WORLD ECONOMIC FORUM

COMMITTED TO IMPROVING THE STATE OF THE WORLD

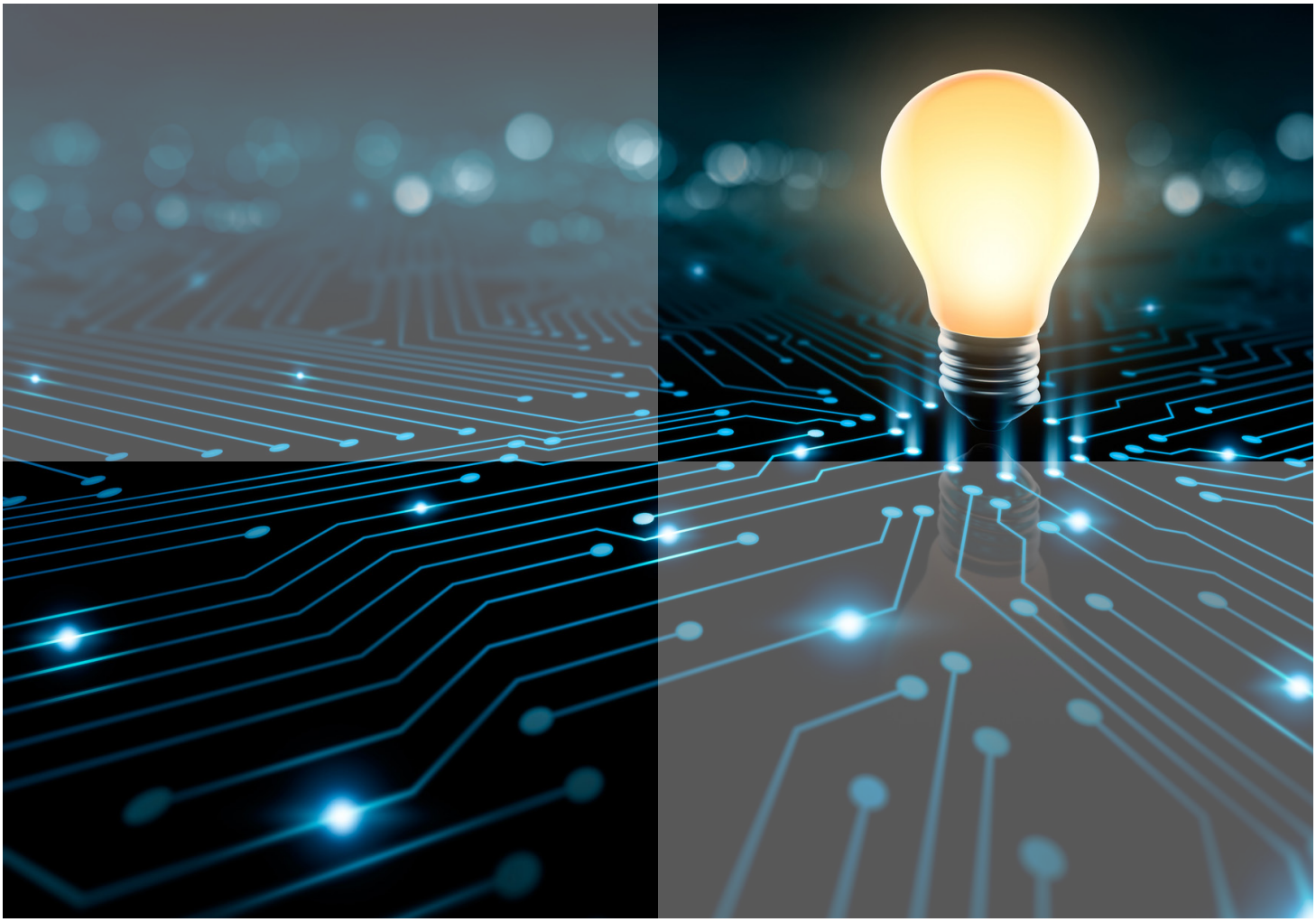
Insight Report

Fostering Effective Energy Transition

A Fact-Based Framework to Support Decision-Making

With analytical support from McKinsey & Company

March 2018



World Economic Forum®

© 2018 – All rights reserved.
No part of this publication may be reproduced or
Transmitted in any form or by any means, including
Photocopying and recording, or by any information Storage
and retrieval system.

REF 201218

Contents

Foreword

A platform for effective energy transition

Energy is a key element of the modern economy. The availability of secure and reliable energy supply is essential for industrial processes and the provision of public services such as lighting, heating, cooking, information and communications technology, and mobility. The energy system is undergoing unprecedented change. The geopolitical landscape of energy is quickly shifting and environmental concerns have shaken the system's foundations. At the same time, the economics of competing energy sources have changed, and the advent of Fourth Industrial Revolution technologies have enabled new business models and made others obsolete. The latter has created significant uncertainty about the pace and destination of the transformation, making a strong case for a systemic, multistakeholder approach that increases transparency on the enablers and reforms needed for countries to achieve an effective energy transition.

The diverse challenges facing the energy system today cannot be addressed by a single government, industry, company or other institution alone. A broader variety of expertise, convictions and resources are required for effective action. Moreover, relevant actors and initiatives must be organized to understand and prepare to successfully leverage the underlying transformational forces and direction of energy transition.

To progress in energy transition, the world requires a collaborative platform that fosters a systemic approach to solving problems and capturing opportunities. As the international organization for public-private collaboration, the World Economic Forum is applying its organizational capacity – its top decision-maker-level multistakeholder communities, convening and facilitation capabilities, knowledge resources and interaction technology – to this purpose.

The System Initiative on Shaping the Future of Energy of the World Economic Forum is creating a platform to foster a common understanding of four aspects of energy transition: 1) destination; 2) imperatives; 3) enablers; and 4) human impact. Through this understanding, the aim is to support the design and accelerate the development of effective policies, corporate actions and public-private collaboration for an inclusive, affordable, sustainable and secure energy future essential for economic and social development.

