noted, "The role consumers are playing in changing the energy outlook is a challenging factor to accommodate. Consumers are increasingly looking to take more control of their energy through the use of smart systems and home energy management, installation of solar panels on their roofs and their e-vehicles as batteries. People still want to make choices and so we want our role to be to help enable that."

Three key areas of growth are the increase in large energy 'prosumers', energy service aggregators and entrepreneurs offering rural energy services for in developing nations.

PROSUMERS

In the many-to-many electricity system model, energy consumers (residential or industrial consumer) with distributed generation capability can become both energy consumers and producers (i.e. "prosumers") that generate power for their own consumption, possibly injecting excess energy back into the grid, as well as drawing from the grid if connected.

34 *Digital Electricity,* Thomas Fritz, Matthias Mohr, and Joerg Staeglich, Oliver Wyman Energy Journal, Vol 3, 2017
35 https://media.ford.com/content/fordmedia/fna/us/en/news/2014/01/08/charge-up-your-home--ford-motor-companys-myenergi-lifestyle-2-0-.html
36 http://greentechadvocates.com/2013/01/28/how-big-a-deal-is-fords-myenergi-lifestyle-collaborative/

Interview: Rob Threlkeld, Global Manager of Renewable Energy, General Motors

"We need a mind-shift on grid operation"

Our company has a four-pronged approach to energy use and management: energy efficiency, sourcing renewable energy from both on-site and off-site production, battery storage to address intermittency, and active policy engagement. Countries and even specific utilities have different levels of sophistication in regards to the elements of our four-pronged approach to energy use and that results in a patchwork of processes across geographies that we and other companies have to manage to achieve our energy targets.

Going forward, there are two key areas for the energy sector, including prosumers, to focus on – the digital transformation of transmission and distribution, and storage.

We need a mind-shift on grid operation. Grid operation is becoming increasingly crucial for both the reliability and cost management of energy. Focusing on the digital transformation of the grid would enable real time pricing and facilitate collaboration and optimization by all players in the system. Increased digitization, increased information flow, increased data processing power, plus improved weather data – will allow for improved grid management.

Storage is fundamental to increase efficiency and to guarantee constant flow on the grid and price stability. Energy storage will become a key part of the grid and we expect the pace of change in storage could be similar to the pace of change in solar technology over past 4-5 years.

Industrial energy consumers and potential prosumers are pushing for increased flexibility and options in energy choice with implications for utilities and regulators. For example, one utility noted, "Very likely in ten years that the demands of consumers will have changed considerably. This will be largely driven by industry and commercial customer preference for type of electricity generation (renewable or low-carbon) rather than additional regulation."

Industrial consumers across all sectors are purchasing renewables to manage costs and volatility in energy prices against rising energy needs, both now and in the future, as well as meeting corporate sustainable goals. For example, it is forecast that by 2025, data centres will rank among the largest users of electricity on the planet and, accordingly, many information technology companies are leading purchasers of renewable energy[37].

Many large industrial prosumers are increasing the use of on-site generation (either solely for their own consumption or connected to the grid) and are pushing utilities and regulators to be proactive in offering innovative service offerings and tariff structures. For example, BMW's plant in Spartanburg, South Carolina, US uses landfill gas to power two gas turbines to provide 11 megawatts of capacity while its Munich, Germany facility uses at least 3,660 solar panels. e-Bay utilizes a 5-megawatt waste heat recovery system and fuel cell array in Utah, USA after it lobbied for changes in state laws that previously prevented businesses from purchasing electricity directly from developers. Coca-Cola has a 6.5-megawatt combined heat-and-power plant in Atlanta, Georgia, US that was commissioned in April 2012. The system (the fifth largest of its kind in the United States) is fuelled by methane captured from a landfill and generates 48 million kWh of power annually. Adobe has installed 20 Windspire vertical-axis turbines; and Apple owns the largest private solar arrays in the United States[38]. Intel has installed the two largest private solar covered

37 *Power Forward 3.0*, April 2017 CDP; Calvert Research and Management; Ceres; and WWF

38 See:https://www.greenbiz.com/article/Apple-Google-Walmart-corporate-renewables-leaders

carports in the US with a total of over 15 MW and covering nearly 6500 parking spaces with clean, solar power. All energy generated is directly connected to the building and no power goes back to the grid.

Featured interview: Marty Sedler, Director of Global Utilities and Infrastructure, Intel

"Regulatory structure and utilities are simply not evolving fast enough or prudent enough to meet the needs of the changing power system"

Managing operating costs and potential cost volatility, while maintaining reliability and quality of supply, is crucial in our highly competitive industry. A greater use of renewable power is part of that process for us, along with a focus on energy efficiency, and it is one of the reasons that we have become the largest voluntary corporate purchaser of green power in the U.S. (per the EPA Green Power Program rankings).

When selecting or growing sites, we consider the future development of the energy supplier and grid, with a consideration of how they align to our strategy, including cost and sustainability goals. In many locations, regulatory structures and utilities are simply not evolving fast enough to meet our needs. This includes potential use of on-site greener generation and use of renewable energy as rather than just the grid, VPPA or PPAs. All options are part of the need for a portfolio supply to optimize supply solutions in the future.

Evolving the energy system to meet the constant changing needs for all stakeholders is certainly challenging, but policymakers can focus on a few areas to help the process. First, we need greater consistency in regulation and rules around distributive generation and renewable energy at a country, regional and state level. Currently, we are faced with wide variations in processes, standards and rules even between states in the USA, complicating efficient supply management. Second, the grid and power generation need to be updated and become smarter, allowing the whole system to become more efficient and reliable. Technology advancements in making data available with analysis, needs to be implemented to secure the cost and reliability of the grid. The fast-growing implementation of distributed generation, much of it renewable and intermittent, makes better data management and controls essential to effectively operate the power systems.

Policymakers can step in to help drive progress on that front by bringing all parties to the table to create a roadmap which includes stakeholders, including consumers and suppliers for optimizing the energy system in the future.

ENERGY SERVICE AGGREGATORS AND OTHER NEW ENTRANTS

Decentralisation, digitalisation and distributed generation are creating new service opportunities for energy providers and aggregators as traditional roles in energy markets are disaggregated[39]. Taken together, these changes open new business opportunities around the management of the generation or consumption of power to ensure system balance. This can include companies that offer battery storage and can inject that into capacity markets or support peer-to-peer electricity trading, or even "a virtual utility". These new businesses are still evolving and forming dynamically by commercial trial and error in the market[40]. In many instances, small players carving out their own niches (e.g., community energy or green energy), either through their pin-point focus on specific customers, or their technology-driven approaches support by the collection and analysis of data, which enables an improved understanding of customers and the development of new value propositions.

Consumers have retail choices in de-regulated markets to choose their electricity provider. Decentralisation, digitalisation and distributed generation further customer choice to include the source and generation of energy (e.g., whether and how to leverage solar PV, storage or participate in micro-grids) and also utilize energy management technologies to better determine how to use energy[41]. Taken together, these

39 http://www.utilitydive.com/news/hiding-in-plain-sight-aggregated-ders-in-wholesale-power-markets/446292/

40 *Get Creative About Flexibility*, Andrew Perry, Oliver Wyman, Energy Journal, Volume 3, 2017

41 http://www.utilitydive.com/news/in-a-distributed-energy-world-customer-choicenot-political-leadershipwil/447145/

technological advances are providing customers with options that allow them to bypass those traditional electricity rate-setting processes[42].

For example in California, the Community Choice Aggregation, which allows entire communities to opt out of utility electric service, is rapidly expanding. The California Energy Commission and Public Utility Commission has forecasted that by the mid-2020s more than 80% of electric demand from retail customers in California may no longer be served by traditional investor owned utilities.

A number of third-party services are also now available which provide bill savings to the customer and aggregated ancillary services to system operators, such as energy efficiency and curtailment service providers. As smart end-use appliances become more prevalent, these third-party providers will likely develop increasingly comprehensive and complex service offerings for both customers and system operators[43].

Other examples include aggregators in the wholesale power markets where managed charging of a large number of e-vehicles can provide monetary value for consumers and provide meaningful demand response capabilities and benefits to the grid. For example, eMotorWerks, a California-based EV charging company, estimates customers may be compensated up to $400 annually for participating in an EV rewards program[44].

RURAL ENERGY ENTREPRENEURS

Rural Energy Entrepreneurs (REE) are companies providing electricity and electricity services to low-income communities and households living in rural areas of developing countries. These organizations typically supply off-grid distributed generation solutions, mostly in the form of PV and solar, for household systems (e.g. backpacks) or mini-grids, enabling sparse rural communities without foreseeable access to the grid, to have energy access in an immediate and affordable way. Policymakers must consider how the growth of off-grid distribution generation will shape their energy system over the mid and long-term.

Rural entrepreneurs typically serve the base-of-the-pyramid population with an average wage of few dollars per day, and may adopt various business models. However, there are common features underlying REE's business model and supporting their success for example, offering bundles of both electricity generation technology (typically solar) and appliances, such as lights, stoves, TV, cell phone charges, and mobile cell payments. REEs offer a diversified range of distributed generation solutions and services that may be suitable for single households or for communities (see Figure 13: Services provided by REE).

42 *Storage: Turning Disruptive Technology into Opportunity*, Arun Mani, Public Utilities Fortnightly, August 2016
43 Distribution System Pricing with Distributed Energy Resources, Report No. 4, May 2016, Berkley Lab
44 Smart Electric Power Alliance's (SEPA) 2017 Utility Demand Response Survey, SEPA

Featured Interview: Andreas Spiess, CEO, Solar Kiosk

"The central grid can be like shooting cannons at birds - bringing an oversized solution to rural challenges"

In a large part of Africa, grid extension will presumably never break even given the buying power and geography constraints of Africa. In sparsely populated areas, central grid extension only makes sense to a certain extent. In this circumstance, the grid can be like shooting cannons at birds - bringing an oversized and outdated solution to specific rural challenges which need a more flexible and decentralised cost-effective approach. In our view, utilities should focus on industrialisation. Entrepreneurial options using new technologies, especially solar, that leverage distributed generation can focus on issuing "right-sized" efficient and cost-effective energy solutions predominately to private households and Small Medium Enterprises (SMEs) in rural areas.

However, energy entrepreneurs providing decentralised distribution generation (DG) face a number of challenges in many countries. Regulation is often premature, unsophisticated, and sometimes seemingly random. For example, DG operators need clarity in future central grid developments and whether DG will be able to feed into the grid if it is developed to their respective sites. Lack of clear regulations deters investors. We also need assurances that our land use and equipment will have regulatory protections. Subsidies need to be given on an equally fair basis to on-grid and off-grid developers. Currency risks have to be hedged at a fair price.

