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RETHINKING THE FUTURE OF ENERGY

SCENARIOS FOR 2050

Discussion paper

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This paper combines experts' perspectives and opinions on the vision of possible energy futures to 2050 obtained from a series of interviews and brainstorming sessions conducted during summer 2017. The coverage and scope of this paper is focused to a brief analysis of the main trends and uncertainties as well as the industry reflections on possible scenarios, with the aim of starting and enriching expert discussion.

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Content

Dear Friends,

The future is hard to predict but it can be shaped. Building scenarios of how it might look, and identifying which driving forces might transform the markets in the coming decades, is the first step towards getting the future under control. Will you be able to hear the weak signals of change and adapt your business model? Will you be driving change yourself? Or will you only face it when it is too late? Your call.

Moscow School of Management SKOLKOVO is a reliable partner of the visionary companies and individuals who are today crafting their future success. We help to build dreams and make them come true. Our professors and consultants guide our clients through transformative experiences, from generating ideas and defining strategies to developing plans, building networks and acquiring resources.

We work with leading international and Russian companies that have real power to shape the future. It is not always about the financial power of the company, but it is always about the power of a dream. That is why we work with companies of any size at every stage, from start-ups to the global corporations, as long as they dare to dream.

This discussion paper presents the analysis of key findings from a series of interviews and brainstorming sessions with energy professionals, and is aimed at facilitating discussion of the future of energy among the cross-disciplinary audience – energy experts, representatives of financial institutions, educators, policy makers and NGOs seeking better alignment of ideas and action towards a better future for everyone.

EY is our longstanding strategic partner who has been supporting Moscow School of Management SKOLKOVO for many years. We appreciate the practical insights from clients and the global industrial vision that EY professionals contributed to this work.

Andrei SHARONOV,

President, Moscow School of Management SKOLKOVO

Dear Friends,

We are happy to present you this discussion paper Rethinking the Future of Energy prepared by the Moscow School of Management SKOLKOVO in cooperation with EY Russia, Energy&Utilities.

The importance of energy for the future of the global economy cannot be overestimated. Growing population, industrialization, urbanization and improving living standards on one hand demand more energy every day, on the other – the climate change and growing concerns over energy security limit the opportunities. All over the world technological developments, policies and business models are being tested for an ability to provide affordable, accessible and acceptable energy solutions. We observe an unprecedented transformation of the global landscape, an energy transition.

As one of the largest supplier of oil and gas, as well as nuclear plants and fuels, Russia has always been a major global energy player. Will Russia be able to keep its global positions in the changing context of the energy transition? Breakthrough in shale oil and gas, accelerating developments in LNG, growing use of renewables, new policies, technological development, including digitalization pose a challenge to the existing position of Russian energy in the world. Russia's own energy landscape has been significantly changing with more inclination towards renewables, distributed power, better energy efficiency and grid improvements.

Scenario approach is one of the most powerful tools when it gets to strategizing in the VUCA (volatile, uncertain, complex and ambiguous) context. Scenarios are not meant to provide answers – they help to ask better questions. The scenarios discussed in this report consider possible energy futures globally and provide an insightful food for thought for energy executives and policy makers as they can shape the further thinking in search for the most specific and unique strategies.

At EY we help our clients all over the world in rethinking the future and in finding the better working strategies for success. We help our clients in Russia with developing scenarios that are mostly relevant for their specific contexts and draw implications that could help them to develop a strategic response – adapt to the changing context, prepare for tapping an opening market opportunity or avoiding the threat to the existing business model.

EY has been a longstanding partner of the Moscow School of Management SKOLKOVO, which provides world-class business education opportunities in Russia for businesses and individual executives as well as an outstanding learning environment, which is a critical enabler for the insightful scenario exercise.

Alexander IVLEV

Country Managing Partner, EY Russia

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Executive Summary

The global energy market is going through unprecedented change. The ability to identify what driving forces will be transforming the markets in coming decades, and be shaping the future for energy, is a key for policy makers and industry in building more efficient responses and capitalizing on emerging opportunities. The volatile context, complexity, and the interdependence of the driving forces, make the future energy landscape so uncertain and ambiguous that forecasts and predictions are not reliable. The scenario approach provides the viable alternative to predictions because it not only helps map possible futures but also reflects effective as well as ineffective courses of action.

The energy sector is well-known for its enormous innovation and modernization cycles. In many cases, it takes decades for a new technology to achieve industrial scale and become visible in the energy mix. This is why if we take too short a horizon it will not let us see the difference; however, if we take one that is too long we will not be able to link the future to the starting point of the journey. 2050 is a time horizon where old inherited energy structures and completely new energy systems will be mixed up all together within the same ecosystem. The possible ways in which the future might unfold by 2050, and how old and new systems might co-exist, will be shaped by a combination of certain obvious driving forces, such as overall macro trends, as well as by a number of far less obvious and quite uncertain developments within the energy sector.

Economic growth and an increasing global population are the most fundamental factors for energy consumption. The rise of the middle class is shifting consumer behaviour and changing the structure of demand. Further ahead, massive digitalization and Industry 4.0 will transform consumption patterns both in the industry and in households. On top of this, the adoption of the UN Sustainable Development Goals actualizes the role of the energy sector as a progressive factor in achieving almost all the defined goals.

There is also a variety of critical uncertainties which may have unpredictable influences on the market. The extent of this varies significantly, which creates numerous possible futures for the energy market by 2050. The most critical one is the increasing power of the consumer. More educated, self-aware and pro-active consumers are gaining influence and causing remarkable changes in markets. The pace of innovation and technology development and implementation will determine what real choices consumers have, and what impact they will make on the energy system. The consistency of climate policies and the maturity of financial institutions will signify how effective the incentives will be for industry and consumers to opt for greener technologies. Three tipping points: the grid cost parity, the electricity and mobility industry convergence and the demise of the central operating system will make a profound impact on the energy sector along the way to 2050.

All these predictable forces and critical uncertainties map the landscape of constraints, opportunities and choices that government, business, and society will face in the energy market by 2050. Among the variety of possible futures, we define four scenarios illustrating specific ways in which these factors could play out.

- **The Day After Tomorrow**
  Lack of efficient and globally coordinated environmental policies, low pace of innovations and poor proliferation of new technologies keeps the status quo for the industry. It is dominated by large players, often centre led national champions, whose scale is a profound foundation of dominance, leaving little space for new industry entrants and consumers' influence. Energy remains largely fossil fuel driven and scarce due to geopolitical divide, limiting economic growth and provoking social or military conflict, while climate change consequences are only worsening.

- **Blade Runner**
  The power of consumers is rapidly increasing supported by availability of diverse innovative technological solutions. Rapid innovation, technologies convergence and digitalization ultimately lead to the commoditization of energy as such and open up opportunities for the new entrants who undermine well-established business models and unbalance the whole energy ecosystem. At the same time the lack of coordinated government policy around the climate change topic fails to address more fundamental shifts in the generation mix and support widespread development of carbon free sources. As a result we live in a highly innovative world with a bad climate.

- **Star Wars**
  While richer nations are progressing in addressing climate change, less developed and emerging nations are faced a hard choice between keeping their global commitments and ensuring local economic growth. Low proliferation of innovation results in the insufficient affordability of low-carbon technologies and advanced financial institutions to invest in scaling them up, more emerging countries depart the climate agreements. The world is divided: wealthy nations live in renewable driven decentralized energy landscape while developing states employ fossil fuel generation mix and nuclear.

- **Interstellar**
  The pace of innovation is kept up to the growing ability of nations to invest into real projects incentivized by the clear climate policy and enabled by the developed financing institutions providing transparent and strong governance. Alignment of innovations and policies ultimately shift the global energy ecosystem to the new level of efficiency and sustainability. Decentral market driven landscape takes place in most parts of the world – renewable energy gains an extraordinary momentum and its pitfalls (e.g. non-affordable energy storage) are long solved.

These possible futures help us make the simple observation that innovation can disrupt markets and climate policies can exclude nations unless multi-stakeholder dialogue involving policy makers, industry, financial institutions, academia and NGOs is ensured. This discussion paper resulted from a series of interviews and brainstorming sessions with industry experts. We hope it will enrich further cross-disciplinary, multi-stakeholder discussions leading to collective action towards a brighter future for energy for everyone.