The aspiration

Previous efforts of the System Initiative on Shaping the Future of Energy explored emerging macro trends in the energy system and their implications for different stakeholders (*Game Changers in the Energy System*[1]) and the creation of a global index to benchmark country-level energy system performance (Energy Architecture Performance Index[2]). The project, Fostering Effective Energy Transition, builds on the insights from these undertakings and adds a forward-looking framework to transform the global dialogue on energy transition. The Forum considers this project as the starting point of a multi-year effort with the aspiration to:

- **Establish an insight-rich framework and fact base** to foster an understanding of both systemic and country-level readiness for effective energy transition that incentivizes leaders to accelerate energy transition within their respective countries and globally
- **Convene all relevant stakeholders** to foster a common and inclusive understanding on national energy transition priorities, which will provide long-term value to society and businesses
- **Curate and facilitate an inclusive platform for public-private collaboration** to catalyse the creation of predictable yet flexible long-term policy roadmaps
- **Highlight good practices from global peers and the Forum's expert community** to accelerate local energy transition efforts and to enable public-private sector collaboration

The key to effective decision-making on energy transition

Leaders in the energy system have highlighted the need for:
1) An effective and inclusive platform for action-oriented dialogue
2) A fact-based framework that supports an unbiased approach to energy transition

Over the course of the last year, the Fostering Effective Energy Transition project contributed to these two requirements by:

- A multilevel dialogue series, addressing energy transition at the global, regional and national levels: This series created a better understanding of countries' transition imperatives and challenges. It initiated a network of actors to enable concrete action within selected regions and countries. Ultimately, these interactions with approximately 200 key stakeholders of energy systems across the world aim to create local platforms to facilitate country-specific transition visions and to support the creation of predictable yet flexible long-term policy roadmaps – an element critical for effective energy transition.
- The Energy Transition Index (ETI), linking the performance of countries' energy systems today with their readiness for the future. This new index highlights countries' comparative strengths and improvement areas and allows private stakeholders to compare countries' relative system performance and transition readiness to identify opportunities and threats to their business.

Executive summary

Background

Globally, energy systems are experiencing significant and fast change, driven by forces such as technological innovation, changes in consumption patterns, supply dynamics and policy shifts. These forces offer opportunities to resolve the challenges that the global energy system faces today, namely: providing energy access to the more than one billion people who lack it, and meeting demand for an additional two billion people by 2050[3],1 while also delivering that energy at an affordable cost and with a declining carbon and emissions footprint.

This poses two key questions for decision-makers: what is required for an accelerated improvement in countries' energy systems and how can the right conditions be put in place that will allow these systems to seize the opportunities from this energy transition. No stakeholder in the energy system can drive such improvement alone. Many actors in businesses, government and society will need to come together, bringing their different viewpoints, priorities and sentiments. To facilitate effective dialogue between those parties, a common fact-base and understanding of the challenges are required.

The Forum constructed an analytical framework, which describes the imperatives of an effective energy transition, as well as a set of enabling dimensions. These are required to support the improvement of countries energy system along these imperatives. The newly developed Energy Transition Index (ETI) allows the assessment of 114 countries' energy systems within this framework, by providing benchmarks across:

- **System performance:** This measures current performance, based on the delivery of the energy system on the imperatives of the energy triangle, namely promoting an energy system that supports inclusive economic development and growth, secure and reliable access to energy, and environmental sustainability
- **Transition readiness:** This measures the future preparedness of countries' systems. Transition readiness is defined using six dimensions, which support effective and timely progress in system performance. They are the availability of investment and capital, effective regulation and political commitment, stable institutions and governance, supportive infrastructure and an innovative business environment, human capital, and the ability of the current energy system to accommodate change.

Key findings

There are three major findings from the ETI:

1. **Over the last five years, more than 80% of countries improved their energy systems, but further effort is needed to resolve the world's energy-related challenges.**

- Current performance and recent improvement in environmental sustainability has been the lowest among the three triangle dimensions. Particle emission levels deteriorated in more than 50% of countries, carbon intensity stayed flat and energy productivity improved by 1.8% per annum, falling short of the 3% per annum threshold believed to be required to meet the Paris climate change agreement.[4]
- Security and access remains the area with the biggest gap between highest- and lowest-performing countries. Almost all countries without universal electricity access have seen progress. However, at the global level, the absolute number of people without access still exceeds one billion.[5]
- Household electricity prices have been rising in real terms since 2013 in more than one-half of countries globally,[6] despite an overall fall in primary fuel prices. These developments increase pressures to improve the affordability of energy.

2. **Countries can foster progress in three ways by: establishing favourable conditions for energy system stakeholders, targeting improvement across all three triangle dimensions, and by pursuing improvement levers with synergistic impact across the system.**

- The presence of enablers (transition readiness in the ETI) is a strong indicator of the increased performance of countries' energy systems. The countries with the highest readiness scores are leading the performance ranking. Without these enablers in place, countries' performance would be average at best. Since transition readiness is multi-dimensional, countries need to establish favorable conditions in all six readiness dimensions to fully capture the opportunities from the energy transition.
- Countries that have not pursued a balanced approach to improve the energy triangle across its three imperatives showed below-average performance improvements. On the other hand, countries that managed to develop high performance levels show more balanced improvement across the three dimensions.
- Removal of fossil fuel subsidies and the reduction of energy intensity are important improvement levers as they showed synergistic impact on other dimensions of the energy triangle. Countries making progress in these two dimensions showed proportionately greater improvement in the other dimensions across the energy triangle.

3. **Countries follow different transition paths and need to develop country-specific roadmaps. Comparative analysis among peers can highlight opportunities for improvement.**

– Countries with high performance and most enablers in place have led the improvement in environmental sustainability, while countries with relatively low performance or readiness narrowed the gap in security and access, and economic developmentand growth.
– Countries are encouraged to benchmark themselves against comparable peer groups (e.g. geographies, development status, energy trade balance) to identify good practice examples and develop suitable improvement levers, applicable to their circumstances.
– Energy importing economies showed higher transition readiness levels and benefitted more from the lower energy prices of the last five years. Out of these countries, some of those with lower performance levels (e.g. People's Republic of China or Kenya) established a working ecosystem of enablers, including strong regulations, infrastructure and an innovative business environment, which helped them attract investment for future improvements.

Moving forward

The ETI can serve as a tool to track countries' performance and readiness as well as to identify energy systems' strengths and improvement areas, business opportunities and threats. In addition to global benchmarking, peer comparisons against countries with similar structural backgrounds and starting positions, it enables identification of relevant reference points. It also supports the development of a vision of energy transition, and ultimately, a roadmap. Such a country roadmap needs to take into consideration that energy transition does not happen overnight and there are high levels of uncertainty in the energy sector (e.g. the pace of technology development, price volatility etc.). Reflecting this, after developing a plan, countries must remain flexible in an everchanging environment.

Previous country-specific energy transition work shows the complexity of the task ahead as well as the benefits that such transition roadmaps can offer. All stakeholders – and policy-makers in particular – are encouraged to use long-term value for a country as the main criterion to optimize a transition roadmap, develop specific plans for each demand sector and align incentives with the longer-term perspective.