It is also really important that all players focused on driving energy access are working together. For example, random donations can be counter-productive for the private sector since they give no incentive for locals in rural villages to purchase solar appliances if they think they may get offered one for free in the future. Unorganised actions, although well-meaning, can be to the detriment of the private sector.

In many instances, the niche market that they have targeted and the particular type of product supplied have allowed energy entrepreneurs to gain their own place in the market and not to compete with utilities. However, there are examples of utilities starting to be active in the same market. As one entrepreneur noted: "The big power utilities should focus on industrialisation, while we focus on energy solutions to predominately private households, small-medium sized enterprises especially in rural areas. We don't see a realistic alternative at least for the next fifteen or twenty-five years." Another agreed: "The central utility should meet demand of industry and the capital as well as rural areas with a lot of demand".

FIGURE 13: Services provided by rural energy entrepreneurs

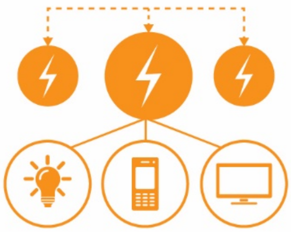
POWER GENERATION

Power generation, usually through a rooftop solar panel and a battery. While being the most inexpensive alternative, it may cause inefficiency and lack of reliability, as the power excess/shortage affecting a community member can't be compensated by the energy demand/supply of another member.

POWER GENERATION WITH APPLIANCES

REs often supply appliances – from lighting and charging systems to refrigerators and TVs – together with power generation. Appliances boost local economies by enabling the development of small businesses and improve the quality of life by cooling medications and food, providing internet access, etc. Appliances are also fundamental to increasing electricity demand, which is the major driver for attracting private investments.

These solutions can serve single households – typically in the form of solar PV connected to a lighting system, phone chargers and other appliances – or can power and provide services at a larger scale (for a group of households or for the whole community) in the form of hubs.



POWER GENERATION WITH APPLIANCES AND MINI-GRID CONNECTION

Mini-grids guarantee power access for the whole community, allowing self-sufficiency and increasing the efficiency and the reliability of the system.

If/when the grid is extended, mini-grids and DG resources can be connected to the grid and can exchange energy.

The presence of REEs in the electricity landscape is affecting power systems structure and evolution. In many developing countries, the deployment of distributed generation, as an alternative to grid expansion to increase energy access, is steering a transition towards hybrid and decentralised systems.

Most developing countries transmit and distribute power through an early-stage network infrastructure. In this context, the integration of distributed generation could improve grid stability by increasing the load at the far ends of the grid. However, too much distributed generation would generate complexity that can be managed only through a smart grid. If distributed generation is connected to the grid, the evolution from an early-stage grid to a smart network infrastructure is a requirement for the transition towards hybrid systems with significant distributed generation or decentralised systems.

On the other hand, the deployment of off-grid generation is not affected by the development stage of the grid: the transition towards decentralisation can proceed even with the existing infrastructure.

Based on interviews and desk research, developing countries are experiencing a transition towards decentralisation along two possible evolution paths. Some REEs envisions a gradual evolution where individual systems will first connect into micro-grids, then micro-grids will connect to other micro-grids and finally, over time, these will all connect to the main network infrastructure. Other entrepreneurs instead believe that the individual units will remain off-grid.

Policymakers and regulators need to consider the near and long-term role of rural entrepreneurs and utilities exploring models to expand off-grid distribution generation in the development of their energy system. Distributed generation is one of the greatest opportunities to expand access to electricity in rural areas. However, a growth in distributed generation and the expansion of the main grid can become two competing alternatives, adversely affecting the actual goal to increase the electrification rate of developing countries. Unless clarity for the integration of a micro- or mini-grid is provided from the onset, the uncertainty arising from this context may limit the investment appetite substantially.

In the immediate and short-term, increased energy access through renewable distributed generation allow countries to make gains on both the energy access dimension of the Energy Trilemma as well as the environmental sustainability dimension as renewable generation may be replacing kerosene or biomass fuels. Further, regulators should consider factors that may inhibit or stall participation of rural energy entrepreneurs (for example, value added taxes on technology imports) and also consider if and how the government or associated agencies can incubate entrepreneurs in their early stages.

BATTERY STORAGE

Storage is a growing aspect of distributed energy resources and is a key factor associated with the increase in distributed generation and especially rewewables based generation. Storage is viewed as critical to managing intermittency issues associated with renewables. Over the past decade, storage installation

Box 4: The Role of Electricity Storage

Electrical storage is challenging: except for small scale capacitors on a very short timescale, electrons don't lend themselves to being herded into boxes for later use, so all storage mechanisms need a chemical, thermal, kinetic or physical proxy. The suitability of a particular method depends on the objectives of the storage. How will the electrical energy be released, and what will be the purpose of doing so?

Power storage is often divided into two categories: generator level storage, and grid level storage.

Generator level storage serves the purpose of extending the availability of electricity from intermittent generation sources: for commercial generators to continue supply when the wind drops or when the sun disappears. This can be achieved by batteries, or more esoteric solutions such as molten salt in solar-thermal installations. Off grid systems connected with Solar PVare examples where batteries are charged during the day, and provide lighting after sunset.

Grid level storage, activated by a TSO or DSO, can be further divided into two objectives, although the two often overlap.

The first is to provide an alternative source of power over a long period, to supplement the generators on the grid; this is usually to provide peaking power, as an alternative to dedicating capacity which would only be used in certain periods. At the moment, this is almost exclusively the domain of pumped hydro, although technological advances promise alternative methods. Access times need to be quick – but minutes rather than seconds – and the quantity of energy needs to be suitably large.

The second is to enhance grid frequency and voltage stability by injecting power into the grid on a time scale as short as fractions of a second, and to allow for transition to alternative generation sources, for example gas turbines, over a scale of minutes or tens of minutes. Where this is the primary objective, speed of access to the power drives the storage method decision. This stabilising need increases proportionally to the reduction in the power mix of generation plant with high rotational inertia (for example turbine generators).

As more and more power comes from wind and solar inverters, the complexity of very short term grid management grows and some form of storage becomes essential, often alongside demand management of some form. Although circumstances vary greatly, 20% intermittent power is often taken as a sort of "tipping point" for grid management storage needs. Whilst batteries of various types are the main focus of attention currently, methods such as flywheels and compressed air are also used.

projects have sharply increased and that trend is expected to continue over the coming years (see Figure 14). The increased utilisation of electric energy storage is driven by the falling price of battery technologies, a rising need for efficient and cost-effective power grids, and favourable energy policies and regulatory environments.

The expansion of storage capacity is allowing new considerations in flexibility in the management of the generation or consumption of power to ensure system balance, which is key to active system management. Regulators are considering the regulatory implications of such innovations and how rules need to be updated to provide clarity on how storage is treated from a connection and charging perspective[45]. For example, in the UK, battery storage technology is being used as a mainstream system tool with 1.2 gigawatts of capacity bid into the enhanced frequency response (EFR) auction in August 2016; and later in December 2016, another 500 megawatts of new-built battery storage projects were awarded 15-year contracts at the capacity market auction.

Featured Interview: Norbert Nusterer, President, Power Systems Business, Cummins

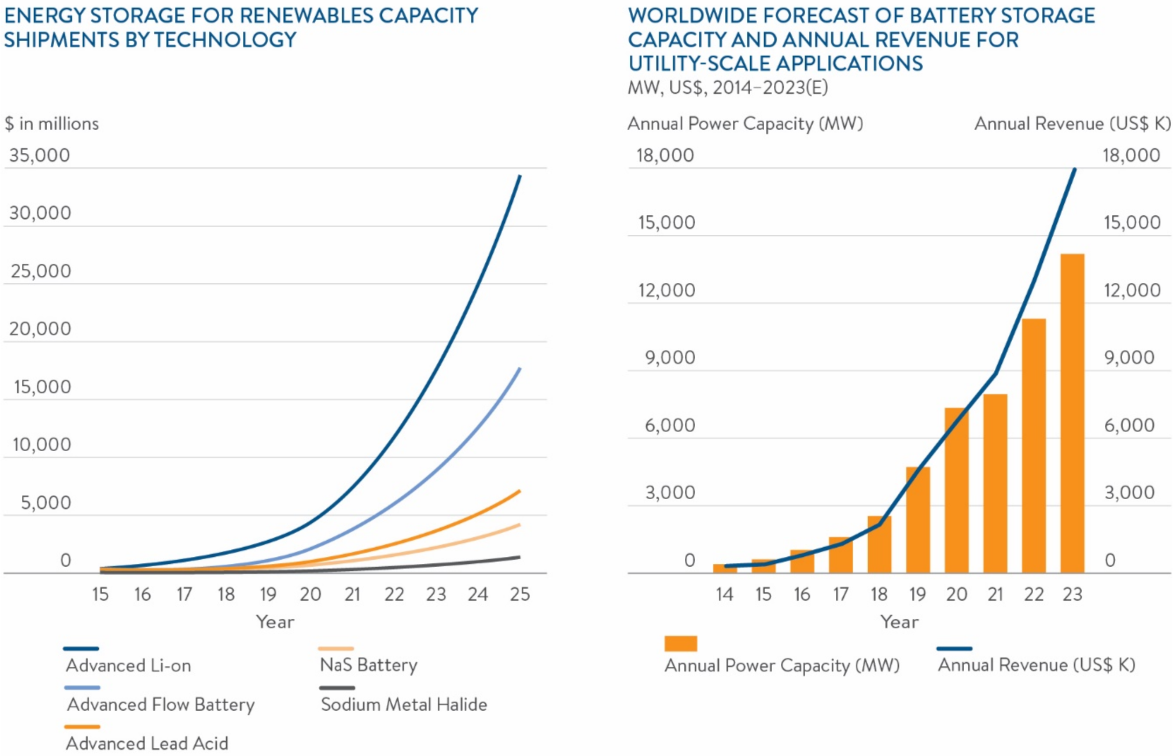
"The model will change quickly as a growing number of stakeholders influence the regulatory framework."

The technology mix of generation with storage will be quite disruptive. Storage, along with the growth of distributed generation and prosumers, are creating new opportunities to deploy assets as balancing forces in the grid. The more volatile the standard grid becomes, the more economic opportunity to be the balancing force in that.

The intensity and speed of the growth of prosumers depends heavily on the regulatory framework and who is allowed to be an active player in the market. Currently, due to regulation, there is considerable under-utilization of assets and the model will change quickly as a growing number of stakeholders influence the regulatory framework. There are also a lot of details to determine. For example, utilizing e-vehicles as grid assets, (e.g., peak shaving.) The technology exists but there are many issues to address, such as how to bill for this use, how to account for it, and how to set the market price for the power drawn out of the battery?