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Introduction

NARRATIVE BETWEEN NOW AND THEN

Thinking of a scenario as a certain development narrative between two conditions of a system, 2050 is probably the most difficult time horizon for building energy sector scenarios. It lies exactly half-way between 'now' and 'then'. Indeed, shorter-term scenarios, like by 2025 or even 2035, can be built based mainly on what is available today in terms of technologies, policies and practices. A combination of long innovation and modernization cycles defines the general institutional inertia of the energy system which protects it from short-term disruptions of the sort we observe in other industries, like ICT for example. Given that the average lifespan of the conventional power plant is between 30 and 50 years, and renewable is between 20 and 30 years, most of today's power generation assets will remain operational for the next 20-30 years and will, therefore, significantly determine the power generation structure in that period. On contrary, constructing extremely long-term scenarios, to 2075-2100, are closer to futuristic exercises. Given the accelerating speed of innovation and the depreciation rate of the existing energy assets, there will inevitably be a completely different energy system in 2075+ from the one we have now. In other words, while scenarios to 2025 could be considered continuations of the present, those extending to 2075 and beyond are better thought of in reverse, as projecting from the future back to the present.

This is the major difficulty with 2050 scenarios. At that point, the energy system will be half-way through a transition from today's energy structures to something completely different. It will therefore most likely contain both at once, the old and the new together. However, that is what makes this exercise so compelling and creative.

In this paper we aim to combine experts' views and opinions obtained from interviews and brainstorming sessions that reflect their vision of the changing landscape of possible energy futures to 2050. The exercise was designed and conducted in an accessible and general manner with the idea of using it as a baseline to facilitate and enrich further industry-expert discussions.

LIMITATIONS

In this exercise, we describe a vision of the main driving forces of the changing landscape of energy market development to 2050, as well as provide short narratives to different scenarios for the future of energy within this time horizon. We understand that local conditions in different parts of the world vary so dramatically that building global scenarios is not practical. Since at this stage we want to keep the exercise reasonably general, we have considered only the major archetypical energy systems like US, Europe and China. We are leaving more detailed projections on specific regional perspectives for a later stage.

In order to keep this exercise accessible, we are not including any modelling, except some indicative numbers for scenarios' energy mixes that were derived from Energy mix forecasts spectrum, presented by EY at one of the recent works[1]. All other projections are based on historical trends and our estimates of how it might develop under various scenarios. Finally, we present the possible futures neutrally, in other words without stating which are desirable or preferable. They are based on predictions of the likely evolutionary development of the energy system and do not give ideas for achieving objectives of any kind.

1 EY, Energy Reimagined: what's the next?

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The World in 2050

In every scenario it is important to distinguish between what we know is going to happen and what we do not know but what would impact the global energy market if it were to happen, although in this VUCA (volatile, uncertain, complex and ambiguous) world this may sound ambitious. First, we will go through the certainties in the market: the main challenges, trends and forces that are likely to shape the global energy landscape over the next few decades. These are derived from studying historical drivers, and they will become stronger by 2050 regardless of any scenarios of energy market development. Next, we will explore the most critical uncertainties disrupting the energy market and assess their likely impact on the basis of their magnitude and the implications for market structure and business models. Both groups of factors, certain and uncertain, help define the changing landscape for energy market development and map the space for scenarios on future of energy to 2050.

CHALLENGE FOR THE ENERGY SECTOR OR WHAT WE KNOW

One of the most significant drivers for the energy market is demographic and socio-economic development. In general terms, population growth drives energy consumption. We need more energy to keep the lights and heating on in people's homes and we need more energy to fuel an economy that will absorb population surpluses and satisfy their growing material demands. By 2050, **global population** is likely to be close to 10 billion[2], adding nearly 40% to the current total. Most of the growth will come from the developing world: South and South East Asia and Africa, and this will increase demand for energy. Africa will account for almost half of the growth in the world's population. But it is not only about increasing volumes, it is also about shifting the structure of consumption. Almost 3 billion people will join the **middle class** by 2050 with most of the entrants coming from today's emerging markets, China and India in particular[4]. Rapid **urbanisation** reflects and supports this growing and changing demand: by 2050 more than 66% of the world's population will reside in cities with an almost 90% increase in Asia and Africa[5]. We are entering the age of gigapolises with infrastructure and consumption patterns increasing **electricity** demand. It is expected that in the next few decades electricity will be the preferred energy carrier. Electricity capacity per capita will sharply increase, especially in China, reaching ~8MWh by 2035[6].

Population growth numbers are enormous, but expected economic growth is even more impressive: **global GDP** will more than double by 2037 and more than triple by 2050. However as emerging markets mature and the working age population growth in developed markets declines, some slowdown in global growth is expected before 2050. Global power is continuing to shift away from advanced economies to emerging markets. China has already become the world's largest economy on Purchasing Power Parity (PPP) and is expected to surpass other economies by other measures too. Some new emerging economies, like Mexico and Indonesia, are forecast to be larger than some major European countries by 2020. Among the fastest growing large economies over the period to 2050 could be Nigeria and Vietnam[7].

Massive **digitalization**, and the transition to **Industry 4.0**, is also having a tremendous impact on many industries, including energy. Digital is transforming consumption patterns both in industry and in households,

2 World Bank, Population Estimates and projections (2017)
3 BP Energy Outlook 2017
4 HSBC Global Research, Consumer in 2050 (2012)
5 UN, World Urbanization Prospects (2014)
6 BP Energy Outlook 2017
7 PWC, The world in 2050: Will the shift in global economic power continue? (2015)

affecting cross-industry partnerships, and optimizing assets use[8]. Traditional manufacturing is likely to become less energy intensive due to innovations in production processes such as additive technologies, automation and robotization. This will lead to a shift in energy consumption. Companies which are not traditional for the industry will start playing a more critical role. Google is an illustrative example of such a trend, with its power-sucking data centres it became one of the world's largest energy consumers[9].

Geopolitical dynamics will have a considerable impact on energy market development. Tensions and conflicts increase countries' isolation and thus create serious difficulties for economic, and therefore energy market growth. They also increase market volatility and result in oil price fluctuations. On the other hand, stable geopolitical conditions drive energy market growth through technology and innovation transfer, global cooperation, etc. Today's dynamic of geopolitical changes already looks unpromising: conflicts in the Middle East, tensions in Europe, sanctions against Russia, Brexit, etc. Alongside some experts' estimates on the spectrum from total peace to total war, we have taken a middle path. This reflects more or less what is happening these days. Some local tensions will emerge here and there, although they will not escalate into serious global conflicts. This will permit at least a minimal level of cooperation across regions, mostly focused on resolving global issues, like environmental concerns[10].

The sustainability agenda is another strong driver in the market. The adoption of **Sustainable Development Goals** (SDGs) in 2015, formulating global development parameters till 2030, drives sustainability concerns at a global level. Today it serves as a universal call to joint efforts to end poverty, protect the planet and ensure that all people enjoy peace and prosperity. 17 specific Goals are built on the successes of the Millennium Development Goals, and include areas such as economic inequality, innovation, sustainable consumption, peace and justice. Energy is crucial for achieving more than half of the SDGs. Beyond the direct impact of providing affordable and clean energy, its role extends from combating climate change to eradicating poverty through advances in health, education, water supply and industrialization, to contributing to a decent working environment and economic growth, and to ensuring responsible consumption and production patterns[12]. Implementation of the SDG agenda calls for a global transformation beyond the energy sector that includes advanced technology solutions, innovation, entrepreneurship, legislation support, new financing instruments and partnerships.

What we see from current forces is that the world is changing dramatically, bringing new challenges and opportunities to the energy market. In a changing landscape, all energy sources and technologies will be required to address the main triple issues: ensure energy security, support affordable energy access and reach environmentally sustainable energy supply. Energy supply should be expanded to meet the growing demand coming mostly from South East Asia and Africa. At the same time, addressing sustainability issues, and keeping up with the transformation of consumption structures require a reconsideration of energy mixes and approaches to making it possible to generate not just more energy but more cost-effective energy with fewer resources. What are the critical factors that will determine how the energy sector responds to this challenge?