The Forum aims to support country-level transition efforts in two ways. It provides transparency on countries' progress, which is achieved by publishing the ETI on a regular basis. The Forum functions as catalyst, facilitator and a platform, all of which are designed to create stakeholder engagement across the energy system and foster the exchange of good practice globally.

1. Context

Globally, energy systems are experiencing unprecedented change, driven by a blend of technological innovation, changes in supply dynamics, consumption patterns and policy shifts.

Innovations in energy technology have reduced costs, created jobs and supported the reduction of CO_2 emissions from the energy sector.

In the last decade, technological progress has allowed new forms of producing, storing, transforming and consuming energy, altering the nature of the energy system. Fourth Industrial Revolution technologies, and digitalization in particular, allow for open, real-time, automated communication and operation of a more efficient energy system. In a recent study, McKinsey's Global Institute estimates the yearly savings potential in the resource industries from these technologies to be $750 to $1,210 million by 2035.[7] The cost of renewable energy technologies decreased considerably[8] and resulted in the creation of new jobs. In 2016, 9.8 million people were employed in renewable energy industries.[9]

In the oil and gas sector, the combination of hydraulic fracturing and horizontal drilling resulted in a sharp increase in shale gas and tight oil production in the United States, impacting global energy markets. In addition, a 42% reduction in US domestic gas prices between 2010 and 2016[10] allowed gas to replace coal in power generation, contributing significantly to emission reductions.[11]

The electricity system is changing, driven by decentralization, electrification and digitalization.[12] Growing decentralized sources offer an alternative to the current grid to deliver power. This is particularly relevant as access to energy increases in remote locations currently outside of the grid.[13] Electrification is critical for long-term carbon reduction goals[14] and technology innovations allow a greater electrification of transport and heating today.[15] The convergence of these trends reinforces and amplifies their individual contributions. For example, the combination of decentralized sources and digitalization has allowed traditional consumers to change their role in the energy system.[16] These changes have already impacted the business model in the electricity sector and are playing an important role in the decisions electric utilities are making for the future.

Energy consumption patterns have fundamentally shifted in the last years, resulting in new demand dynamics.

Global energy demand growth has been driven by emerging economies like India and China. From 2005 to 2015, primary energy consumption in non-OECD countries grew at a rate of 3.6% p.a.[17], while OECD countries' consumption decreased 0.3% p.a. Although energy per capita has peaked in most mature economies, on a global level, economic growth and energy consumption are also being decoupled. For example, in 2016, global energy demand grew by 1.1%, while GDP grew 3% in the same period.[18] Moreover, countries are pursuing policies to nudge consumer behaviour towards energy-efficient options. For instance, China phased out imports and domestic sales of high-wattage bulbs between 2012 and 2016, resulting in an estimated 48 billion kilowatt hours of power saved per year.[19]

Policy-makers have started to adapt energy policies, and new coalitions have been formed to address challenges and harness opportunities associated with these developments.

Changes regarding energy policies are being undertaken globally. Examples include the 195 countries signing the Paris Agreement in 2015;[20] several countries successfully promoting low-carbon energy generation; India[21] and China[22] revisiting the planned expansion of their coal-fired power generation fleet; and countries announcing the phaseout of internal combustion engine cars over the next decades.[23] In 2016, 90% of new power sector capacity additions in Europe were in renewable energy.[24] Furthermore, international efforts have been put in place to address access to energy,[25] the transition to renewable energy,[26] increased energy productivity[27] and tracking progress towards sustainable energy goals.[28]

The importance of evaluating and adjusting policy environments to meet the demands of the energy transition will be critical. While a long-term vision and objectives are necessary, remaining flexible in a dynamic environment is also important. Many governments have begun implementing policy measures surrounding the shift to sustainable energy, although fewer are outlining clear and extensive energy transition plans to improve delivery across the three corners of the energy triangle.

Countries can use these game-changing trends to enhance their energy systems and improve the well-being of their populations.

Understanding the urgency and implications of these trends is critical to businesses, governments and society as a whole. In many cases, responding to them will require fundamental shifts in how businesses are run, policies are set, household choices are made and stakeholders collaborate with one another.

Opportunities from an improved energy system are significant. The UN states that "a well-established energy system supports all sectors [of an economy]: from businesses, medicine and education to agriculture, infrastructure, communications and high-technology. Conversely, lack of access to energy supplies and transformation systems is a constraint to human and economic development."[31,32] Energy system improvements should foster economic development for the 1.2 billion people without electricity and 2.7 billion people without clean cooking fuels.[33] Anthropogenic climate change (its impact on global GDP of at least 5%)[34] can also be addressed, as the energy system is responsible for more than two-thirds of anthropogenic greenhouse gas emissions globally.[35]

Box 1: What is the energy system?

Energy systems are complex and at the heart of every country's economy. They comprise diverse stakeholders, various energy sources and all energy-consuming sectors, including industry, buildings and transport.

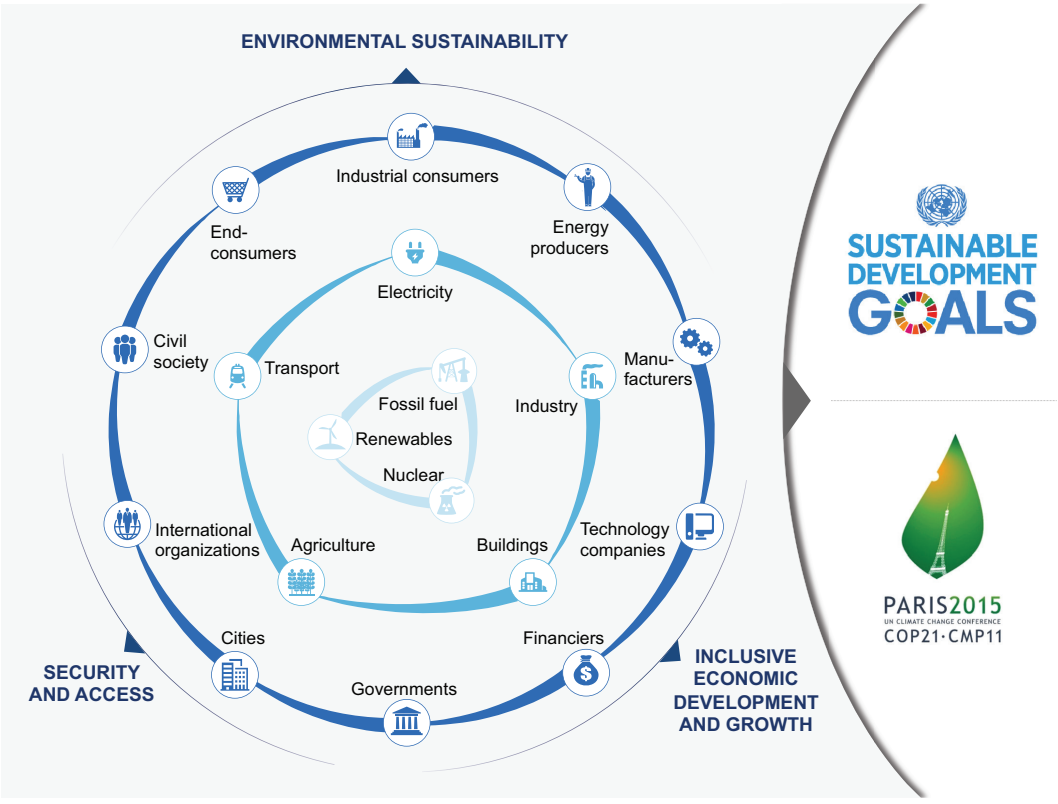
Energy systems aim to support society in the three dimensions of the energy triangle: 1) inclusive, economic development; 2) environmental sustainability; 3) secure and reliable access to energy.