45 *Get Creative about Flexibility*, Andrew Perry, Oliver Wyman Energy Journal, Vol 3, 2017

FIGURE 14: Projected global growth in battery storage



Source: Navigant Research, JPMorgan, Oliver Wyman

Global energy storage capacity along with revenues from utility-scale applications are expected to increase dramatically over the next 5-7 years. Market analysis predicts that storage capacity will increase by 700% between 2017-2023 which, combined with a similar increase in revenues from utility-scale applications, will result in close to 16 GW of global energy storage capacity and almost US$18 m in global revenue in 2023[46]. To date, the geographies that have been predominantly involved in storage projects are Asia (China, Japan, India and South Korea) followed by North America (the United States) and Europe (Spain, Switzerland and Italy). Innovative companies are exploring how to capture the full commercial value from storage as system tool and other companies are exploring how peer-to-peer trading and local marketplaces that manage the allocation of demand and generation.

The importance of storage as part of an active system management is illustrated by Australia's turn to battery storage to manage the Energy Trilemma as renewables and distributed generation increasingly penetrate the energy mix.

46 Navigant Research, JPMorgan, Oliver Wyman analysis

Box 5: Australia to turn to battery storage to manage the energy trilemma

How to balance the Energy Trilemma during the energy transition has been at the centre of the Australian debate over the past two years[47]. The government is examining how storage can help the country meet environmental sustainability goals, improve system reliability and help manage electricity costs. The Australian government has put out a tender for a 100 MWh energy storage project. This storage capacity would be an alternative to building power plants and additional transmission lines and would support the integration of renewables into the grid while guaranteeing system stability.

Indeed, DER, in particular batteries, have been gaining momentum also among Australian consumers and industries: DER penetration rate is above 15% and it is expected to increase in the future. Forecasts envision a significant drop in the price of batteries (40-60% decrease in price) that are expected to lead to an increase to 1.1 million battery storage systems installed alongside new rooftop solar PV systems in households by 2035. In addition, the share of electric vehicles, constituting only 0.2% of Australia's total vehicle sales in 2015, is expected to increase to 18% of vehicles on the road by 2035[48].

The energy storage capacity in developing countries is expected to grow from the current 2GW to more than 80GW in 2023[49]. In developing nations, where there is limited or unreliable connections to the main power grid, energy storage systems (ESS) can help address some of the many energy issues, such as efficiency, security, availability and rising energy demand. For example, energy storage used in conjunction with distributed generation and local grids can reduce inefficiencies caused by using weak existing grids in markets with underdeveloped infrastructure. Moreover, energy storage systems are quicker to build and more cost-effective than traditional, centralised grids, allowing countries to increase access to electricity for its citizens in a timely, budget-friendly manner.

E-VEHICLES

E-vehicles, including cars, trucks, buses and other industrial vehicles (e.g. forklifts) sales are expected to grow significantly over the next decade supported by sales bans on internal combustion engine vehicles (ICEVs), aggressive targets for the growth of electric vehicles (EVs) and incentives to consumers. For example, Norway has a complete ban of pure ICEVs sales planned for 2025, and both France and the UK have recently announced an end to sales of pure ICEVs by 2040 as part of an ambitious plan to meet targets under the Paris climate accord, and China has noted that it is reviewing such a ban. New Zealand aims to have 64,000 EVs by the end of 2021[50]. Other countries, such as India aim at selling only EVs by 2030 and China intends to increase the share of EVs to more than 20% by 2025 as part of its goals to reduce air pollution, become energy self-sufficient and build a leading position in the global EV market.

The increase in EVs has two clear impacts on the energy system: an increase in the consumption of electricity and an increase in the number of batteries (storage) available to connect to the system. EVs, as distributed energy resources, can help manage variability in electricity generation that is expected to accompany the growth of distributed generation and renewables (see Figure 15). The storage capacity of EVs can be leveraged by utilities, load balancing authorities via aggregators, or other interested parties to provide grid services such as capacity, emergency load reduction, reserves, or regulation, or to absorb

47 *Independent Review into the Future Security of the National Electricity Market: Blueprint for the Future*, Commonwealth of Australia 2017
48 *AEMO Insights: Electric Vehicles*, Australia Energy Market Operator and Energeia, 2016
49 *Energy Storage Trends and Opportunities in Emerging Markets*, World Bank, 2017
50 Ministry of Transport New Zealand, 5 May 2016, Electric Vehicles Programme

excess generation from renewable energy resources, such as solar and wind. For example, one survey of US utilities revealed that 69% of respondents indicated that they are planning, researching, or considering distributed energy resources programs that integrate EV managed charging, compared with 20% that currently have no interest[51].

The integration of EVs provides a good example of distributed energy resources integration as part of an active system management as it highlights three key distributed energy resources integration mechanisms: (1) vehicle to grid dispatch; (2) active demand management and (3) active demand response programmes. Demand management via rates or managed charging can help support shifting demand to non-peak demand hours. Looking forward, vehicle-to-grid (V2G) dispatch could allow further integration and management of demand by using a plugged-in EV with available charged battery capacity to feed power back to the grid[52].

FIGURE 15: Integrating EVs as DERs into the power system

DEMAND MANAGEMENT VIA RATES

Demand management via time of use (TOU) rates can encourage customers to shift EV charging towards non-peak demand hours, i.e. late evening and early morning hours, and also improve utilization rates for utilities. However, utilities have found that customers often schedule their vehicles to begin charging the moment off-peak rates begin, resulting in sharp load ramps. More flexible TOU rates can help manage that challenge as well as encourage customers to change EV charging patterns. This would reduce the need for utilities to upgrade transformers in areas with high concentrations of e-vehicles that may strain equipment if all charged simultaneously.

MANAGED CHARGING

Managed charging allows a utility or third-party to remotely control vehicle charging by turning it up, down, or even off to better correspond to the needs of the grid. Managed EV charging can also be a useful means of aligning variable renewable energy with EV demand and thereby manage the challenge of the "duck curve." For example, the Los Angeles Department of Water and Power (LADWP) "Charge Up L.A.!" program offers rebates for residential or commercial chargers. In return, recipients must agree to participate in LADWP's demand response program for the life of the installation in the event the utility needs to curtail power use.

V2G DISPATCH

Vehicle-to-grid (V2G) dispatch is the use of a plugged-in EV with available charged battery capacity to backfeed power to the grid. Nissan and multinational power company Enel confirmed plans to launch a major vehicle-to-grid (V2G) trial – the first ever carried out in the UK. The trial will work by installing and connecting one hundred V2G units at locations agreed by private and fleet owners of the Nissan LEAF and e-NV200 electric van. EV owners will then have the flexibility and power to sell stored energy from their vehicle battery back to the National Grid.

BATTERY SWAPPING

Battery swapping allows consumers to recharge their EV by swapping their low level batteries with fully charged batteries. This method is fast, it allows charging at any time, and can be very effective in locations where few households have access to parking equipped with EV chargers. However, it has some downsides, consumers may receive an old battery in exchange for their new battery and the absence of battery standardization could be a challenge. Initial efforts at battery swap stations in the US, Denmark, and Israel were not successful, but may be effective in different locations.

Source: WEC / Oliver Wyman

51 Smart Electric Power Alliance's (SEPA) 2017 Utility Demand Response Survey, SEPA

52 Smart Electric Power Alliance's (SEPA) 2017 Utility Demand Response Survey, SEPA

The adoption of EVs is strongly impacted by two key factors: legislations/regulations and infrastructure. For example, the growth of EVs in India may be impacted by grid reliability and this will impact private or public charging infrastructure developments. In other locations, for example, China, where multi-family dwellings are common (compared with the North America where single-family homes with garages to charge cars at night predominate), determining the best infrastructure and rates and processes to charge cars may be more complex. Policymakers and regulators have a critical impact on the pace of electrification of the transportation sector and making EVs an attractive consumer choice.

Providing the right framework and setting the correct incentives can stimulate the core players to participate and set the necessary impulses for electrification to gain traction faster. The availability of necessary infrastructure and ease of use of the infrastructure is one of the uncertainties in the market. Governments must consider if or how they want to stimulate the large-scale construction of necessary (public as well as private) infrastructure for EVs. Indeed, one study by a US municipal utility estimated 17% (12,000) of the utility's transformers may need to be replaced due to EV-related overloads, at an average estimated cost of US$7,400 per transformer[53].

Featured interview: Michael Tinskey, Global Director of Vehicle Electrification & Infrastructure, Ford

"The pace of innovation on batteries and re-charging has increased at a faster pace than expected."

Policymakers should look to integrate energy and transportation policies to couple electric vehicles with the projected growth in renewables. E-vehicles, effectively integrated as distributed energy resources, can help manage the 'duck curve' challenge associated with the increase of solar PV.

The pace of innovation on batteries and re-charging has increased at a faster pace than expected. However, the wide-spread adoption and embrace of e-vehicles by customers will require a rethinking of grid governance to manage energy demands. Customers need a consistent, homogenous, inter-operable charging network. For example, in the USA, states and utilities are implementing e-mobility policies and rates independently.

This approach will not meet the needs of customers. In order for EVs to work at a systems level, the infrastructure development needs to be coordinated, for example, strategically spaced out charging stations. Automakers have a role and shared goal in pushing the focus on customer needs. In Europe, automotive producers are working together to install charging infrastructure and are collaborating with utilities.[54]

The role of the utilities, automotive producers, or even third parties in developing the charging infrastructure can depend on the rate systems of and revenue drivers for utilities – in particular how demand charges factor as a component of utility revenue. Demand charges are higher in [the] USA compared to Europe and this can influence the utilities desired role in E-mobility.

53 *Utilities and Electric Vehicles: The Case for Managed Charging*, Smart Electric Power Alliance, April 2017

54 https://media.ford.com/content/fordmedia/fna/us/en/news/2016/11/29/bmw-daimler-ford-volkswagen-audi-porsche-plan-ultra-fast-charging-major-europe-highways.html

3
Establishing new rules to achieve long-term energy goals

3. ESTABLISHING NEW RULES TO ACHIEVE LONG-TERM ENERGY GOALS

The energy system is transitioning at an unprecedented pace. As the CEO of a transmission system operator noted: “Policy regulation will have to change fast to enable things to happen. Often regulation is thought of after a change, however it is important for regulations to keep up-to-date with how the market is progressing.”