8 World Economic Forum, How will the digital revolution transform energy sector (2016)
9 Utility Drive, Is Google becoming an energy company? (2014)
10 The Energy Research Institute of the Russian Academy of Science, Global and Russia Energy Outlook 2016
11 UNDP, UNDP Support to the Implementation of the 2030 Agenda for Sustainable Development (2016)

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IN SEARCH OF A SOLUTION, OR WHAT WE DO NOT KNOW

The energy sector is seeking a response to the greatest-ever challenge of how to ensure energy security, support affordable energy access and reach environmental sustainability in the energy supply. In our view, there are four major factors that will shape the energy eco-system's transformation by 2050: changes in consumption patterns, climate change policies, the pace of innovations and technology development, and the enabling environment. Each of these four factors has its own variations that are keys to scenario building and which create an almost infinite number of futures for the energy industry. We will explore these uncertainties and some outcomes that will underpin possible scenarios for the energy market.

CONSUMPTION PATTERNS

Energy consumption patterns are the most important starting point because they help us understand demand and the way different consumers will collectively shape the energy eco-system in 2050. The transformation of the energy landscape is driven not only by an increase in consumption per capita linked to growing wealth, but also by changes in consumers' behaviour. Consumers are becoming more educated, self-aware and pro-active, they are getting used to a wide variety of options that are available due to digitalization and technological advances. Modern consumers are also becoming more responsible, and they tend to make their purchasing choices based not only on the final characteristics of a product or service but also on whether it is produced or delivered in an environmentally friendly and socially sound way.

Such changes in consumption patterns are transforming many industries and even creating the base for the development of new niche markets. Examples are the emergence of crowd-funding and P2P financial platforms as an alternative to traditional funding; abandoning traditional commuting and moving to a car-sharing model; or using Airbnb instead of hotels. All such cases illustrate how changes in consumer behaviour disrupt existing models and shape the way markets operate.

One of the most prominent tendencies reflecting changes in consumption patterns and causing a remarkable change in markets is a move **from centralized to decentralized** model. For example, in airlines, the choice between traveling long distance with no connection, or through hubs, determines innovation in aircraft design and network infrastructure which lead to two different models: hub-and-spoke and point-to-point. In retail, some people tend to buy things once a week in malls on the outskirts of cities while others go every day to nearby corner shops.

In the energy industry, this trend of moving from centralized to decentralized systems is reflected in more empowered consumers deciding for themselves how they power their homes and fuel their vehicles. Individual consumption patterns show that households in the US and Europe tend to build distributed power generation and, more than that, responsible and educated consumption using digital tools and smart metering can reduce individual consumption dramatically, especially when consumers become electricity suppliers and sell energy from their own solar panels, for example. The emergence of this new type of consumer, called "prosumers", brings new forms of interaction, from one-way to more active two-way communication supported by distributed control and monitoring systems. This trend creates challenges but at the same time opens vast opportunities for utilities, distributed energy companies, battery storage providers, and other innovators to capitalize on emerging business models.

Decentralized energy is not only gaining momentum in advanced economies, but is also playing a crucial role in less developed countries. For example in Africa, where about 1.2 billion people live without access to

an electric grid[12], distributed energy generation is becoming a key source of electricity and thus a contributor to economic growth. According to experts, estimates of the compound annual growth rate (CARG) from 2016 to 2020 for the global distributed energy generation market is expected to reach 11.4%[13]. Such intensive development of distributed systems leads to changes in the power supply system itself and increases the need to create a new type of energy supply infrastructure which would help to meet the changing demand for the emerging active consumers who becomes the main participants in the market.

Increasing decentralization as a result of the rise of distributed energy systems and greater customer control over electricity usage is driving the evolution of a new type of system – energy cloud and the Internet of Energy (IoE)[14]. This combines the advantages of centralized and distributed systems and features two-ways energy flows, shared infrastructure with many users connected to multiple many-to-many networks, and blended centralized and decentralized control and management. The share of prosumers is increasing significantly, they are actively engaged in energy transactions.

As the shift to a decentralized system takes hold, it is more likely that companies that manage consumer interactions will become the energy companies of the future. Google is an example. It has invested over USD 1 billion in renewable power plants[15] in recent years, and appears poised to become a major player in the energy sector by empowering consumers through giving them control of their energy use. Likewise, Amazon's popular Echo voice-activated speaker can run with a growing number of apps or so-called "skills" related to energy usage. The "My Utility" function allows consumers to monitor and control their energy use.

A separate but possibly influential tendency is overall instability due to wars and climate change-related disasters that require not only distributed but also mobile power generation solutions. It is well known that a surge in distributed power in the US happened right after the 9/11 attack, as people lost trust in centralized infrastructures.

Centralized systems, on the contrary, are important when governments and producers are having more power and shaping industry structures. Large utilities traditionally play an essential role in developing centralized power generation, both conventional and renewable. China continues to build tens of gigawatts of large coal-fired power plant every year, and they will definitely survive to 2050. In a country-to-country perspective, an illustrative example is the European electricity grid initiative that aims to create a pan-EU super grid linking renewable energy projects across North Africa, the Middle East and Europe to secure energy supplies.

Transportation is another domain relevant for the empowered consumer. Citizens are eliminating or reducing automobile ownership and are turning to on-demand solutions, while the sharing economy is developing as well. Infrastructure development and changing consumer preferences increase the availability of alternative vehicles and light fuels. By contrast, in centralized energy systems, government spends public funds to build infrastructure and implement policies that incentivise people to use public transport rather than their own cars. Such centralization could be a government response to climate change issues and an effort to improve the quality of life.

Remarkably, all these examples and differences are reflected in the market structure. The shift from centralized models to decentralized ones means customers gain more

12 OPIC, Off the grid in Africa: Why distributed power in becoming a key source of electricity (2016)
13 Global Opportunity Explorer (2016)
14 Navigant, Energy Cloud White Paper: Emerging opportunities of the Decentralized Grid (2015)
15 The Guardian, Google – leading the way on renewable energy (2013)

power, and forces companies to change with them. For example, in the US, which has more decentralized energy systems and so-called independent power producers (IPP), having large utilities in the background increases fragmentation and creates more competition in the market. The centralized systems in the EU are mostly managed by large players in the market; this keeps control over supply and the value chain up and downstream. At the same time new players have been constantly increasing the competitive pressure and force incumbents to reconsider their strategies.

The increasing role of consumers and changes in consumption patterns is already determining the landscape and altering existing business models in many industries, including energy where they shape the way electricity is generated and distributed, and the way the transportation system is organized. In this exercise, in some scenarios of the energy market in 2050 more importance and power will be given to consumers rather than to utilities or other market actors, while in others their impact will be limited.

CLIMATE CHANGE POLICIES

Environmental issues, and climate change, are the one of the very few areas of global consensus. There is a changing perception of climate change due to such events as the US withdrawal from the Paris Agreement. It is getting clearer that in general climate change is becoming a bottom-line guiding principle for national energy policies. The choices about how to deal with climate change issues, and address a wider sustainability agenda at the international and national levels, will determine the future of the energy sector.

On the international level, the first steps towards organizing a system of **global climate management** were made in 1992, when UN Framework Convention on Climate Change was signed, with the later adoption of a number of documents on global climate management. The landmark event happened in 2015 when the Paris Agreement was ratified by 146 countries. This aims to limit the increase in the global average temperature to well below 2°C, and to try to limit it to 1.5°C. It also aims to decrease **GreenHouses Gas (GHG) emissions**, increase **renewable energy** use and promote **carbon capture**. With the energy sector accounting for about two-thirds of global GHG emissions, transformations in the market would make a tremendous impact on achieving climate change commitments. Some national governments choose to align their climate action agenda through Nationally Determined Contributions (NDCs) and set targets for emissions reductions by 2030. At the same time there is certain deterrence to the coordinated climate action with the President Trump's administration decision to quit Paris Agreement.

How the international framework will be improved and whether it will be possible to co-ordinate further commitments and approaches to address global issues, is an open question which could "play" differently in each of scenarios. Differences in countries' starting positions, such as levels of industrial development and access to technologies and funds, lead to difficulties in formulating one-size-fits-all approach to reducing GHG emissions and addressing climate change. As a result, while some countries could progress in energy security and sustainability, others could still struggle to adequately address climate change issues and meet commitments of the 2015 United Nations Climate Change Conference (COP21).

National policy development will be influenced by the trade-off between rapid economic growth and "green" economic development. While many developed economies already take steps to accelerate their transition to a low-carbon, resource-efficient and socially inclusive green future, this is a challenging question in most emerging markets, which are going through a rapid industrialization stage requiring substantial energy supply. The great dilemma for the less developed countries is whether to preserve the quality of the environment at the expense of economic growth and development, or to pursue

economic growth and development, through industrialization, at the expense of environmental quality.