The boundaries of energy systems have recently started shifting. The stakeholders are diverse, including:

- End consumers
- Industrial consumers, e.g. chemicals, materials, metals and mining, mobility, manufacturing
- Energy companies, e.g. oil and gas, electric utilities, renewables developers, service companies, technology and equipment providers
- Financial sector entities, e.g. commercial banks, private equity, institutional investors, development banks
- Policy-makers, e.g. legislators, ministries of energy, environmental agencies, financial regulators
- Cities, e.g. mayors, city planners, mobility providers
- International organizations, e.g. International Energy Agency (IEA), International Renewable Energy Agency (IRENA), International Energy Forum (IEF), United Nations Framework Convention on Climate Change (UNFCCC), Organization of the Petroleum Exporting Countries (OPEC)
- Civil society, e.g. academia, civil society organizations, philanthropists

Figure 1: The energy system

Source: World Economic Forum with support from McKinsey & Company



2. Effective energy transition

Modern industry and society are intrinsically linked to energy production, delivery and consumption. Hence, energy transition has repercussions across business decisions, policy objectives and consumer behaviour. It is therefore more important than ever to carefully steer the transformation towards a future energy system that delivers an optimal balance across the three triangle imperatives: economic development and growth, universal access to secure and reliable supply, and environmental sustainability.

What does "effective energy transition" mean?

Effective energy transition is a timely transition towards a more inclusive, sustainable, affordable and secure global energy system that provides solutions to global energy-related challenges, while creating value for business and society, without compromising the balance of the energy triangle.

Achieving simultaneous improvements in these three areas is not trivial or straightforward, and decision-makers will sometimes be faced with hard choices and trade-offs. Specific actions will not always be complementary and synergistic, and outcomes will differ based on countries' circumstances and priorities. For example, emerging economies need to meet rising industrial and residential demand under the constraints of environmental sustainability, and some resource-rich countries will need to diversify revenue to reduce dependency on fossil fuel exports. At the same time, countries will need to carefully manage system reliability and labour issues resulting from the changing energy mix, and markets will need to evolve to efficiently integrate new technologies and solutions while coexisting with legacy infrastructure. Businesses need to prepare for the impact on their existing business models from new technology, system solutions, consumer expectations and policy environment.

While energy transition presents opportunities to optimize the allocation of resources through the adoption of new technologies, create jobs through new business models and reduce environmental footprints from the energy value chain, it also poses risks of socioeconomic shocks from ill-informed decisions. Energy transition can be viewed from multiple lenses. The challenge is not restricted to lowering the carbon intensity of the energy supply, or the electrification of transport, or the efficient consumption of energy, or harnessing the potential of digitalization and decentralization. It is rather a complex process with multiple interactions and feedback loops between these transformational cues and other elements of the economy and society. In that light, the design of the energy transition requires a broad interdisciplinary mobilization of expertise, convictions, resources and multistakeholder collaboration.

To better inform decision-makers about the competing nature of energy transition end objectives and the state of interdisciplinary forces at play, a robust fact base is necessary to understand the status quo and to identify systemic reforms that will enable an effective energy transition. The proposed analytical fact-based framework does not only allow countries to benchmark the performance of their energy system, but also assesses countries' readiness to address the opportunities and challenges of energy transition.

System performance

Building an optimal energy system requires a tailored approach. Necessary actions for improvement will differ based on country-specific factors, including – but not limited to – socioeconomic growth priorities, natural resource endowment, demographics, dependence on energy imports/exports, depth of capital markets, business climate, etc. However, at its very core, the energy system is expected to serve three imperatives at the country level, which can be used as levers for global benchmarking (Figure 2).

As an input to a wide array of industrial processes and residential applications, energy is a driver of economic and human activity. Universal access to a reliable and secure energy supply is a crucial element of a well-performing energy system. The security and reliability of the energy supply need flexible and resilient infrastructure, a diversified supply base, and governance and emergency response mechanisms to hedge against geopolitical, technological and financial risks. Given that energy is still coupled to economic development and growth, countries will need to carefully approach security and reliability while maintaining affordability to ensure that their citizens can access public services and industries can remain competitive. A strong energy system also contributes to economic output and employment, and generates fiscal revenues. Moreover, given the challenge of reducing the environmental footprint of the energy value chain, countries will need to optimize security, reliability and economic growth while investing in the integration of low-carbon technologies and the minimization of negative environmental externalities.

There is no single way to deliver across the three key imperatives, and each country will define its own pathway. Moreover, evidence suggests that not all countries can simultaneously achieve the theoretical maximum on each dimension. The analytical framework devised improves decision-making while acknowledging the trade-offs.