The impact and uptake of new technologies including distributed generation and associated distributed energy resources is unclear. Yet, to ensure countries meet their often conflicting Energy Trilemma goals, providing certainty to energy sector participants in this ‘Grand transition’ will be key. Policymakers and regulators must support a dynamically resilient energy system that is sufficiently agile to leverage new opportunities while not undermining existing effectiveness.

The process of managing the energy transition to accommodate increased distributed energy resources may not be smooth in many countries and will challenge all participants. In part this is due to the varying pace of change across all the components of the evolving electric system. For example, technology developments in renewable energy generation have increased the effectiveness and decreased the cost of solar PV technology, however storage technology is still developing, as is the widespread use of electric vehicles and associated e-vehicle charging infrastructure. There are variations in consumer demand for distributed generation, with some large industrial prosumers pushing for greater flexibility in distributed generation and also some residential customers are leading the adoption of residential distributed generation. Yet not all industrial or residential consumers can support or want distributed generation options. Mobile payments are allowing rural entrepreneurs to sell distributed generation equipment and appliances directly to those not currently served by the central grid. As a result, charting the path to an ‘ideal’ future energy archetype requires both changing the existing system while developing the new – all with uncertain but accelerating timelines.

As one large transmission operator noted, “We are watching and learning to see who does what well. We don’t have the answers, but we are learning fast.” Another noted, “…. around the world, there will be leaders, learners and laggards and in ten years, there may be 100 different versions or interpretations on how best to get somewhere in this direction.“

To navigate forward, policymakers and regulators should:

- Enable a dynamic and resilient market framework with the agility to adapt with the transitioning energy system;
- Establish robust technology-neutral standards that will be key to building more dynamic and resilient market frameworks to support transitioning energy systems;
- Anticipate the emerging roles for empowered and proactive consumers by ensuring that the market framework can adapt to their evolving and shifting needs.

3.1 ENABLING A DYNAMIC AND RESILIENT MARKET FRAMEWORK TO ADAPT WITH THE TRANSITIONING ENERGY SYSTEM

Making the market framework dynamic and resilient to change

There is no single ‘correct’ framework for the transitioning energy system. Interviews with all players in the system have stressed that the key to managing this period of rapid energy transition successfully is to facilitate a market framework that can evolve with new technologies, challenges and opportunities with a strong focus on shifting and rising consumer preferences (both large industrial and residential). As utility leaders commented, “What needs to change will lead policy and policy will be playing catch-up to customer preferences.” And another energy leader noted, “Given the pace at which DG is developing in Africa, the regulatory framework does not have a chance to keep up with developments”.

The impact of new technologies can be unclear and market frameworks must be technology neutral in order to maintain flexibility to incorporate new technologies and services.

Focus on evolving customer choices and demands

New technologies are providing consumers with new opportunities and the market framework design should be adaptable to enable consumers, including residential, community and industrial, to make those choices.

As noted by one utility leader, “Consumers are increasingly looking to take more control of their energy through the use of smart systems and home energy management, installation of solar panels on their roofs and using batteries for their e-vehicles.” Another noted, “It is very likely in ten years that the demands of consumers will have changed considerably. This will be largely driven by industry and commercial customer preference for [the] type of electricity generation (renewable or low-carbon) rather than additional regulation.”

At the same time as the focus on consumer choice, policymakers must recognize the need to maintain a balance on the Energy Trilemma. This will be challenging and can create hurdles that must be addressed in the transition to ensure all three elements of Trilemma stay in balance.

Re-define evolving roles and responsibilities

Fundamental to the transition of the energy system from a centralised model to a hybrid model will be revisions in policy design, where policymakers and regulators need to define who can participate in the energy market, how they can participate, and how they can charge for services provided.

The market framework must provide clear definitions of roles and responsibilities between actors, and clarity on the processes and supply of services. As one survey respondent noted, “The regulatory regime, in managing transition, should offer equal opportunities to incumbent and new entrants”.

Managing the evolving roles in a period of transition will require regulators to address potentially conflicting goals and objectives among the various actors in the energy system. For example, some countries have established a limit on the maximum number of off-grid concessions, which can prevent rural energy entrepreneurs from achieving economies of scale. This is deterring investors and businesses from operating in those countries. At the same time, grid extensions often do not provide electricity access at the pace and cost of off-grid solutions, which is resulting in an electrification deadlock. As one energy leader noted: “If you just neglect contradictions then you are going to run into very dangerous terrain”.

In defining roles, re-consideration of what needs to be regulated within the energy sector as the energy system evolves to a more hybrid model may be required. De-regulation allows for market players to develop and contribute. As one energy leader noted, “The current market design is in a hybrid format, with a mixture of subsidies, market-based specific regulatory measures and typical free market development and it is difficult to see how this can continue.” However, de-regulation may not support the provision of necessary system services required to balance the Energy Trilemma. Policymakers will therefore need to find the right balance between measures that facilitate market access to new entrants and measures that create an enabling environment for the secure, reliable and affordable provision of necessary system services.

Innovated pricing structures

As recognised in WEC’s Scenarios analysis, electricity demand will increase and therefore the market frameworks will need to be sufficiently responsive to facilitate the required investment.

Investment in new generation capacity requires suitable long-term visibility of expected revenues. This is true irrespective of the policy, market and regulatory frameworks. In a central energy system, this certainty is provided by the regulator, who allows the monopoly to recover its cost from the consumer. As countries move towards hybrid systems, policymakers need to create an enabling environment for system services that are required to manage the increasingly networked energy system.

For example, in the USA, regulators across different states are assessing how to revise rate designs for utilities to ensure a robust system when supporting the growth of DG. Ultimately as one utility leader noted, “Antiquated pricing structures are a challenge and we need more sophisticated pricing structures.” Issues under consideration include how or whether to use ‘volumetric energy charges’—charging customers based on energy use— or fixed charges that are not dependent on usage. Net-metering options are proving contentious for many utilities concerned about recovering costs. Overall, studies highlight that an increase of DG in the system tends to overall off-set costs for utilities since it increases system reliance and decreases the need for large capital investments in new power plants[55]. Taken as a whole, studies show that increased DG is a net benefit to the electricity system and pricing and rates need to reflect that while allowing appropriate cost recovery.

Where there is a goal to increase and integrate DG and DER into the market, regulators have to establish clarity for these options to participate in the market and align issues such as rate structure to support such growth. For example, it is important to set out clear options for connecting to the grid, net metering; peer-to-peer electricity trading or selling to aggregators; etc.

As noted by rural energy entrepreneurs, “Since the introduction of mini-grids has been fairly recent, at the moment there is no policy to protect the operation of mini-grids and policy is not encouraging the adoption of small-scale solar projects.” Another noted, “There is a real need for clear technical documents that are able to outline what happens once the grid arrives in rural areas. An assurance from the Government that once the grid has arrived, that we would be able to sell any excess energy produced back into the grid would be a good first step.” In such situations governments may need to clarify who can leverage feed-in tariffs. For example, the removal of capacity barriers allowing only medium-large generators to have access to these tariffs (for example, in Kenya the minimum capacity to have access to the feed-in tariff is 50 kW).

Clarity on rate options and how to participate in the market is an important issue in both developed and developing markets. For example, peer-to-peer trading is being piloted in various areas, including the

55 https://www.brookings.edu/research/rooftop-solar-net-metering-is-a-net-benefit/

Brooklyn Micro-Grid in New York City which is testing how various energy resources, including solar energy, batteries, and other technology, can be brought together within one community microgrid and to allow sales and purchases of electricity among neighbours. An interesting element of the pilot is the use of blockchain technology to facilitate trading[56].

Box 6: Blockchain and distributed energy resources

Blockchain could offer a reliable, low-cost way for financial or operational transactions to be recorded and validated across a distributed network with no central point of authority. Pilot projects in the use of blockchain are already taking place: in New York State, neighbours are testing their ability to sell solar energy to one another using blockchain technology; and in Austria, the country's largest utility conglomerate, Wien Energie, is taking part in a blockchain trial focused on energy trading with two other utilities.

These pilots are illustrating how blockchain can help address the challenge of updating and improving centralised, legacy systems with a distributed hybrid system made up of a patchwork of both large power plants and microgrids powered by distributed energy resources. There are a few areas where blockchain technology can support and accelerate the trends of digitisation and decentralisation and support evolving demand for electricity in smaller, lower value blocks and at higher frequency. For example, peer to peer trading is one potential application being tested with the Brooklyn Microgrid. Blockchain could also support grid flexibility allowing businesses to trade their option to use electricity during a given time frame; for example, a factory could sell five minutes of unused power during a down time to a different factory that needs the additional power[57].

3.2 ESTABLISHING ROBUST TECHNOLOGY-NEUTRAL STANDARDS KEY TO BUILDING MORE DYNAMIC AND RESILIENT MARKET FRAMEWORKS TO SUPPORT TRANSITIONING ENERGY SYSTEMS

Standardisation is a valuable mechanism to manage an increasingly complex energy system as new technologies are deployed and new actors enter the market. Standards can help ensure that new technologies remain interoperable with a country's existing and potential infrastructure. They provide critical clarification around processes and improve efficiency.

Establishing standards can both enable and speed the energy transition and provide assurance to all players the evolving energy system – policymakers, incumbent actors, new entrants and consumers – that technologies will be safe and effective over time. Policymakers and regulators should focus on five key areas:

- Standards for project development and financing processes and documentation;
- Standards for technical and service harmonization of DG and DER;
- Standards to promote uptake and integration of DG and DER;
- Standards for quality and safety;
- Standards for interoperability.

56 https://www.nytimes.com/2017/03/13/business/energy-environment/brooklyn-solar-grid-energy-trading.html?_r=0; https://www.scientificamerican.com/article/a-microgrid-grows-in-brooklyn/

57 *How Utilities Are Using Blockchain to Modernize the Grid*, James Basden, Oliver Wyman and Michael Cottrell, Oliver Wyman, Harvard Business Review, March 27, 2017

Standards for project development and financing to reduce costs and inefficiencies

Standard regulations, processes and templates for licensing, permitting procedures, and so forth for distributed generation projects can be an effective way to increase the integration as well as the pace of adoption of DG. As one executive noted: “in countries where districts apply different regulations, companies cannot easily expand their reach to provide services to more households”.

The process for renewable power purchase agreements (PPAs) for example can be complicated and time-consuming to harmonize. In regulated markets, large consumers are creating one-on-one arrangements with utilities, or utilities are developing new approaches such as green tariffs. As one large multinational noted, “Large consumers often need to navigate a vast array of location specific regulations within a country, region and geography.”