There is a strong trend of GDP-GHG decoupling across the world. Recent developments demonstrate that GHG emissions stayed flat in 2014 and 2015 while GDP continued to grow. The UK is an illustrative case, demonstrating an increasing divergence between economic growth and CO2 emissions. The country achieved six years of absolute decoupling where real GDP grew at the same time as GHG emissions declined[16].

Once the choice to integrate climate change commitments to national agendas is made, the strong enabling mechanisms, including diversification of financial instruments, raising awareness and building human capacity, should be developed and implemented. As for possible responses to climate change, countries can make a choice and implement policies towards either **mitigation and/or an adaptation strategy**. Mitigation is a more proactive strategy focused on reducing and stabilizing levels of GHG in the atmosphere to slow down climate change. It involves improving supply and distribution efficiency; spreading market mechanisms for decarbonization across countries when the power sector is switching from coal to gas and to low carbon power sources such as nuclear and renewables. This is supported by the adoption of lower-carbon technologies and energy-efficiency solutions. More fossil fuel power plants are equipped with Carbon Capture and Storage (CCS). Development of carbon sinks like forests and algae fields could be also a part of climate change mitigation.

On the other hand, an adaptation strategy is aimed at enhancing resilience and reducing the vulnerability of the whole energy system to actual and expected climate change effects, like extreme weather events, water availability, and unusual seasonal temperatures. Some adaptive practices include the introduction of improved technologies that enhance the energy and water-use efficiency of energy processes (e.g. off-shore and flood-plain infrastructure against flooding and sea level rises), cooling systems in thermal power plants, microgrids and distributed generation, etc.

The future of energy will depend on the further development of international frameworks, the choices countries make about responses to climate change, and the efficiency of environmental policies that will enable nations to move to clean energy and a more sustainable future. In each of scenarios these factors will mix in a different way to create a specific landscape for market development.

INNOVATIONS AND TECHNOLOGIES ADVANCEMENT

One of domains for disruption is the advance in **energy technologies** that shape the way energy is produced, distributed and consumed. Given the long innovation and modernization cycles in energy, we take it that only existing technologies can reach an industrial scale by 2050. Cost efficiency could accelerate the advancement and deployment of a wide range of low-carbon energy technologies in the next few decades, which would have a considerable impact on energy systems. The most important tendency here is the learning curve driving down the LCOE (Levelized Cost of Energy) for renewable energy and electricity storage technologies. Falling equipment costs and growing efficiency increase the deployment of new technologies and drive its scale and competitiveness in markets. At the same time, the emergence of new manufacturers adopting new technologies intensifies market competition, which drives down technology costs even further. Such a combination is leading to a decline in the cost of energy from renewables, making them competitive against conventional technologies.

16 World Resource Institute, The Roads to Decoupling: 21 Countries Are Reducing Carbon Emissions While Growing GDP (2016)
17 IRENA, The Power to Change: Solar and Wind cost reduction potential to 2025 (2016)

To date, this transformation is most visible in the power generation sector, where dramatic cost reductions for **solar** photovoltaic (PV) and, to a lesser extent, for **wind** power, are driving high levels of investment in renewables. In the last 15 years, solar PV LCOE has fallen by 57% and has a further potential to go down by 59%. Wind power has dropped by 12-15% (on and off-shore, respectively) and the further potential is 26% and 35% by 2025. Overall, for almost all scenarios, we see a similar vector for development. Wind and solar, for both local and industrial use, will be the growing technologies by 2050, satisfying a significant part of the new demand.

Gas will stay one of the main sources of energy. Expected growth is supported by its increasing role in the world's transition to a cleaner energy future. **Shale gas** technology has proven its commercial and industrial worth and will help gas remain one of the key primary energy resources. This will mostly affect North America where shale gas is booming. Already by 2014, shale gas production together with unconventional gas reached 10% of global gas production, creating competition to natural gas markets[18].

Due to tightening emissions standards, **oil** consumption will increase moderately. Experts estimations on the peak demand of oil, such as from Royal Dutch Shell and Statoil, varies suggesting that it could come in late 2020-2030s, while International Energy Agency (IEA) forecasts that oil demand will likely to continue to grow out to 2040[19]. In any of these cases the growth will be tempered by competition from the development of alternative transport fuels, like **gas, bio-fuels**, supported by the adoption of emissions standards, transport diversification, EVs (Electric Vehicles) and the construction of proper infrastructure. **Methanol** in increasing is its role for trucks and ships, where oil-based fuels have traditionally been considered the only cost-effective option. **Hydrogen** has also started to receive increasing attention as an alternative fuel, however there is still an array of technical, social and infrastructure issues need to be resolved before it become economically competitive and viable.

The slowest progress by 2050 will probably be seen in clean coal technology. Although coal reserves are relatively large, there seems to be a public consensus that this technology is not worth further development for both environmental and economic reasons. Thus, the role of coal will decline in most regions. According to IEA coal demand has already dropped in 2015 for the first time in the century and not expected to reach 2014 level again until 2021. The global market is shifting towards less developed regions in Asia and South Africa, where it will stay is a predominant fuel in energy mix, with expected further acceleration in next decades.

As environmental concerns discourage investment in new coal projects, in many regions, existing plants are being equipped with **Carbon Capture and Storage (CCS) technologies**. As CCS provides an efficient solution for decreasing carbon dioxide emissions, some of the European countries, North America, and other are already running initiatives to support CCS projects. However, there are still some challenges such as price uncertainty and lack of transport network to move the captured dioxide. To take off to the larger scale it will require investments, infrastructure and developed regulatory mechanisms.

Although the world has a huge unused **hydropower** potential, it is unlikely that large hydropower plants will have a large share in the new-build over the next few decades. Despite low-carbon power generation, the environmental impact of large-scale hydropower plants is often considerable. Adverse impacts include flooding of agriculture land, forced relocation of people, and damage

18 World Energy Council, World Energy Resources (2016)
19 Financial Times, Big energy fears peak oil demand is looming (2017)

to wildlife. These limit the further development of this type of power generation. Besides environmental factors, large capital investment, long construction cycles and a huge dependence on seasonal factors make large hydropower schemes economically fragile. At the same time, small-scale hydro turbines prove to be a growing niche technology that has a strong potential of making considerable local impact, specifically in the emerging markets.

Nuclear remains the only carbon-free source of baseload power. Low share of fuel in the costs of electricity makes it predictable in the long term. The issues of safety, long construction cycles and large capital investment have been addressed by ongoing improvements. Major breakthrough innovations in nuclear that are expected to be commercialized in the next two decades are small modular reactors below 100MW and the next generation of reactors, capable of utilizing spent fuel accumulated from the past generation. The combination of these two promises an expansion of small scale plants producing affordable and carbon-free electricity.

Other areas of critical technology development are **energy storage** and effective **power transmission and distribution management (smart grids)** that would permit the incorporation of intermittent sources of power, like wind and solar, in the grid. Both smart and conventional grid infrastructure development is most expected in Europe, Furthermore, experts estimate that the micro grid market which also paves the path for broader use of renewables and distributed will reach 38.9 bln USD by 2022, with a CARG of 12.35% in the same period[20].

However, technology development on its own will not have the same impact on energy systems as **convergence** with other technologies. For example, digitalization enables power transmission and management solutions that have not been available before, and provides opportunities all along the power-industry value chain, from generation to customer relationship management. The use of smart meters, energy management systems, automated demand response or microgrids will shape the way market and energy system functions. The development of energy storage defines how consumers could become independent from the grid. Or the Internet of Things and smart homes might drive consumers' lifestyles and consequently define electricity demand and energy efficiency. Technology development is creating an environment for transformational changes in industries. For example, Intelligent Transportation Systems (ITS) utilize sensors and optimize routes, etc., and provide an opportunity for reduced energy consumption. As technologies continue to develop, their cost rapidly decreases, making them more affordable and widespread. For example, **electric vehicles** (EVs) are already a reality. In 2016 in total it has exceeded 2 mln vehicles[21] and is expected to grow further, which would significantly change the transport sector's energy demand.

Advanced materials are another essential that offer great potential in increasing energy efficiency. In particular using lightweight structural materials instead of heavy steel components in cars manufacturing allows to carry additional emission control, electronic and other systems – which are especially important in hybrid, electric and plug-in hybrid cars – and thus results in lowering costs and maximizing energy efficiency.