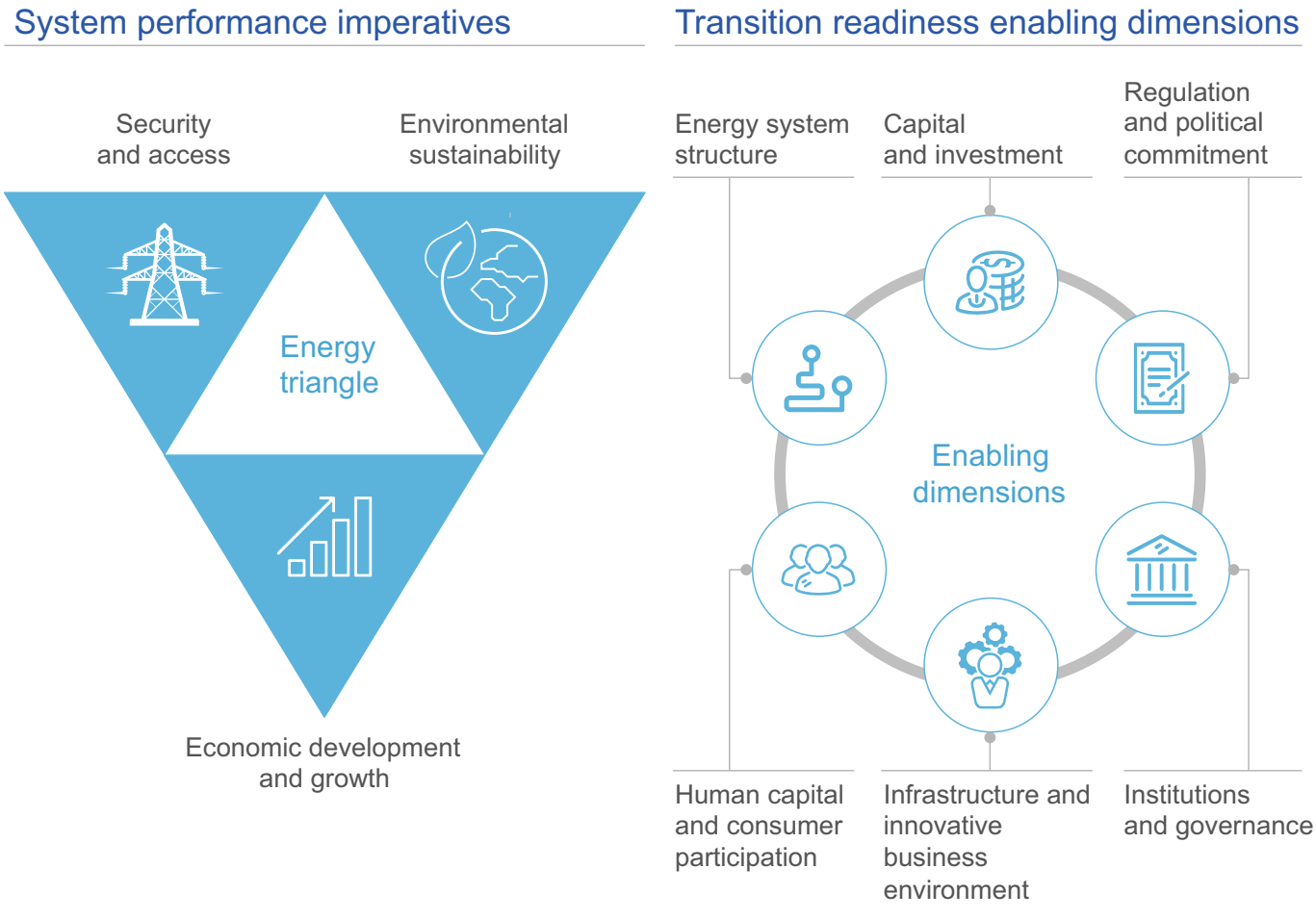
Transition readiness

The success of country-specific actions for improving energy system performance across the three aforementioned imperatives depends on a wide set of enablers. For the purpose of our framework, "transition readiness" refers to the degree to which a country's energy system has the political, economic and social structures in place to allow a transition to a more secure, reliable, inclusive and sustainable energy system that fosters greater economic development. A thorough understanding of these structures as well as the degree of improvement potential therein are essential to ensuring an effective energy transition. The transition readiness component presented in this framework identifies key enablers and supports decision-makers in prioritizing actions towards creating a robust enabling environment for energy transition (Figure 2).

The extent to which a country is ready for transition is primarily determined by existing energy infrastructures, the credibility and stability of long-term political commitments, and the availability of capital to finance the energy transition. Regulatory frameworks need to balance the need for providing certainty while showing flexibility to effectively integrate new technologies and business models when dealing with existing structures. An effective energy transition also relies upon a working market design, investment attractiveness, multilateral partnerships and the presence of a dynamic environment of innovation. Above all, energy transition has societal implications and, in the end, consumer behaviour will determine the acceptance of future energy systems.

Figure 2: System performance and transition readiness

Source: World Economic Forum with support from McKinsey & Company



Box 2: Power sector market design

The importance of power market design in enabling energy transitions has been a consistent theme throughout the dialogue series. While no consensus exists on what constitutes high-quality market design, the takeaways from the interaction with the consulted experts include:

- Although there is no one-size-fits-all solution, regulatory frameworks should take (long-term) country visions and entire value chains into consideration.
- Reforming a market is complex, subject to historical legacies and influenced by existing dynamics. Inefficiencies that increase system costs or pose a risk to energy system functionality are not necessarily avoided by a market redesign and may put investments at risk.
- The forced unbundling of the power sector to create transparency and promote efficiency in the grid and generation businesses, the opening up of power generation (and retail markets) to competition, and auctions for new capacity in conventional and renewable energy are becoming the new normal.
- Shorter (e.g.15-minute) intraday auctions (as introduced by Germany in 2015) can better match the production of intermittent renewable generation, and in particular the ramp-up and ramp-down of solar generation.
- Different sources of flexibility (distributed generation, including microgrids and minigrids, batteries, demand-side management) should be allowed to compete in the market for offering ancillary services (as is already happening in the United Kingdom), by removing current regulatory barriers.

However, this process is continuously evolving. Europe, often seen as one of the more advanced power markets, is now in the process of reinventing itself with the Energy Winter Package debate. The key question remains how to ensure regional coordination while sufficiently considering national circumstances and ensuring economically viable investments.