The creation or use of entities that can assist with the administration process can provide a platform for a more rapid and increased integration of DG through the removal or reduction of time-consuming processes present in many existing procedures - especially in Sub-Saharan Africa. One example is ‘Solar Energy Standardisation Initiative’ developed by leaders in energy, finance and law in June 2016 to facilitate global solar development. The Initiative brought together stakeholders from the public and private sectors to define and agree on a standard template for solar project documents that are effective and acceptable by finance institutions[58].

There can be a general issue of inconsistency approval processes between the central and local level. A development bank director noted that “investment into smaller scale projects often requires approval from different Government entities, at the local and central level, however disagreement amongst these parties can often cause the length of the approval process to increase dramatically. This can act as a deterrent for investment into small projects, with the result being that sometimes more time is invested into small projects than large ones”.

Standards for technical and service harmonization of DG and DER

Technical and service harmonization will be critical as overarching networks or open business models become more important for customers[59]. For example, the development of enablers such as smart phone applications that allow different e-vehicles charging stations owned by different utilities or operators to work together; for example, apps such as ‘PlugSurfing.[60]’

While addressing the technical aspects of standards – the interconnection process, inter-operability, quality and security of the equipment and licensing and permitting procedures - policymakers must also ensure above all that the established rules enable flexibility.

Given the rapid pace of change in the energy transition, standards that have been enforced and worked for long periods of time are now being viewed as increasingly less valid and restrictive. The rules on which they are established may not be suitable for a future in which distributed generation is likely to play an

58 http://www.irena.org/News/Description.aspx?NType=A&mnu=cat&PriMenuID=16&CatID=84&News_ID=1454 . Henning Wuester, Director of IRENA’s Knowledge, Policy and Finance Centre quoted

59 *The Gas Station’s Digital Future*, Ifran Bidiwala and Eric Nelsen, Oliver Wyman, 2017 and *Will Digital Spark A New Automotive Industry*, Matthias Bentenrieder, Lars Stolz, Juergen Reiner and Christoph Möller, Oliver Wyman, 2016.

60 https://www.plugsurfing.com/en/

increasingly prominent role. Energy leaders have highlighted that pace and review process of setting standards needs to be quicker; as the CEO of a safety authority in a province in North America has commented: “Technology is moving fast, and so codes and standards need to be created fast enough to keep up. Typically it takes three years for the whole process to occur – this is not quick enough. Ideally we need a timescale of one year.”

A regulatory environment that does not encourage a periodic review of standards, for example, can mean that codes are not always reflective of current and future market developments. Thus, regulators must ensure that the correct frameworks and mechanisms are in place to allow such flexibility, and secondly that standards allow for such flexibility to accommodate for future developments. The use of a Principle-Based Regulation approach can support the needed flexibility for future technology developments. “Given the emergence of new technologies that are bringing complexity to a historically simple regulatory environment, prescriptive-based regulations that are typically overly specific, inflexible and do not allow for much manoeuvrability may not be particularly suitable as a future regulatory mechanism.”

Standards to promote uptake and integration of DG and DER

Standardisation is not only important to avoid stranded assets but also to promote the uptake of new DER technologies. The DER integration challenge in the absence of adequate standards is evident when considering the integration of electric vehicles. As one executive noted: “The biggest challenge is a very inconsistent charging approach. Utilities tend to meet the needs of customers in just one geographic area. They don’t work in cooperation with other utilities across different geographical areas. This has been the largest issue because each utility is implementing their own e-mobility policy and rates independently.”

E-vehicles are particularly likely to require the establishment of appropriate standards to enable their take-up. For example, various technical standards regarding power level or sockets, or billing models are present in the markets. The industry is maturing and standards are being developed. Distributed energy resources could help support e-vehicles with the development of a consistent homogenous inter-operable charging network. For example, the development of uniform and non-proprietary communications messaging protocols that can enable the managed charging functionality in an EV and provide an improved EV customer experience. For example, with eRoaming, the consumer can access all charging stations with one contract through automatic payment authorisation and optimised load management, providing grid services based on charging costs, owner preferences, and vehicle-specific parameters such as battery wear”[61].

61 Smart Electric Power Alliance’s (SEPA) 2017 Utility Demand Response Survey. See also, https://ec.europa.eu/jrc/en/news/new-european-interoperability-centre-electric-vehicles-and-smart-grids-opened

Set standards for quality and safety

The implementation of standards that prioritise for quality and safety in appliances can help give confidence to consumers that a product will be a good long-term investment. This can be particularly true in developing countries. As one executive noted: “Standardization of solar PV devices through testing and appropriate labels would encourage transparency and trust in using PV devices, since currently people are sold a variety of different devices with varying quality”.

It is recommended that adequate standard setting is enforced through an approved Government or independent body - such as ISO, ANSI or BSI - so that sufficient rigour can be maintained which will promote confidence and trust from consumers. Developing countries can consider adopting internationally harmonized standards.[62]. For example, the World Bank’s global certification scheme launched in 2010 for pico-scale solar products in 11 countries across Africa through its project ‘Lighting Africa’, which had the aim of boosting consumers’ confidence by ensuring a minimum level of product quality[63].

Standards for interoperability

The interoperability of existing and incoming systems is key to long-term integrated electrification planning, and needs to be regulated through grid codes and standards [64].

Clarity and standards on interoperability are fundamental to ensure that distributed generation assets do not end up ‘stranded’ once the grid has expanded or if technology evolves. Indeed, ensuring that DG assets can be connected to the grid (should it extend to that region) can give consumers faith that their investment into a new DG technology is sound. An example is the development of low-voltage direct current (LVDC) standards to ensure PV DG can support an array of household appliances[65].

In countries with limited energy infrastructure, for example, standards can enable a smooth integration of off-grid distributed generation into the national grid. As one CEO of a rural entrepreneur company based in Kenya has noted, “There is a real need for standardisation in order to help mini-grids integrate into the national grid”.

In the absence of existing standards, some initiatives are driven by industry rather than mandated by the government. A CEO of a company that provides solar micro-grid solutions across Africa for example stated that: “[Our company] is ensuring that all their systems are fully ready for interconnection already - everyone who is in mini-grids should think of doing this.” In addition, the CEO of a technology venture noted: “There is a risk of system integration later but some organisations are ensuring that all their systems are fully ready for interconnection already. It’s a question of engineering and need for foresight. It makes business sense to ensure connectivity.”

62 https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/10231.pdf
63 http://www.sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/Market-Pico-Solar_WEB.pdf
64 http://ieg.worldbankgroup.org/Data/reports/lp_off-grid_electricity_1116.pdf
65 https://www.lvdcconference.com/wp-content/uploads/2017/06/Keynote-Speech-RojasManyame_Day-2_Nairobi.pdf

3.3 ANTICIPATE THE EMERGING ROLES FOR EMPOWERED AND PROACTIVE CONSUMERS BY ENSURING THE MARKET FRAMEWORK CAN ADAPT TO THEIR EVOLVING AND SHIFTING NEEDS

Historically consumers have paid a passive role in the electricity market framework but new technologies and services are empowering consumers and enabling them to become much more proactive participants. Technology will provide new options to access and consume energy so the framework design will need to enable consumers to make those choices.

Enabling consumers to become more empowered may require policymakers and regulators to reconsider their approach to market framework design. Given that the consumer benefits of emerging technologies are not always apparent, it may make sense for regulators to reverse engineer by considering what future services that consumers may want, and consider how the framework design would need to evolve with new market entrants to enable consumers to make those choices, while still keeping in the Trilemma goals in balance.

In addition to developments in market framework and rate design, policymakers and regulators need to other remove barriers to entry and address other factors that may inhibit change. Figure 16 summarizes the differing factors inhibiting and enabling the pace and extent of DG increases.

FIGURE 16: Inhibitors and accelerators of DG uptake

INNOVATIVE UTILITIES AND NEW ENTRANTS

- ✓ Fast moving utilities responding to change
- ✓ Non-utility companies offering electricity services
- ✗ In developing countries, highly unpredictable initial demand and demand growth makes accurate business modelling very difficult

FINANCING

- ✓ Green bonds
- ✓ Financing policies (subsidies, feed-in tariffs, net metering)
- ✓ Use of auctions
- ✗ Challenges in rural areas to access private finance due to: lack of predictable cash flows, FX risk, contracts prone to delays, etc.

CONSUMERS' PREFERENCES/ MARKETING FORCES

- ✓ Enables self-sufficiency and energy independence
- ✓ Improving reliability of electricity
- ✓ Basic energy access
- ✓ Energy cost management
- ✓ Environmental sustainability goals
- ✗ Ability to afford up-front costs for DG equipment

TECHNOLOGY

- ✓ Increased DG power and efficiency
- ✓ New entrants supporting DG and DER utilization (e.g., energy aggregators)
- ✓ Decreasing cost of storage
- ✓ DG/DER enabling technology (e.g., mobile phones, mobile payments, block chain, enabling peer-to-peer energy trading, electric vehicles; smart grid; smart meters; smart homes)

POLICY/REGULATIONS

- ✓ Clarity of regulations for prosumers to inject electricity to grid
- ✓ Clarity around grid expansion and timing
- ✓ Government incentives – subsidies, feed-in tariffs, programs to promote DG; rate and tariff flexibility
- ✗ Regulatory uncertainty, lack of consumer protection, lack of technical and quality-of-service regulation (in particular in emerging markets) deters investments
- ✗ Trade/technology barriers
- ✗ Environmental sustainability goals

Source: World Energy Council, Oliver Wyman, 2017

New service requirements in a non-vertically integrated market

For some countries, the new electricity system will require an independent system operator with transparency and clarity to manage the grid in a non-vertically integrated market.

Developing a market for system services will require well-functioning retail markets where consumers have the ability to switch suppliers easily, have access to clear information, and can make informed choices. In order to engage consumers successfully in providing system services, administrative processes should be made as simple as possible (e.g. single billing through an independent actor should be promoted). Efficient arrangements for data handling are a pre-requisite alongside ensuring that consumers retain confidence that the privacy of their data is being suitably safeguarded.

Ensure information to support customer choices

Regulators and policymakers can support the dissemination and promotion of information on the retail market (e.g., mailing campaigns or websites) and how to enter the distributed generation market. The widespread take up of distributed generation technologies can be stunted by the lack of awareness regarding the process of how to enter the distributed generation market, and the options available for consumers.

Governments can also provide guidance to small power producers (SPP) and consumers through, for example, a website portal on how to gain access to, and use financial benefits from Renewable Certificates or other incentives. For example, research on the uptake of residential distributed generation in the UK found: “By far the most commonly cited barrier to distributed generation was a lack of reliable information on the options available. Whilst there are some excellent examples of advice provision, there is a lack of co-ordination and clarity. In some areas, information tailored to the needs of potential distributed generators simply does not exist”[66].