Innovations and the pace at which digital and energy technologies are developed, adopted and scaled-up influence how the global energy market will look in 2050. They also bring dramatic changes in emerging economies and accelerate their economic growth by leapfrogging the old technology and taking advantage of the latest available.

20 Global Opportunity Explorer, Discover opportunities at the edge (2017)
21 IEA, Global EV Outlook 2017: Two million and counting (2017)

KEY TIPPING POINTS

EY has recently published a research around key tipping points that will make a profound influence on the Energy sector in a not too distant future. The research compares three costs per MWh: cost of transmission and distribution, fully delivered cost of electricity and LCOE of a combined Solar PV and battery. The results make a profound impression:

- Tipping point 1 – when off-grid energy reaches cost and performance parity with grid-delivered energy – will arrive as early as 2021 in Oceania.
- Tipping point 2 – when electric vehicles (EVs) reach price and performance parity with combustion engine vehicles – will follow from 2025 across the globe
- And tipping point 3 – when the cost of transporting electricity exceeds the cost of generating and storing it locally – will hit the US Northeast region first in 2039.

This research was done for nine technologically advanced regions of the world, which are located in moderate climate conditions. Regional aspects do matter, of course, as energy transition is largely influenced by demography (population concentration in big cities requires central energy supply), climate (northern regions get little sun in the winter) and historical energy landscape. The economy focus also matters (again, industrial economy will be more prone to use large and cheap baseload energy than the service one). Finally, access to cost competitive fossil fuel sources will provide little incentive to switch to renewables. The speed of innovation proliferation is a major unknown – in some markets it can be swift and seamless, in the other markets more time and effort will be required but one thing is clear - it is not a matter of "if" anymore, more of a matter of "when" and "how".

For this exercise we take it that in some scenarios energy markets can experience a high rate of innovation, technology adoption and convergence with other solutions or they can be developed more through modernization of energy technologies and the energy system itself. The variations will depend on regulation and supporting mechanisms, as well as on customer engagement to scale up the benefits of new energy technologies and innovations. Other powerful factors that would define the rate of innovation and technologies adoption in different scenarios include relative technology / cost competitiveness of renewable energy vs. fossil fuels and nuclear, as well as availability of investments and openness of economies that would impact innovation and technologies transfer.

ENABLING ENVIRONMENT – GOVERNANCE, FINANCE, PUBLIC OPINION

Building favourable conditions to ensure energy security, affordability and sustainability is crucial for the energy market policy implementation stage.

Strong **governance** is a significant influencer that supports changes in the market. Such intergovernmental organization as World Bank, EIB, EBRD, Asian Development Bank, and others are making sizable contributions to investing in low carbon projects and leveraging private capital. They unify and coordinate national policies and support the transition to a low-carbon sustainable energy market. Meanwhile industry specific institutions such as IRENA, IAEA, WEC, IEA, usually serve as the principal platform for

international cooperation, a centre of excellence, and as a source of policy, technology, and financial knowledge on energy development. NGOs are also valuable actors that advocate increasing awareness in society and business, and bridge the interests of various stakeholders. Undoubtedly the development of such institutions creates a solid base for transforming governance in the market.

Another critical enabler is funding. Access to **affordable finance** is a pre-condition for energy market and sustainable development. It is estimated that in order to fulfil climate commitments, annual investment in clean energy should reach USD 500 bln by 2020 and up to USD 900 bln by 2030, meaning a doubling or even tripling of the current levels in the next 5-10 years[22]. Investment in achieving SDGs is even higher. More than USD 3.9 tln total annual investment is required, while the investment gap today is USD 2.5 tln[23].

To make the progress towards defined commitments the capacity of existing sources and available mechanisms will have to be enlarged significantly. The **Green Climate Fund** within the Framework Convention was specifically created to assist developing countries with adaptation and mitigation practices. Since COP21, developed countries have committed to mobilizing USD 100 bln a year by 2020 in climate financing from a wide variety of sources to help address the needs of developing countries. Initial resource mobilization has already raised more than USD 10 bln with 50% expected to go to the most vulnerable countries[24]. But whether these funds will be distributed fairly, and become efficient financial instruments, is an open question.

Other instruments are emerging as well. One is the **green bond market**, which is an essential tool in the transition to a low carbon economy. Labeled Green bonds together with unlabeled climate-aligned bonds form the so-called Climate-Aligned Bond Universe. As of 2016 it accounted for USD 964 bln (USD 118 bln and USD 576 bln respectively) and keeps growing[25]. The use of the proceeds on energy projects accounts for ~19% of the climate-aligned bonds market, and ~28% of the labeled bonds market.

One more possible source of funds is institutional investors, such as pension funds, insurance companies, sovereign funds, etc. With their USD 71 tln in assets institutional investors have an important role to play in financing clean energy projects. Private investors are another promising source of funds. The most recent development is the emergence of the so-called **Socially Responsible Impact** (SRI) type of investment strategy. SRI is an investment discipline that considers Environmental, Social and corporate Governance (ESG) criteria to generate long-term competitive financial returns and positive societal impacts. The annual total size of SRI investment is up to USD 20 tln with double-digit growth in most sub-categories. This is a very promising and potentially significant contributor to the green energy growth. Whether these financing mechanisms will be available for stakeholders will define the development of energy markets.

Public awareness is also shaping the landscape. In the US, Canada, Europe and Japan, more than 90% of the public is aware of climate change, though in many developing countries this rate is significantly lower[26]. The situation by 2050 could change in a positive way, driven by increasing literacy levels, information availability, and the efforts of business to educate consumers. Government initiatives in developing certificates of origin, promoting Minimum Energy Performance Standards (MEPS) and energy labels

22 IRENA, Unlocking Renewable Energy Investment (2016)
23 OECD, The Development Co-operation Report 2016: The Sustainable Development Goals and Business Opportunities
24 Green Climate Fund, From Signatures to Action – GCF Funding Proposals Need to Meet the Ambition of the Paris Agreement (2016)
25 Climate Bond Initiative, HSBC, Bond and Climate Change: The state of the Market in 2016
26 Yale School of Forestry & Environmental Studies, Climate Change Communication Program, Survey: Climate Change Awareness and Concerns (2015)

for electrical appliances, vehicles or buildings will force producers to replace many products by more efficient ones, and will also help persuade the population at large to adopt a more ecologically responsible way of living. One of the examples is the Guarantee of Origin (GoO), developed in Europe to label electricity from renewables. As of 2016 Germany, Switzerland, Sweden and the Netherlands were the largest markets for GoOs in Europe.

The future of energy markets will depend on how well aligned the development of all these key enablers is: governance, financial instruments and public awareness. For the sake of this exercise we are assuming that in some scenarios an enabling environment will be developed in a smooth and interrelated way, creating transparent and clear supporting mechanisms for stakeholders and leading to policy efficiency. The other end of the possible spectrum of outcomes is that the market will lack structure and interconnectedness, thereby hampering policy implementation and market development.

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Framing the Future for Energy

All the predictable forces and critical uncertainties described in a previous part are making a tremendous impact on the market and ultimately will shape the way the energy sector will look in 2050. The extent to which uncertainties develop will map the landscape for numerous variations of possible futures.

We believe that of the described enablers, the greatest impact will come from consumers and their changing expectations, not only of final products and services but also for exclusive experiences. More empowered consumers are causing remarkable changes in markets and having an impact on existing business models. However, we recognize that only those consumer choices and expectations that make a real difference are those supported by commercialized technical and innovative solutions. Thus, for this scenario we are taking the pace of innovation and technology development as well as degree of convergence with other technologies as one of the major determining factors for the energy future.

TABLE 1. OVERVIEW OF UNCERTAINTIES SHAPING THE MARKET

Uncertainty	Variations
Consumption pattern	High vs low consumer empowerment
	Centralized vs decentralized system
Innovation and technology development	Rapid vs slow pace of innovation and technology development
	High vs low degree of convergence
	Relative technology / cost competitiveness of renewable energy vs. fossil fuels and nuclear
Environmental policies	High vs low international framework efficiency
	Strong vs weak legislation
	Mitigation vs adaptation approach
Enabling environment	Strong vs weak governance
	Widespread and sufficient financial instruments vs not widespread and insufficient
	High vs low public awareness

When it comes to climate policies and an enabling environment, we assume that the extent to which policies are transparent and efficient, as well as aligned with international climate action frameworks, will create a variety of futures. Efficient and harmonized enablers supporting implementation and enhancement of these policies will make it possible to progress towards a low carbon economy and a sustainable future. Combining these factors, the matrix below reveals central ideas for four scenarios named after famous sci-fi movies and illustrating possible energy futures in a time horizon to 2050.