Box 3: Energy efficiency as an important improvement lever

Since 2010, improvements in energy efficiency have reduced energy intensity at a rate of 2.1% p.a.36 In addition to helping flatten global greenhouse gas emissions, this lowers the economic cost of energy to society, can help reduce energy import dependency and reduces the opportunity cost of fuel self-consumption.[37] Several countries have made considerable progress in energy efficiency savings over the last 10 years. For example, energy intensity in China fell 5.2% in 2016,[38] with full reduction potential still untapped. The energy productivity bonus, defined as the difference between actual GDP and notional GDP, assuming the previous year's energy intensity level, is estimated at $2.2 trillion in 2016 globally.[39]

In many cases, energy efficiency measures provide net economic benefits as well as opportunities to simultaneously improve environmental sustainability and reduce cost for individual stakeholders. It is estimated that by 2030, 30% of the carbon cost curve, or 11 $GtCO_2$ p.a. of energy efficiency measures, will be cost-negative. This will be driven by measures in the buildings and transportation sectors.[40]

1. However, reducing energy intensity and capturing the full potential from energy efficiency improvements is challenging.
2. In markets where the price of energy is significantly lower than total energy cost to the economy (e.g. from sizeable subsidies, or externalities), economic incentives for conserving energy usage have been eroded.[41]
   In the residential and transportation sectors, the measures to capture energy intensity need to address several million consumers, placing increased importance on behavioural changes and the consumer adoption of key technologies.[42,43]
3. In several cases (e.g. space heating and insulation[44]), efficiency measures require upfront investment that will only pay back over time, requiring a long-term perspective, high consumer awareness of the economic benefits and the availability of capital.[45]
4. Policies, mandatory standards and regulations play a crucial role in implementing effective energy efficiency measures and incentivizing consumer and industrial adoption. However, the ambition and effectiveness in the deployment of energy efficiency policies varies widely at a global level.[46]

3. Energy Transition Index (ETI)

The ETI evaluates 114 countries that represent more than 98% of global GDP and global energy system carbon emissions, approximately 90% of the global population, and about 60% of people without access to electricity.

The ETI provides both a high-level assessment and comparison of countries globally and individually against a defined target benchmark.

Box 4: Introduction to the Energy Transition Index
Background

Since 2013, the Energy Architecture Performance Index (EAPI) has helped decision-makers better understand energy systems and assess the current energy architecture performance of individual nations. In an environment of rapid transformation, it has become increasingly important for decision-makers to also understand the drivers and bottlenecks for future improvements in their energy systems. The newly developed ETI introduces the concept of transition readiness. In addition to measuring countries' energy system performance, it evaluates the extent to which countries have created the conditions for business and society to seize the opportunities that energy transition offers.

Methodology

The ETI is a composite index that focuses on tracking specific indicators to measure the energy system performance and transition readiness of 114 countries. At its core are two equally weighted sub-indexes: the system performance score and the transition readiness score (see the Addendum on the methodology in the appendix for further details).

1. System performance score
The system performance score is calculated with 17 indicators, which are defined using the three imperatives of the energy system (energy triangle): economic development and growth, environmental sustainability, and security and access.

2. Transition readiness score
The transition readiness score is calculated using 23 indicators, which define six enabling dimensions: capital and investment, regulation and political commitment, institutions and governance, infrastructure and innovative business environment, human capital and consumer participation, and energy system structure.

Scores (on a scale of 0-100%; with 100% being the target value) and associated rankings are calculated for each of the indicators, creating the system performance and transition readiness scores, using various well-established statistical methods. These numbers are then aggregated to calculate a score and ranking for each of the three dimensions of the triangle (system performance) and the six enabling elements (transition readiness). The aggregation of system performance and transition readiness results in the overall ETI score and ranking.

General findings

Countries show a wide range of system performance and transition readiness scores. On average, performance scores in environmental sustainability are the lowest, while security and access scores are highest (Figure 3). Differences among different country categories in both system performance and transition readiness are elaborated below.

Comparing performance and readiness shows that countries scoring high on transition readiness are more likely to have high system performance (Figure 4). The relative importance of different transition readiness dimensions is likely to vary, depending on the countries' specific energy system challenges. However, the absence of enablers along the six dimensions is expected to slow down long-term system improvement. When performing well across regulation, capital and investment, institutional stability, infrastructure and business environment, and human capital, countries are four to six times more likely to rank in the top performance quartile. On the other hand, all 28 countries with the highest measured readiness rank in the top half of the index.

Figure 3: Transition readiness versus system performance

Source: World Economic Forum with support from McKinsey & Company

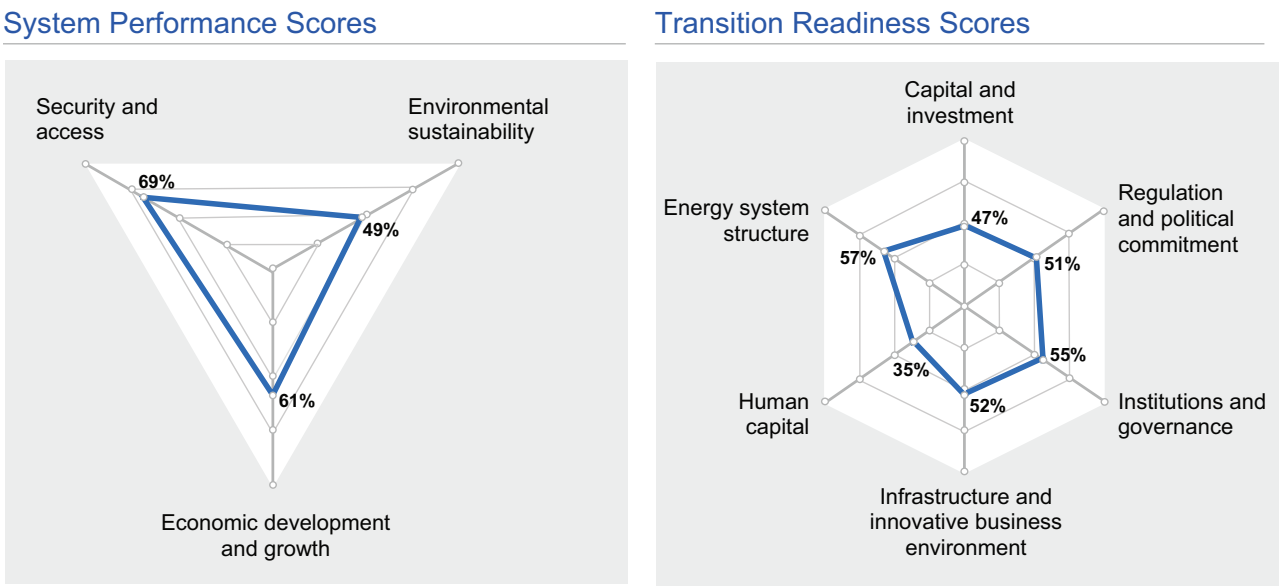
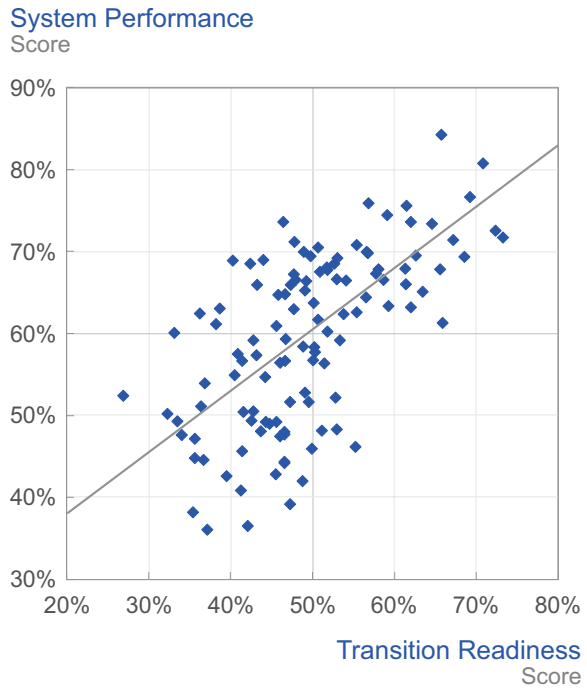