Reduce barriers to Financing

A significant barrier to entry for distributed generation technologies, for both investors and consumers, surrounds the issue of cost, either for entry by investors or for uptake by consumers. In established markets, new entrants frequently must incur additional costs in order to enter a market. These can significantly discourage such new entrants and thus inhibit the effective integration of distributed generation. Equally consumers in rural areas can find it difficult to accumulate capital to provide for an initial investment into distributed generation technologies.

Ease of product introduction into a market and can translate to a lower overall cost for the consumer, helping to spur utilisation of distributed generation technologies that can increase energy access and penetration of distributed generation; for example, solar PV in Sub-Saharan Africa where, the unconditional removal of VAT on PV equipment has helped to promote the market in Kenya, Tanzania, and Uganda. These countries benefit from strong market growth leading to an increased number of households gaining access to off-grid electricity.

Policymakers must also consider the unintended impacts of subsidy programs on the development of the energy system. Subsidies are often fundamental to boost energy equity and to attract private investors however, risks of subsidy discontinuity can lead to uncertainty in financing conditions. Subsidies can also deter peer-to-peer trading, as subsidies may be higher than wholesale market prices, creating no incentive

66 https://www.ofgem.gov.uk/ofgem-publications/52326/review-distributed-generation.pdf

for people to sell energy to their neighbours. Other options, such as incentives to connect people who live close to each other, may instead support the sharing economy.

Align regulatory frameworks

The inability of private investors to obtain land rights for the building of distributed generation projects can significantly impact the effective integration of distributed generation. Providing a clear framework on land rights and ownership can provide the foundation that encourages investment. "Projects can collapse due to opposition from communities. Therefore, community engagement is an important factor when considering whether or not to build renewable energy projects."

Policymakers should also consider the impact of limits on the number of connections available to rural entrepreneurs. As one organization noted, "The off-grid market needs scale, for example, we would like to set up 200,000 connections but the government may limit us to 50,000 connections which does not make business sense. We need a clear path"

Build skill capacity sets to support technology adoption

Often there is insufficient talent within the sector to enable adequate maintenance and training for installation of new technologies. As one rural energy entrepreneur noted, "Capacity building and training are vital, and often overlooked." For developing countries, talent capacity is a challenge across all sectors but has been noted before in our reports in all aspects of project development. This recommendation supports the need that if developing countries wish to expand DG, they need to also consider the necessary human capital to support and look to the private sector to support training and /or training schemes as community colleges, etc.

Government departments, especially those responsible for creating and enforcing regulation in the trade and industry sector and skills development, should work together in a collaborative approach to create a roadmap to ensure that the skills base in maintaining and installing DG technologies is maintained.

In the developed world, there is also a need to build skill sets in new energy technologies as the numbers involved in these sectors increase. For example, in the USA, just under 374,000 people were employed in solar energy, while coal, gas and oil power generation combined had a workforce of slightly more than 187,000[67].

67 https://www.energy.gov/sites/prod/files/2017/01/f34/2017%20US%20Energy%20and%20Jobs%20Report_0.pdf

Conclusions

6. CONCLUSIONS

The three trends of decarbonisation, digitisation and decentralisation are changing energy demand and supply to transform the global energy sector at an unprecedented pace and scale. The individual impact of each of these trends upon the energy sector would be large but these trends are reinforcing each other and are helping to create a new potential emerging trend of empowered consumers, if regulators enable this.

The energy transition to a low-carbon future is not solely about electricity but will have wide ranging impacts across many economic sectors. The pace of the transition will vary across countries and the adoption rates of electrification technology will vary because of a confluence of changes and technology evolutions. There is also latency in transition due to installed technology and infrastructure base. For example, in the transport sector, there will be a clear shift towards electricity in public and personal transportation away from hydro-carbons. In other areas, gas will remain for many years as a viable low-carbon option for heating and cooking in certain regions. Nonetheless, the energy transition will have a significant impact on the power sector and how countries seek to navigate competing challenges posed by the Energy Trilemma.

Decentralisation is driving the growth of distributed energy resources including distributed generation although there is some ambiguity about which energy archetype will emerge. While decentralisation implies greater fragmentation, the Council’s most recent World Energy Scenarios see the energy transition shifting demand towards electricity and doubling demand by 2060, which would reinforce the need for networks. Developed countries will need to adapt existing infrastructure to incorporate the deployment of more variable renewable generation together with more diverse electricity demand from e-vehicles etc. Decentralised generation will help to improve access in developing countries but could also be the initial steps towards to creating boarder networks incorporating grid expansion and centralised generation to meet rising electricity demand.

The emerging trend for consumer empowerment is particularly interesting as previously passive participants at the end of the power line can now become increasingly active. Larger consumers such as firms are already supporting distributed generation to manage their energy costs and to meet their own environmental targets and will further push towards greater decentralisation. At the same time, new service providers are looking aggregating households to explore similar cost and environmental opportunities. The potential rise of the empowered consumer suggests that the optimisation of the energy system is now moving from the transmission to the distribution level.

These trends are creating new opportunities to balance the Energy Trilemma although this will require managing a greater diversity of market actors and technologies without fragmenting the energy system.

Key findings

The survey of, and various interviews with, energy leaders all pointed towards distributed energy resources becoming increasingly important to the global energy system in the context of the energy transition. Improved efficiency and falling technology costs were seen as being key to further accelerate this trend, with distributed generation, particularly renewable, playing an increasingly key role.

From the survey, more than 50% of energy leaders expected an increase in the share of installed distributed generation capacity to 15% and higher for installed generation by 2025. This reflected a significant shift in the generating mix and a notable increase in the anticipated pace of change, although with large regional variations. Policymakers, energy utilities, innovative new entrants and consumers are the driving forces behind the increase in distributed generation, pursuing electricity access, affordability and competitiveness as well decarbonisation goals. Small-scale industry level off-grid and household level on-grid were seen as the most common forms of distributed generation in many countries.

Along with the increase in distributed generation, energy leaders considered that energy storage, and particularly batteries were becoming a key future element of the grid to enhance system efficiency and cost stability. The energy leaders noted that over the past decade, storage installation projects have sharply increased and expected that trend to continue. However, there was considerable concern that without suitable dynamic policy frameworks, these opportunities could stall, with energy leaders having mixed views on the ability of the regulatory frameworks to adapt at the same pace as technology and consumer demands.

As the decentralisation trend continues in many countries, the research undertaken identified four power system archetypes. Each archetype represented a different combination of centralised and decentralised generation, including a centralised, two hybrids and a decentralised system. Recognising these emerging systems will be important for policymakers and regulators to consider how to manage the complex transition and evolution of the power system.

The interviews with energy leaders highlighted five key themes.

1. Countries that do not take the necessary steps to integrate distributed energy resources will face heightened energy security risks, potential infrastructure redundancies and investment challenges that will adversely affect their Energy Trilemma performance.
2. Decentralisation adds new resources and creates new actors in energy markets, provided governments and regulators are prepared to allow them to access it. Market entrants such as large energy 'prosumers', energy service aggregators and rural energy entrepreneurs offer new sources of generation, supply and demand management. As countries transition to hybrid systems, policies, roles and responsibilities need to evolve.
3. Maintaining system reliability will become increasingly complex, and new approaches to system management, supported by enhanced information technology systems, will be required to ensure energy security. This also creates the opportunity to improve system resilience through greater diversity of supply and generation, together with improved grid management.
4. Distributed generation technologies and standalone micro-grid or off-grid systems can provide electricity access at a faster rate and lower cost than conventional grid connections. This could allow developing economies to consider 'leap-frogging' some degree of centralised generation infrastructure to increase modern energy access and meet global sustainable development goals.
5. Energy access and use is being opened up as consumers (especially companies) take control of how their energy needs are met and managed, enabled by growing options for distributed energy resources. If regulations and regulators empower them, consumers have the option to generate power for their own consumption and sell their excess electricity back into the grid, to leave the grid completely, or only use grid supply to supplement their own generation. They can choose electricity providers and utilise new energy management technologies to determine how to use energy. New technologies, such as blockchain or predictive analytics, will support this trend. Policymakers must evolve regulatory frameworks to integrate new opportunities arising from distributed energy resources and, potentially, more proactive consumers to respond to rising and rapidly evolving demands and options for energy use.

Implications for the energy sector

To achieve long-term energy goals and navigate the Energy Trilemma, policymakers and regulators need urgently to focus on these emerging technologies which can create new opportunities but also potentially disrupt existing market frameworks, roles and responsibilities. This may include a reconsideration of the energy services provided and how the costs for energy services are recovered.

As countries transition from one archetype to another, the role of energy incumbents will change. This transition will need active management given the financial exposure of other economic sectors. Without coherent and predictable policy and regulatory frameworks in place, incumbents may refrain from making the necessary and new investments that may in turn affect system reliability and affordability. Energy incumbents need to work with regulators to develop effective and responsive tariff and pricing models to cover the cost for operating, upgrading and maintaining grid as well as the benefits of the utility providing back-up capacity.

If consumers – residential, commercial and industrial – are enabled by regulators to exploit these new opportunities, regulators will also need to ensure equity for all consumers across the energy system. As distributed energy resources give consumers with financial capacity the opportunity to manage energy cost and price volatility, it exposes those consumers without financial capacity to price increases.

Distributed energy resources also could offer scope to reduced carbon emissions and address localised pollution. At the same time, they provide opportunity to further improve energy efficiency. Already, some empowered consumers are already using distributed energy resources to meet their own environmental sustainability goals. Regulators will need to consider how their market frameworks can adapt to support suitably distributed energy resources while improving the environmental sustainability of their power systems. Without appropriate integration of distributed energy sources, there is also a risk of unintended changes to the energy mix leading to a short-term shift towards fossil fuels, rather than renewable energy sources.

Recommendations

The energy system is transitioning at an unprecedented pace and navigating this new landscape will require new ways of thinking. Policymakers will need to develop their own in-depth analysis of the potential opportunity and challenges that may arise in their own countries or regions from adopting distributed energy resources. The 2017 World Energy Trilemma research has identified three key focus areas for policymakers and industry leaders to build a resilient energy system of tomorrow:

- Enable a dynamic and resilient market framework with the agility to adapt with the transitioning system. The market framework must be responsive and resilient to the future changes that will arise from new consumers and evolving customer needs and technological advances, as well as changing roles and responsibilities of market participants. Within this dynamic environment, regulators will need to enable adaptable funding mechanisms for rates and charges to support the necessary continued investment in the energy system.

- Establishing robust technology-neutral regulations supported by agreed standards to build a more dynamic and resilient market framework that supports transitioning energy systems. This includes standards for project development and financing to reduce cost and inefficiencies. Technical interoperability and service harmonisation, as well as standards to promote uptake and integration of distributed generation and distributed energy resources, are critical.