TABLE 2. SCENARIOS MATRIX

Innovations & tech development: high pace	**Blade Runner** The power of consumers is rapidly increasing supported by availability of diverse innovative technological solutions. Rapid innovation, technologies convergence and digitalization ultimately lead to the commoditization of energy as such and open up opportunities for the new entrants who undermine well-established business models and unbalance the whole energy ecosystem. At the same time the lack of coordinated government policy around the climate change topic fails to address more fundamental shifts in the generation mix and support widespread development of carbon free sources. As a result we live in a highly innovative world with a bad climate	**Interstellar** The pace of innovation is kept up to the The pace of innovation is kept up to the growing ability of nations to invest into real projects incentivized by the clear climate policy and enabled by the developed financing institutions providing transparent and strong governance. Alignment of innovations and policies ultimately shift the global energy ecosystem to the new level of efficiency and sustainability. Decentral market driven landscape takes place in most parts of the world – renewable energy gains an extraordinary momentum and its pitfalls (e.g. non-affordable energy storage) are long solved.
Innovations & tech development: low pace	**The Day After Tomorrow** Lack of efficient and globally coordinated environmental policies, low pace of innovations and poor proliferation of new technologies keeps the status quo for the industry. It is dominated by large players, often centre led national champions, whose scale is a profound foundation of dominance, leaving little space for new industry entrants and consumers' influence. Energy remains largely fossil fuel driven and scarce due to geopolitical divide, limiting economic growth and provoking social or military conflict, while climate change consequences are only worsening.	**Star Wars** While richer nations are progressing in addressing climate change, less developed and emerging nations are faced a hard choice between keeping their global commitments and ensuring local economic growth. Low proliferation of innovation results in the insufficient affordability of low-carbon technologies and advanced financial institutions to invest in scaling them up, more emerging countries depart the climate agreements. The world is divided: wealthy nations live in renewable driven decentralized energy landscape while developing states employ fossil fuel generation mix and nuclear.
	Weak climate change policies	**Strong climate change policies**

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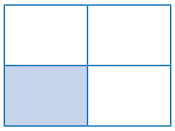
SCENARIO 1. THE DAY AFTER TOMORROW



Lack of efficient and globally coordinated environmental policies, low pace of innovations and poor proliferation of new technologies keeps the status quo for the industry. It is dominated by large players, often centre led national champions, whose scale is a profound foundation of dominance, leaving little space for new industry entrants and consumers' influence. Energy remains largely fossil fuel driven and scarce due to geopolitical divide, limiting economic growth and provoking social or military conflict, while climate change consequences are only worsening.

This scenario is called after a famous science-fiction disaster film, which depicts catastrophic climatic effects following the disruption of the North Atlantic Ocean circulation in a series of extreme weather events – precisely what can happen if the climate changes are neglected and the players do not deploy innovations that may jeopardize their status quo.

This is the world with predictable energy system and conventional business models. The power of consumers is extremely limited, and the highly concentrated market is mostly driven by a small number of large players, who are controlling the whole value chain down and upstream.

International climate agreements remain a high-level concept that has never been operationalized in enforceable and accountable policies. Governments keep their verbal commitments to climate action but in practice, national policies are focused on energy security and efficiency. Two degrees commitment has long been forgotten.

Utilities focus their strategies on utilizing and extending lives of the existing capacities rather than on investing in the new technologies and addressing environmental issues. Overall technological advancement has long slowed down and got mainly limited to incremental innovation aimed at cost efficiency and extended lifetime of the power generation and transmission assets. Nevertheless, energy efficiency and power saving technologies have not reached sufficient maturity and spread so the overall energy intensity remains high. Small-scale generation, power storages, smart grids, etc. – remain low in the research and development agenda and have never been implemented on the industrial scale.

Centralized large-scale power generation supplemented by the extensive grid prevail in the market. Energy mix is reflecting the market developments and remains heavily dependent on fossil fuels. Coal still dominates in the global energy mix, followed by gas and large-scale off-shore wind and solar, that are the top three cheapest sources of electricity by far that have been fastest growing sectors. Hydro and nuclear remain to be the only source of carbon-free baseload power keeping their share in the mix mainly thanks to the industrializing emerging economies. Macro-regional grids development aimed at providing unprecedented interconnectedness and security of supply span across some areas in Europe and South East Asia. Oil-based fuels dominate in the transport sector, while electric vehicles that have never gained sufficient scale, remain a niche product for 60+ environmental enthusiasts. Strong overall reliance on fossil energy resources time to time bring peak oil back to the international debate, leading to chaotic oil

prices volatility and that of the value of the whole industry sectors.

Green financing dropped from its peak in 2020 due to the lack of synchronized international and national standards. Traditional financial instruments work as usual however overall financing capacity remains insufficient to address the global demand for energy infrastructure. Lack of new financing instruments and sources and slowed down learning curve have undermined development of energy infrastructure in the less developed parts of the world - billions still have no access to electricity.

Because of inefficient local policies and lack of adequate enablers, the overall effect of environmental policies is not sufficient to fulfil climate change commitments, and the minor progression is mostly driven by modernization across energy systems and increased energy efficiency. Rising temperature, polluted air, destroyed ozone layer and devastating solar radiation. The climate action strategy has silently shifted from mitigation to adaptation approach aimed at increasing resilience of critical infrastructures against climate change outcomes and extreme weather conditions and natural disasters. The general public is furious: environmental protests are widespread, environmentalists NGOs radicalize and fight guerrilla wars against energy companies and polluting industries – nevertheless, no political party has ever been successful in turning public expectation into a viable policy.

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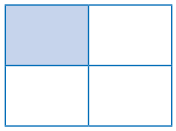
SCENARIO 2. BLADE RUNNER



The power of consumers is rapidly increasing supported by availability of diverse innovative technological solutions. Rapid innovation, technologies convergence and digitalization ultimately lead to the commoditization of energy as such and open up opportunities for the new entrants who undermine well-established business models and unbalance the whole energy ecosystem. At the same time the lack of coordinated government policy around the climate change topic fails to address more fundamental shifts in the generation mix and support widespread development of carbon free sources. As a result we live in a highly innovative world with a bad climate.

Blade Runner, filmed in 1982 and widely regarded as the best sci-fi movie of all times gives the climate change a starring role. In this film, the Earth is devastated by the ravages of climatic shifts in temperature and sea level rise, which has plunged large chunks of Los Angeles into Pacific Ocean. The city is living under a constant rain while new technologies dominate robotics, air transportation and other domains.

This world is characterized by the greatest ever pace of innovation, technologies development, and digitalization, constantly transforming energy landscape. Technology convergence, digitalization and decreasing costs of renewables have pushed the market to the customer-centric and decentralized extreme.

Consumers experience has been significantly redefined. Energy has become a mature service, pretty much like telecoms back in 2020. Customers' choice is largely driven by technologies, they look for the newest products and services, replace their devices and upgrade to the latest solutions as soon as they get introduced to the market. Circular economy and supportive financing have reduced upgrade and switching costs for consumers. Information society at its large has led to fully aware and conscious consumers' choices. Moreover, consumers are now actively engaged in the market activity and taking more ownership not only on their energy consumption but production as well: prosumer phenomenon has long become a proven business model across the markets.

Open borders facilitate technologies and finance transfer across regions enabling emerging to leapfrog and take advantage of the newest technologies. Developments on the energy supply side reduce significantly energy costs providing a greater access to energy for all which ultimately contribute to the global economic growth.

Energy now available for everyone but the industry has gone through dramatic transformations and lost many. The business landscape is now being dominated by a large number of smaller players as well as entrants from other industries: energy sector has been highly influenced by Google, Apple, IBM and their Asian peers, such as Huawei, Lenovo, Alibaba, and Softbank. Micro-power generators, smart-grids, battery storages and other technologies have empowered myriads of business model innovators who have populated the market. Accelerated learning curve and spread of low-cost producers have led

to the commoditization of power generation technologies, killing margins for manufacturers. GE and Siemens survive only thanks to constant acquisitions of start-ups in technology and the long-ago spin-offs of manufacturing to the low-cost markets.