Figure 4: Performance/readiness matrix

Source: World Economic Forum with support from McKinsey & Company



The assessment of system performance and transition readiness scores as well as the recent trajectory between 2013 and 2018 provide three major takeaways:[47]

- Countries are moving in the right direction, yet the pace of progress is not sufficient to address the challenges of the global energy system.
- Transition pathways differ among countries, but lessons can be learned from improving and well-performing countries.
- Peer group analysis and a country-level indicator assessment can contribute to countries' transition vision and roadmaps.

Recent performance trajectory

Globally, countries improved in all three dimensions of the triangle between 2013 and 2018. The improvement was primarily driven by higher performance in economic development and growth, followed by security and access, and environmental sustainability (Figure 5). On a more detailed level, improvement has had various causes, with 10 out of 12 indicator categories showing positive changes (Figure 6).

Of the 114 countries covered in this index, 93 have experienced improved performance. Out of those 93, 45 countries have improved their energy systems in all three dimensions of the energy triangle. This indicates an overall positive trajectory. However, accelerated improvement is required to capture opportunities and address the challenges of energy transition.

Economic development and growth

Progress in economic development and growth, the dimension with the biggest change, has been driven by fossil fuel subsidy removal. Countries in the third performance quartile[48] showed the highest average improvement, which allowed them to narrow the gap with the top half of the ranking.

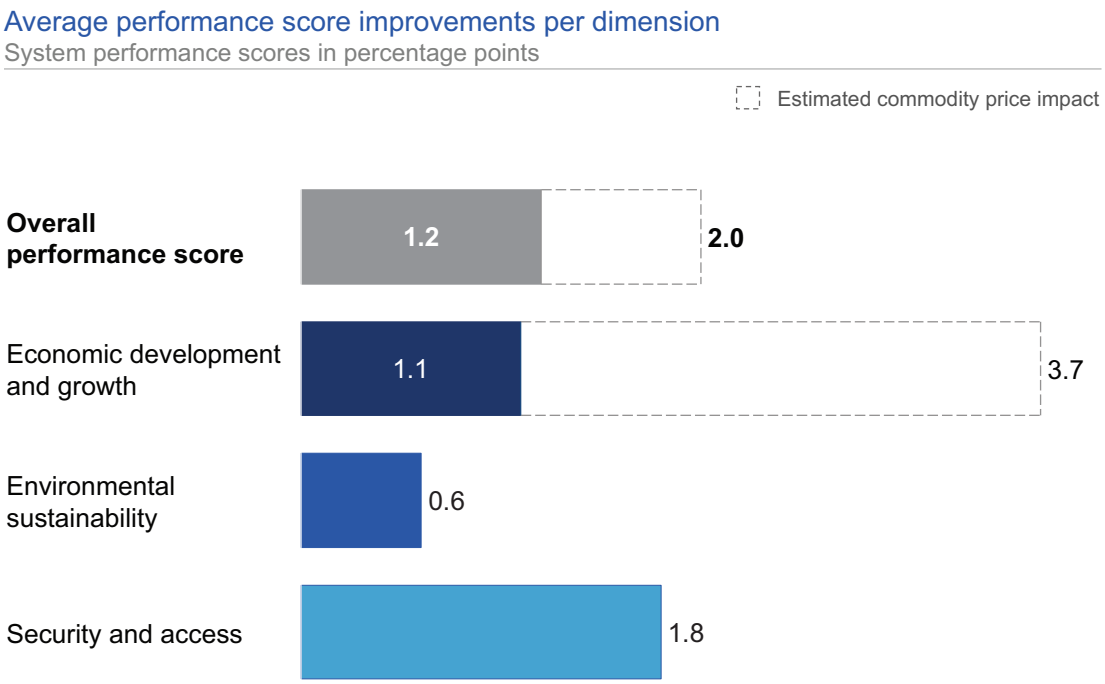
Generally, countries benefitted from lower commodity prices, which can be described as non-structural improvement, driven by external factors. Assuming 2016 commodity prices for 2013, the improvement rate in the economic development and growth dimension would be smaller by two-thirds (Figure 5).

Security and access

Improvement in security and access was driven by increased electrification and better quality of supply, especially for countries in the bottom half of the performance ranking. These countries also narrowed the gap with the top performance quartile and made strides towards the goal of universal access to modern forms of energy. Almost all countries without universal electricity access improved in this dimension. In absolute terms, however, the number of people without access to electricity is not declining quickly enough to meet the UN objective of universal electrification by 2030, and still exceeds 1 billion people globally.[49] The gap between security and access scores of the top and bottom performers remains the largest within the three dimensions of the triangle.[50]

Figure 5: Average performance scores, 2013-2018

Source: World Economic Forum with support from McKinsey & Company



Environmental sustainability

Among the three dimensions of the triangle, environmental sustainability poses the biggest challenges, with the lowest performance and improvement rates. The numbers indicate a complex journey towards an energy system that supports the targets of local air pollution and greenhouse gas emissions in line with the Paris Agreement. Between 2013 and 2018, 45 countries saw decreasing scores in this dimension. Also, air pollution remains a major challenge, with PM2.5 emissions worsening for 67 countries, causing around 6 million premature deaths per year globally. Carbon intensity scores stayed flat and even countries in the top performance quartile have potential for further improvement. Energy intensity improvement has been driving progress in environmental sustainability. Decreasing energy intensity and improving efficiency are two of the key levers to achieve the goals of the Paris Agreement. However, the current energy productivity improvement rate of 1.8% p.a. is falling short. The Energy Transitions Commission estimates that a reduction rate of 3% p.a. is required to limit global warming to below 2°C.'