- Allow and plan for aggregator services to empower proactive consumers by ensuring that the market framework can adapt to their evolving and shifting needs. Technology will provide new options to access and consume energy so the framework design will need to enable consumers to make those choices. This will require a different approach of considering what consumers may want and 'reverse engineering' a market framework to facilitate new market entrants while keeping the trilemma goals in balance.

The energy transition is an unstoppable phenomenon. There will be leaders, learners and stragglers, and adapting to this new reality with innovative policy responses and new business models will require a massive effort. The ability of companies and policymakers to respond rapidly, creatively and collaboratively will determine the pace and shape of the global transition and, in turn, affect the ability of societies across the world to navigate the Energy Trilemma of security, sustainability and equity successfully. Governments and regulators need to plan for the transitions and anticipate its likely impacts on energy systems and market actors.

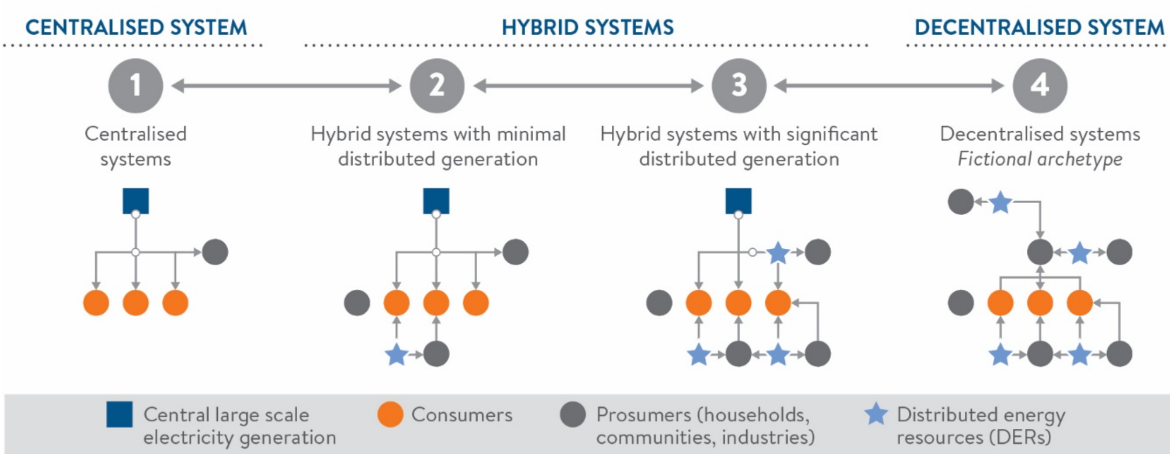
Appendices

APPENDIX A: ENERGY ARCHETYPES

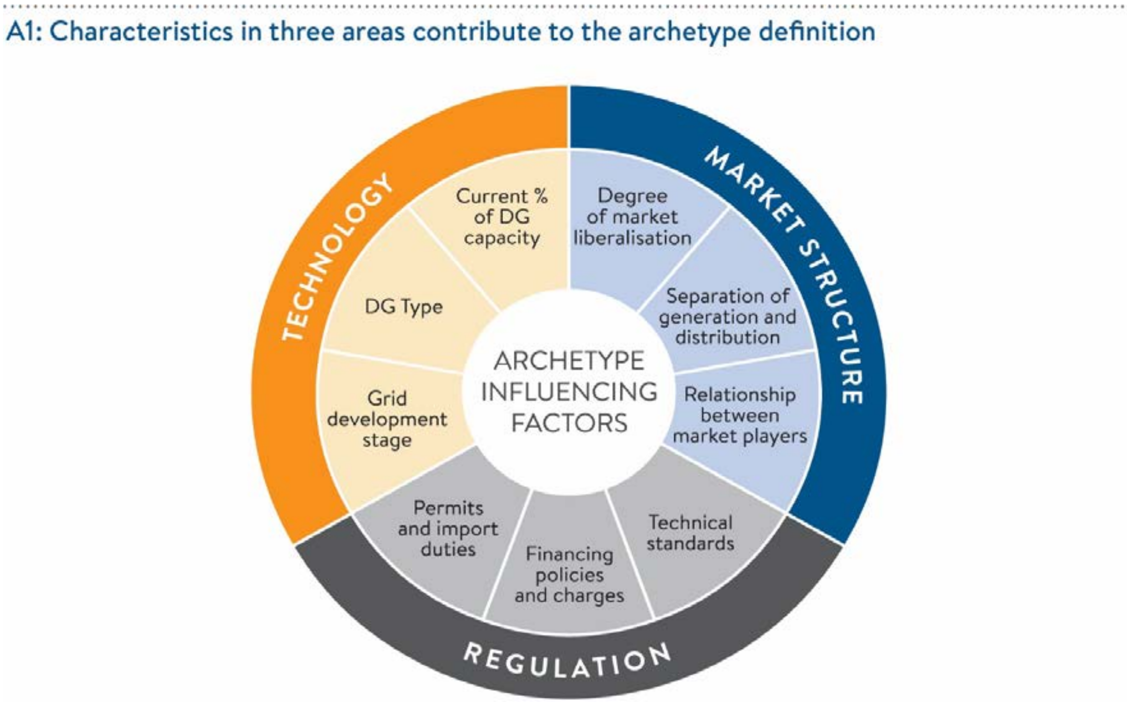
With the introduction of distributed generation, the electricity system in many mature economies with a well-developed energy infrastructure is transitioning from a centralised model with large centralised generation plants distributing to customers, to an evolving decentralised model, with multiple generation points contributing to the electricity system. The same technologies are enabling economies that are developing their energy infrastructure to consider and adopt a range of options in how to develop their energy systems.

In order to understand the challenges and opportunities faced by electricity systems in the context of this transition, four archetypes, each representing a different combination of centralised and decentralised power systems can be identified, including a centralised system, a decentralised system, and hybrid systems presenting intermediate characteristics.

FIGURE A: Emerging energy system archetypes



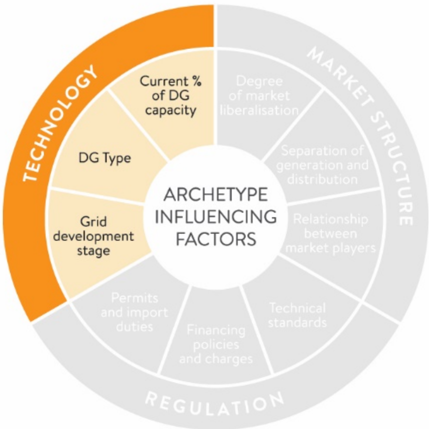
The archetypes and key characteristics can be further understood by examining 3 key influencing factors: technology, market structure and regulation.



Technology

Recent technology developments in both energy generation and also in information and communications are a fundamental element enabling decentralisation. With distributed generation technologies, power generation can shift from central large scale power plants to an array of medium and small scale generating sources that can include renewable powered DG in addition to natural gas, etc. In order to assess the degree of decentralisation several aspects should be considered:

A1a: Emerging energy system archetypes – Technology



GRID DEVELOPMENT STAGE

3 key grid types are identified:

1. **Early-stage grid.** Grid development is limited and concentrated around urban areas; in rural areas grid connections are sparse and the electrification rate is low. This grid type is typical of developing countries
2. **Traditional grid.** The grid infrastructure is well-developed and extended, ensuring a high electrification rate. The grid is able to accommodate a one-way electricity flow from large power plants to consumers.
3. **Smart grid.** Smart grids are characterised by the integration of information technology into the grid infrastructure. The result is a grid enabling a two-way flow of energy and information, allowing system operators to efficiently manage power flows and consumers to optimise their consumption by having easier access to their own data.

While countries with a traditional grid are more likely to have a centralised system, countries where the infrastructure is already "smart" can handle the increasing complexity caused by grid-connected DG more easily. Countries where the grid is in the early-stage can rapidly increase electricity access through off-grid solutions.

DG TYPE

Four main DG types are identified:

- Single DG solutions connected to the centralised grid
- Micro/mini grids (semi-independent) and connected to centralised grid
- Micro/mini grids (fully independent) and not connected to centralised grid
- Single DG solutions off-grid

DG in centralised systems usually has the purpose of emergency power generation and takes the form of single DG solutions connected or not connected to the grid. More sophisticated dispersed generation types, such as mini or micro grids, characterize more decentralised systems.

Off-grid alternatives are typical of developing countries, where the transmission and distribution networks have limited extension. In developed countries, where there are very high electrification rates, most of the DG solutions are grid connected.

CURRENT % OF DG CAPACITY

The higher the penetration rate of DG, the more a system is decentralised. Archetypes have been differentiated according to the share of DG capacity in the system:

- Centralised systems: **DG below 5%**
- Hybrid systems with minimal DG: **share of DG** capacity **between 5% and 30%**
- Hybrid systems with significant DG: **DG above 30%**
- Decentralised systems: **DG capacity close to 100%**

Market structure

Market structure is another relevant defining characteristic of decentralised systems. If distributed generation technologies are widespread but electricity is managed centrally, then the system is not decentralised.

The key aspects determining the electricity market structure are:

A1b: Emerging energy system archetypes – Market structure

DEGREE OF MARKET LIBERALISATION

In **centrally planned markets** the decision making process and electricity management are fully centralised, with regulators controlling the supply of energy. Consumers are not allowed to participate in the electricity market and the utility has full ownership of all electricity market segments. These systems are the opposite of **market-based systems** where there is wholesale and retail competition and the utility has a more narrow role. In between these extreme market models, there are systems with intermediate characteristics. These include the single-buyer model, with IPPs generating power and selling it to a vertically integrated utility, the unbundled system, where vertically integrated utilities are split into companies operating power generation, transmission, and distribution, and the wholesale market competition system, where competition is introduced in the wholesale market.

Centralised systems can work with any market structure. The market-based approach, instead, is typical of hybrid systems: in competitive markets there is room for both new products (DG) and new market participants (consumers). All the intermediate systems may characterise hybrid systems with minimal DG.

It is worth noticing that DG is affected primarily by the structure of the retail electricity market, as prosumers are directly involved; wholesale markets, instead, do not have a strong influence on DG.

SEPARATION OF GENERATION AND DISTRIBUTION

The relationship between central utilities and DG evolves across the archetypes

- In centralised systems: central utilities own majority market share with limited DG
- In hybrid systems with minimal DG: central utilities are supplemented by DG or central utilities lose market share with increasing uptake of DG.
- In hybrid systems with significant DG: DG substantially contributes to power generation or has majority market share; central utilities supplement for reliability or are starting to develop capacity
- In decentralised systems central utilities have disappeared and power generation is completely decentralised

As power systems evolve towards decentralisation, the ownership structure of the generating assets changes: centralised utilities are either investor- owned or state owned. DG assets can be either owned by governments, investors or utilities (offering services to customers for a fee) or they can be owned by consumers or communities (acquiring them through a lease).