Technological disruption has though insufficiently affected the energy mix. While coal is widely replaced by gas, share of renewables is not dramatically increasing to lead to their greater cost efficiency. Greater decentralization and technologies advances are driving the development of small nuclear reactors; however they still remain an isolated phenomenon, far from the mainstream.

Climate change issues however have not been successfully addressed by accelerated innovation. The governments struggle to keep up with transforming markets and implement sound green policies: they are always late, and the policies have never made a considerable impact. With little or no coordinated government support, critical innovations miss the climate change agenda. While not as dramatic as the previous one, this scenario also fails to address the climate change phenomenon to its full extent and achieves only an incremental improvement.

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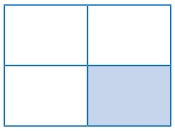
SCENARIO 3: STAR WARS



While richer nations are progressing in addressing climate change, less developed and emerging nations are faced a hard choice between keeping their global commitments and ensuring local economic growth. Low proliferation of innovation results in the insufficient affordability of low-carbon technologies and advanced financial institutions to invest in scaling them up, more emerging countries depart the climate agreements. The world is divided: wealthy nations live in renewable driven decentralized energy landscape while developing states employ fossil fuel generation mix and nuclear.

Star Wars is an almost 40 year old movie franchise but its spectacular confrontation of Good and Bad empires in the space fascinates the hearts of several generations.

This is the tale of two worlds. Differences in the countries' starting positions such as level of industrial development, access to technologies and access to financing have become their destinies. While richer and more innovative countries have been accelerating towards a high-tech, low carbon, resource-efficient, and socially inclusive green future, others have traded environment for economic growth and got stuck in the past with conventional technologies and limited financing.

In a brighter world, where local climate action regulation has successfully been implemented and enforced, new instruments and new sources of green financing provide sufficient support for innovation and investment. The energy mix here has become pretty low carbon. Large-scale offshore wind, solar and other renewables have substituted fossil fuel generation in the mix, leaving significant space only for gas. Coal-fired power plants have long been decommissioned, baseload power has been provided by large scale nuclear. Continent-wide grids connect Europe, North America and some archipelagos in Pacific, ensuring unprecedented energy security. Nevertheless, the volume and the growth rates of the brighter world has not been enough for optimizing learning curve, so the technological advancement remains largely marginal and the prevailing technical solutions are of 20-30 years old. Although digitalization has widely penetrated into the utilities and end-user domains, it has not made a considerable impact on business models and technological landscape. Centralization prevails and becomes a part of climate change response. Large players controlling power generation and transmission dominate the market. Governments are proactively focused on incentivizing optimization of energy demand, such as shifting consumers away from vehicles towards sustainable public transport, biking and promoting shared transportation options. This becomes even more relevant for high-density cities where traffic congestion and air pollution are growing concerns. People demonstrate a high level of awareness and responsibility and consciously cooperate with the governments.

In the darker world, people sacrificed environment and voted for growth. This difficult trade-off was particularly relevant for emerging and less developed countries going through rapid industrialization, which required access to the affordable energy. These nations have left climate agreements and have never implemented any sound local climate policies - their focus has always been on building affordable

and reliable energy infrastructure to satisfy growing needs of industry and population. The fossil fuel based power generation still dominates the energy mix. Gas has increased its role; however, coal remains the key source of power. Nuclear follows coal as a source of baseload power, while large-scale wind and solar farms remain marginal in the mix. At the same time, for many emerging countries decentralization and distributed power systems have proven to be an affordable solution for bringing electricity to the rural areas and providing energy for all. Distributed energy ecosystem encompassing both new technology and the enabling environment that involves such components as rooftop or portable solar, mini-grids, small scale storages, remote sensors and mobile payments - have been slowly developed with the immense involvement of international development financial institutions, such as World Bank and Silk Road Fund, as private investment are not available for this part of the world. People here are generally passive and do not have a considerable stake in the energy agenda.

Overall climate action remains weak due to the absence of the general frameworks that everybody would comply with. Reducing environmental impact in some parts of the world get neglected by growing footprint in other. Remarkably, countries start moving from the darker world to the brighter world as soon as they reach the certain level of industrial development as well as certain level of environmental threat, which makes it possible that slowly but surely the whole world will get brighter. Hopefully, before the end of times.

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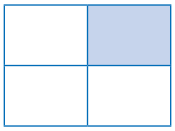
SCENARIO 4. INTERSTELLAR



The pace of innovation is kept up to the growing ability of nations to invest into real projects incentivized by the clear climate policy and enabled by the developed financing institutions providing transparent and strong governance. Alignment of innovations and policies ultimately shift the global energy ecosystem to the new level of efficiency and sustainability. Decentral market driven landscape takes place in most parts of the world – renewable energy gains an extraordinary momentum and its pitfalls (e.g. non-affordable energy storage) are long solved.

The central idea in this widely acclaimed film is that the human race on the verge of extinction resulted from the climate deterioration finds new ways for survival through the exploration of space, time and gravity.

This is the world of harmonized international policies and effective national regulation on climate action with the mature enabling environment supporting innovation and driving the change towards the clean energy future. Governments are leading the collective action, supporting innovation in technology and finance, securing enabling environment.

The 2015 Paris Agreement has since been developed into a complex coherent universe of both international and national frameworks and roadmaps that eventually resulted in the coordinated action towards keeping two-degree commitment while ensuring energy security and affordability. It was made possible not only on the basis of a good will of governments but also due to the whole system of monitoring, evaluation, incentives and enforcement, supported by wide public debate involving all stakeholders. International cooperation in this open world is a driving force for accelerating technologies and financing transfer across the markets. All these result in a sound enabling environment that drives markets to sustainable energy future.

Consumers have the stronger voice. Their values drive the overall shift of consumption to the products and services that meet the highest levels of environmental and social expectations, energy included. Consumers are perfectly knowledgeable about the technologies available to them and are actively engaged in managing and reducing their energy use. This goes in concordance with the government initiatives that also focused on managing the demand-side and encourage market player to reduce energy consumption. Green certification and integrated reporting with increased transparency standards have been adopted everywhere. Environmentalist NGOs have become the most effective partners of energy industry in identifying and solving environmental issues.

Originally initiated by the governments on both international and national levels, establishment of the government led development of financing institutions, aimed at supporting innovation and green energy projects implementation, and was quickly supported by the financial industry that came up with the number of new clean-tech financing instruments. Green bonds are now widespread and diverse which make it possible to fund carbon-free energy infrastructure development and climate aligned projects.

Innovation has been dynamic and versatile.

Accelerated learning curve in renewables of all kinds, complemented by the incremental innovations in gas and nuclear has ensured broad variety of power generation technologies. Digitalization and high technology convergence have shifted the market to the complex energy system with both huge centralized generation facilities and wide deployment of small-scale power generation, like rooftop solar panels, microturbines, etc., as well as new quality of customer experience at the end-user side, empowered by the development of the smart-grids, internet of energy and emergence of prosumers. The interconnected macro-regional grids provide the unprecedented level of power transmission across the markets ensuring security and affordability. Significant progress has also been achieved in the electrification of transport; high adoption of electric vehicles is driven by their attractiveness to consumers and cost-effectiveness.

Business landscape now represents a synergetic co-existence of large transnational corporations and niche innovative players, some originating from energy, others coming from digital. Prior to this perfect settlement there were years of market transformations and competitive wars, mainly driven by the emergence of the whole variety of small and agile innovative companies loaded with digital technologies and fuelled by available financing, introducing new business models and disrupting the conventional markets. Accelerated pace of technological development and significant regulatory change created additional stresses to the evolving environment which some companies failed to adapt. Eventually it all has settled down with the rise of the Asian players and some iconic western companies of the past being fatal casualties. Now those who managed to respond with new business models and a diverse set of consumer offerings enjoy the benefits that market brings.

Gas has increased its share in the energy mix widely replacing coal, which is now absolutely marginal. Renewables have strengthened their role and now they are on pair with gas. With increased investments in technological development and decreasing capital costs, solar and wind of all capacities and types have been growing more rapidly than any other source. Even though alternative energy is increasingly cost-competitive and storage technology holds great promise, alternative energy systems alone is not be capable of meeting the baseload generation needs of the developed economy in the industrialized world. Large-scale hydro keeps on slowly losing its share as the old plants get decommissioned while no new large hydro being built due to negative environmental impact these projects make. Nuclear energy development has re-gained its pace and now nuclear is the most reliable and carbon-free source of baseload power. Technologies advances drive the development of small nuclear reactors that reflects the demand of the decentralized system. More attention is given to nuclear waste management bringing recycling to the commercial stage.