RELATIONSHIP BETWEEN MARKET PLAYERS

The presence of vertically integrated utilities is usually not favourable to DG: **if generation and distribution are not independent then utilities may have incentives to exclude prosumers from retail markets.**

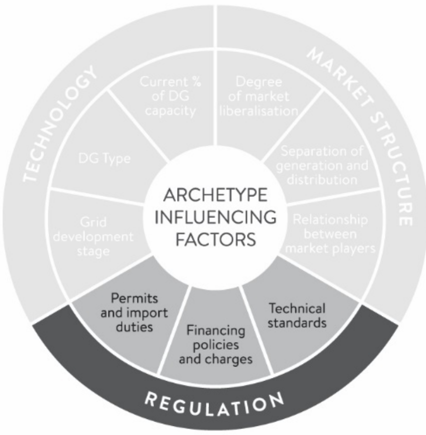
While vertically integrated utilities may be present in centralised systems or in hybrid systems with minimal DG, hybrid systems with significant DG and decentralised systems are characterised by independence between generation and distribution.

Policy and regulatory framework

The policy and regulatory framework is an important factor affecting power system archetype and the pace of evolution between different archetypes.

There are three main types of policies affecting distributed generation; these policies have to be carefully planned as their design can either support or deter a shift to distributed generation:

A1c: Emerging energy system archetypes – Regulation



TECHNICAL STANDARDS

Regulation setting specific technical requirements for the connection of DG to the grid is a sign that the amount of DG installed in the country is significant.

The introduction of technical standards eases the interconnection process and lowers connection costs, encouraging DG uptake.

Technical standards are typical of hybrid or decentralised systems.

FINANCING POLICIES AND CHARGES

Key financing policies include: **subsidies, feed-in tariffs, and net metering**. All of these measures **promote DG adoption**, either by offering a reward for the electricity prosumers add to the grid (feed-in tariffs and net-metering) or offering funds for installing DG technologies (subsidies). However, complex subsidy structures discourage DG adoption.

Rules on **interconnection charges** have to be carefully designed because they **may deter investments in DG**. As an example, prosumers required to pay deep connection charges, i.e. charges including both cost of connection to the grid and upstream network reinforcements, may be discouraged from installing DG due to the expensive connection costs. Shallow connection charges, which include only connection costs, could be a less impactful alternative. **Connection costs can also be socialised to incentivise DG**.

Finally, **use-of-system charges could prevent the uptake of DG**: even if prosumers are not currently required to pay these charges, they are likely to be introduced as DG capacity increases in the system.

PERMITS AND IMPORT DUTIES

Installing DG technologies is usually subject to permit approvals (site permits, land-use approvals, building permits, air permits, etc.). **The permit approval process can be complex and costly and may hinder DG**.

Import related taxes on distributed generation equipment, in particular in developing countries, **can significantly impact energy price and inhibit DG expansion**.

A.2 FOUR ARCHETYPES

The resulting four archetypes have the following characteristics:

CENTRALISED SYSTEMS

Centralised system

		SYSTEM WITH VERY LIMITED DG	SYSTEM WITH A CENTRALISED MARKET STRUCTURE
TECHNOLOGY	Current DG share	Below 5%	Any DG share
	DG type	Single DG solutions connected or off-grid	Any DG type
	Grid development stage	Traditional grid or early-stage grid	Any grid development stage
MARKET STRUCTURE	Degree of market liberalisation	Any market structure	Centralised market
	Separation between generation and distribution	Vertical integration or separation	Vertically integrated utilities
	Relationship between market players	Central utilities own majority market share with limited DG	Central utilities own majority market share with limited DG
REGULATION	Technical standards	Not present	Present in case DG share is significant
	Financing policies and charges	Not present (financing policies could be present in systems willing to transition to hybrid systems)	Not present
	Permits	Not present	Not present

Two main system types can be identified under the centralised archetypes:

Systems with very limited distributed generation

- The key determinant of centralised systems with very limited distributed generation is the absence, or the very limited presence, of distributed generation (share of distributed generation capacity below 5%).
- Distributed generation is present with single generators either grid connected or off-grid, with the purpose of emergency power generation.
- Central utilities generate the bulk of the electricity and are supported by traditional grids or early stage grids accommodating a one-way power flow from large power plants to consumers.
- The market structure, which is a less relevant determinant compared to technology, can vary from central planning to a competitive market approach.
- Due to the absence of distributed generation, regulation is not needed; financing policies, however, might be in place to stimulate distributed generation adoption and may indicate a system transitioning towards a hybrid system.

System with a centralised market structure

- The prevailing characteristic of this system is the centralised decision making process and electricity management: these features do not allow the system to be decentralised, as they limit consumers' participation to the electricity market.
- Technological aspects do not have a crucial role in determining the characteristics of this system: distributed generation capacity can range from limited to significant levels and the grid can take any possible shape.

Hybrid system with minimal DG

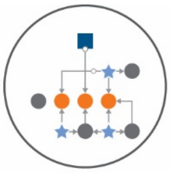
Hybrid systems with minimal DG

TECHNOLOGY	Current DG share	Between 5% and 30%
	DG type	Single DG solutions connected to the centralised grid *or* Micro/mini grids semi-independent and connected to centralised grid *or* Micro/mini grids fully independent and off-grid *or* Single DG solutions off-grid
	Grid development stage	Traditional grid transitioning towards a smart grid and accommodating DG solutions connected to the grid *or* Early-stage grid supplemented by off-grid DG
MARKET STRUCTURE	Degree of market liberalisation	Mixed economy where market government still plays an important role *or* Market-based approach with competitive retail electricity markets
	Separation between generation and distribution	Utilities may be vertically integrated *or* Independence between electricity generation and distribution
	Relationship between market players	Central utilities own majority market share supplemented by DG *or* Central utility to lose market share with increasing uptake of DG
REGULATION	Technical standards	
	Financing policies and charges	Either regulation has already been enacted *or* Regulation is in the process of being approved
	Permits	

The hybrid system with minimal DG is a centralised system starting to develop characteristics of a decentralised system.

- Distributed generation supplements central utilities, with a penetration rate going from 5% to 30%.
- Distributed generation types differ according to the development stage of the grid: in countries where the grid is at the early-stage of development, off-grid systems are a valuable option to increase electricity access.
- In developed countries, with a traditional grid transitioning towards a smart grid, distributed generation is more likely to be connected to the grid.
  The market is either liberalized or presents mixed features of liberalisation and government intervention.
- Financing policies and technical standards either have already been enacted or are in the process of being approved, with subsidies present to encourage adoption of distributed generation.

Hybrid system with significant DG

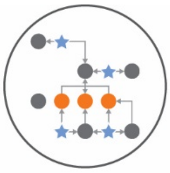


Hybrid systems with significant DG

TECHNOLOGY	Current DG share	Above 30%
	DG type	Single DG solutions connected to the centralised grid *or* Micro/mini grids semi-independent and connected to centralised grid *or* Micro/mini grids fully independent and off-grid *or* Single DG solutions off-grid
	Grid development stage	Smart grid with distributed generation connected to the grid *or* Early-stage grid supplemented by off-grid DG
MARKET STRUCTURE	Degree of market liberalisation	Market-based approach with competitive retail electricity markets
	Separation between generation and distribution	Independence between electricity generation and distribution
	Relationship between market players	DG substantially contributes to power generation supplemented by central utilities for reliability *or* DG has majority market share and central utilities are starting to develop capacity
REGULATION	Technical standards	Technical standards are well established and present for many years
	Financing policies and charges	Feed-in tariffs well established and present for many years Connection charges do not deter DG uptake Use-of-system charges may have been introduced for distributed generators
	Permits	Permits do not deter DG uptake

- This archetype is characterized by a significant penetration of distributed generation (more than 30% of installed capacity).
- In developed countries the grid infrastructure takes the shape of a smart grid, as a response to managing the considerable amount of distributed generation present in the system.
- In developing countries the significant amount of off-grid distributed generation compensates a less developed grid at the early stage.
- Consumers are allowed to participate in the retail electricity market, which is completely liberalized, and utilities managing electricity distribution are not responsible for power generation. Distributed generation substantially contributes to power generation and central utilities supplement or start to develop capacity. Regulation on distributed generation is well established and it has been present in the system for many years. Use-of-system charges for distributed generators may have been introduced.

Decentralised system



Decentralised system

TECHNOLOGY	Current DG share	100%
	DG type	Single DG solutions connected to the centralised grid *or* Micro/mini grids semi-independent and connected to centralised grid *or* Micro/mini grids fully independent and off-grid *or* Single DG solutions off-grid
	Grid development stage	Smart grid
MARKET STRUCTURE	Degree of market liberalisation	Market-based approach with competitive electricity markets
	Separation between generation and distribution	Independence between electricity generation and distribution
	Relationship between market players	DG has majority market share and central utilities have disappeared
REGULATION	Technical standards	Technical standards are well established and have been present for many years
	Financing policies and charges	Feed-in tariffs/net metering are well established and have been present for many years Connection charges do not deter DG uptake Use-of-system charges have been introduced for distributed generators
	Permits	

- In decentralised systems power is generated by a mixture of mid and small scale generation assets located close to consumer site with no central generation.
- The multitude of generating assets is either off-grid or connected through a sophisticated and highly technological smart grid.
- Completely liberalised markets are peer-to-peer markets where utilities, companies, communities and households are all market participants buying electricity from, and selling electricity to any

other market participant. This is a key difference compared to hybrid systems, where prosumers have signed a bilateral agreement to sell the excess electricity they produce to utilities at a fixed price (feed-in tariffs) or at a predetermined rate (i.e. the rate at which they buy electricity through net-metering). Generation and distribution are unbundled.

- Both financing policies and technical standards have been in force for many years; use-of-system charges for distributed generators have been introduced to maintain and finance a well-functioning smart grid.

APPENDIX B – EXPERT INTERVIEWS

The World Energy Council and Oliver Wyman, a subsidiary of Marsh & McLennan Companies, would like to thank the following global energy leaders and their teams for taking the time to talk to us during the preparation of this report and for taking an active role in driving forward this critically important dialogue regarding our global energy future. Your perspectives and insights have been very helpful and enriched the process greatly.
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- Marty Sedler, Director, Global Utilities and Infrastructure, Intel Corporation, United States
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