Climate action has been a huge success: two-degree commitment has been fulfilled and the new even more ambitious sustainable development goals have been discussed by the UN in 2050.

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TABLE 3. SCENARIOS COMPARISON

Variations		THE DAY AFTER TOMORROW	BLADE RUNNER
Consumption pattern	High vs low consumers' empowerment	Low	High
	Centralized vs decentralized	Centralized mostly	Decentralized mostly
Innovation & technologies development	Rapid vs low pace of innovations & technologies development	Low	High
	High vs low degree of convergences	Low	High
	Relative technology / cost competitiveness of renewable energy vs. fossil fuels and nuclear	Low	High
Climate policies	High vs low international frameworks efficiency	Low	Moderate
	Strong vs weak local legislation	Weak	Weak
	Mitigation vs adaptation approach	Mitigation	Adaptation
Enabling environment	Strong vs weak governance	Weak	Moderate
	Widespread and sufficient financial instruments vs not	Widespread, but mostly local solutions	Widespread and sufficient
	High vs low public awareness	Medium	Medium
Market concentration	Dominance of large players vs small number of players	Large companies prevails, no space for new entrants	Large number of smaller players as well as entrants from other industries
Environmental impact	Low vs high impact on environment	High impact – Minor progression on climate commitments due to higher cost efficiency	Moderate to high impact – Moderate progression on climate commitment is driven by incremental impact of renewables
Energy mix* **numbers are rounded*	Fossil fuels vs low carbon mix	Share of fossil fuels – 80%, nuclear 5%, renewables – 15%	Share of fossil fuels – 75%, nuclear 10%, renewables – 15%
		Fossil fuels dominate – Coal is a main source – Gas increasing its share – Oil stays the main transportation fuel – Renewables – moderate growth, mostly in large scale – Nuclear – no significant increase	Towards low carbon – Coal is widely replaced by gas – Oil is decreasing due to the rise of bio-fuels and methanol – Renewables moderately increasing its share due to cost efficiency – Nuclear – small reactors development

STAR WARS		INTERSTELLAR
Developed markets	***Emerging markets***	
High	Low	High
Complex with dominance of centralized	Centralized – in industrial countries, decentralized – in more developing	Complex – huge centralized systems with decentralized
Moderate	Low	High
Moderate	Low	High
Moderate	Low	High
High	Low	High
Strong	Weak	Strong
Synergy	Adaptation	Synergy
Strong	Low	Strong
Widespread and sufficient	Not widespread	Widespread and sufficient with strong green focus
High	Low	High
Few large companies dominating the market	Large number of small companies	Coexisting of large utilities with transformed models & niche innovative players
Low impact – Some progression due to renewables adoption	High impact – Almost no progression on climate commitments	Low impact – Two-degree commitment is fulfilled
Share of fossil fuels – 60%, nuclear 10%, renewables – 30%	Share of fossil fuels – 80%, nuclear 5%, renewables – 15%	Share of fossil fuels – 60%, nuclear 10%, renewables – 30%
Towards low carbon – Coal is decreasing significantly – Gas share goes up replacing some coal – Oil – moderate growth – Renewables – rise is driven by tech. development – Nuclear – increasing as a main carbon free source for baseload power	Fossil fuels dominate – Coal and gas has a significant share – Oil is the main transportation fuel – Large wind and solar farms are marginal – Nuclear – increasing as a main source for baseload power	Low carbon mix – Fossil fuels replaced widely by renewables – Methanol is starting to replace oil in transport – Nuclear increasing as the only carbon free source for baseload power, small modular reactors & new generation development

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Concluding Remarks

The world is changing and so does the energy sector. Nobody really knows what will happen tomorrow and the only value of walking into the future is finding a good reason to act differently today. What are the lessons learned from this scenario exercise? What we can start doing now to ensure the better future for all?

We have clearly recognized that the influence of consumers can rapidly and uncontrollably raise in the future being supported by the innovators empowering them with real tools to demand unique experience. Innovation which is usually good for consumers might not necessarily be as good for the markets: rapid innovation and convergence of technologies can disrupt markets and undermine well-established business models of conventional players that eventually can disbalance the whole ecosystem and end up in failing. The major challenge here is digitalization that has already transformed a number of markets like air travels and taxi and energy can be the next. This opens up an opportunity for new players but at the same time creates a challenge for the existing ones. How digital a traditional player can be and whether anyone can control convergence of energy and digital will be a key discussion point in many boardrooms in the next years.

Another worrisome consideration that we have made is that the need for urgent climate action that looks like one of the very few ideas uniting so many nations can end up tearing them apart. Picture of heads of states at the COP21 in Paris in 2015 reflects an amazingly rare consensus which however remains intact only if it is about the agreement in principle on general frameworks. It will not be the same when some nations will have to make a difficult choice between keeping their global commitments and providing local economic growth. If the future does not bring us affordable and efficient low-carbon technologies in power generation, transmission and storage, if the financial institutions fail to secure the infrastructure investment supporting large scale implementation of these technologies - countries will start leaving that once promising picture made in Paris in 2015. What use of creating incentives for using what is not there yet?

The simple final observation is that only hand in hand innovation and policy action can build a better future for everyone. When the pace of innovation is being kept up to the growing ability of nations to invest into real projects incentivized by the clear climate policy and enabled by the financing institutions providing transparent governance - that is what will shift the global energy ecosystem to the new level of efficiency and sustainability. It may sound like an obvious idea but the implementation is not that obvious. We believe that achieving this alignment in actions needs an alignment in ideas first, which requires a constant multistakeholder dialogue involving policy makers, industry, financial institutions, academia, and NGOs or in other words - an ability to work together towards common future.

At the end of the day, no matter how diverse our views can be - we will all have the same future. Why not take a chance to create it together?

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References

EY, When energy customers go off-grid, will utilities be left in the dark? (2017), available from the link
EY, Why the rise of electric vehicles will mean more to utilities than just increased electricity sales? (2017), available from the link
EY, Energy Reimagined: what's the mix?
BP, Energy Outlook 2017
IRENA, The Power to Change: Solar and Wind cost reduction potential to 2025 (2016)
World Energy Council, World Energy Resources (2016)
World Economic Forum, How will the digital revolution transform energy sector (2016)
HSBC Global Research, Consumer in 2050 (2012)
PWC, The world in 2050: Will the shift in global economic power continue? (2015)
The Energy Research Institute of the Russian Academy of Science, Global & Russia Energy Outlook 2016
UNDP, Support to the Implementation of the 2030 Agenda for Sustainable Development (2016)
OPIC, Off the grid in Africa: Why distributed power in becoming a key source of electricity? (2015)
Navigant, Energy Cloud White Paper: Emerging opportunities of the Decentralized Grid (2014)
The Guardian, Google – leading the way on renewable energy (2013), available from the link
World Resource Institute, The Roads to Decoupling: 21 Countries Are Reducing Carbon Emissions While Growing GDP (2016)
Global Opportunity Explorer, Discover opportunities at the edge (2017)
International Atomic Energy, Global EV Outlook (2016)
IRENA, Unlocking Renewable Energy Investment (2016)
OECD, The Development Co-operation Report 2016: The Sustainable Development Goals and Business Opportunities
Green Climate Fund, From Signatures to Action – GCF Funding Proposals Need to Meet the Ambition of the Paris Agreement (2016)
Climate Bond Initiative, HSBC, Bond and Climate Change: The state of the Market in 2016
OECD, The Role of Institutional Investors in Financing Clean Energy (2016)
Yale School of Forestry & Environmental Studies, Climate Change Communication Program, Survey: Climate Change Awareness and Concerns (2015)
World Bank, Population Estimates and projections (2017)
UN, World Urbanization Prospects (2014)

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Acknowledgements

This work would not have been possible without significant input from colleagues below, who informed the project's approach, provided ideas and reviewed drafts. Their support and insights have made invaluable contribution to the development of the report.

Anton PORIADINE, Partner, CIS Strategy & Customer Leader, EY

Tatiana MITROVA, Director, Energy Center, Moscow School of Management SKOLKOVO

Alexey KHOKHLOV, Head of Power Division, Energy Center, Moscow School of Management SKOLKOVO

Alexey KALININ, Academic Director, Institute for Emerging Market Studies, Moscow School of Management SKOLKOVO

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