Box 5: Sector-specific approach to carbon emission reduction

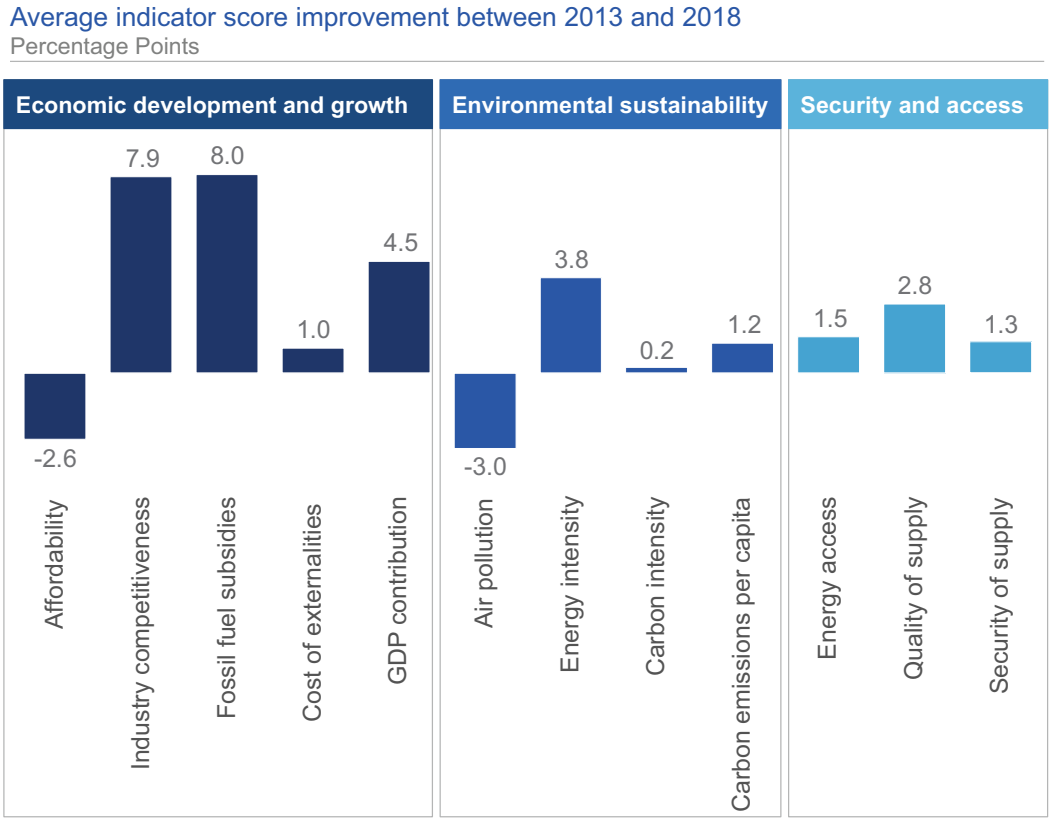
Progress in environmental sustainability has been more challenging to achieve among the three imperatives, so it is important to learn how to improve within this dimension. The following analysis focuses on how to foster more effective carbon emission reductions in the energy system.

After decades of continuous growth, global energy-related emissions began stagnating in the last three years.[54] To build on this trend and reduce carbon emissions in line with the Paris Agreement, a sector-specific approach is required. Electricity and heat account for approximately 40% of global carbon emissions, followed by about 25% from transportation, 25% from industrial activity, and 10% from the residential and public services sector.[55,56]

The carbon intensity of energy systems around the world varies depending on the nature of primary energy supply, economic activity, climate, etc., and ranges from coal-heavy energy systems to systems with a mainly low-carbon energy supply.[57] The sectorial breakdown of carbon emissions also varies widely among countries. For instance, with a carbon-free electricity system, Paraguay's carbon emissions are almost exclusively from transport (>90%), while over two-thirds of Estonia and Bahrain's carbon emissions are from electricity and heat generation.

Figure 6: Global performance improvements, 2013-2018

Source: World Economic Forum with support from McKinsey & Company



China and Vietnam have a relatively high share of emissions from industry (>30%), while a comparatively large share of Switzerland and France's emissions are from residential and public buildings (>30%).

Hence, countries will have varying strategies and a different mix of methods to reduce emissions – such as increasing energy efficiency, reducing carbon intensity in the electricity sector through lower-carbon alternatives, greater electrification of the economy, carbon capture utilization storage and lower-carbon alternatives in industrial processes.[58]

Several countries with already low-carbon-intensive electricity sectors are now pursuing transport electrification. Norway, the Netherlands, Switzerland, Sweden and France are among the front runners on e-mobility.[59] China – also among the leading countries in e-mobility – may not capture the same emission reduction benefits of the electrification of transport due to a high share of coal in its power generation mix, although e-mobility will help reduce inner-city air pollution.[60] India, another country with air pollution challenges, announced the ambition of ensuring that all new cars sold from 2030 will be electric cars.[61]

Japan, with comparatively high carbon emissions from the power sector, is pursuing another strategy to reduce emissions. It plans to make hydrogen fuel (expected to be produced from clean energy in the long run) a pillar of its energy system. A potential additional benefit would be the reduction of import dependency (if produced domestically) and the diversification of supply risks.

An assessment of global carbon emissions between 2010 and 2014 shows that simultaneously improving along all sectors of the economy is challenging. Less than 10% of countries reduced carbon emissions while increasing their economic output during that period. The decarbonization of power and reduction of emissions from the residential sector were the largest improvement drivers for countries with the highest carbon emissions improvement rates between 2010 and 2014.[62] These countries rank in the top half of the ETI, and six of them show top quartile readiness scores. Electricity systems progressed on decarbonization in the same period, with more than 60% of countries improving the carbon intensity of electricity and heat generation. With renewable-power generation-capacity additions exceeding conventional generation since then,[63] further decarbonization of the power sector is expected.

In the transportation sector, less than 30% of countries had reduced carbon emissions between 2010 and 2014 – the lowest number in the aforementioned four sectors. This can be observed in the United States, the country with the highest reduction of absolute tons of CO_2 emissions.[64] While carbon emissions from electricity and heat generation fell by 9% between 2010 and 2014, emissions from transportation increased by 3%, despite slightly improving carbon intensity in the transport sector.[65]

Different transition pathways

Countries can be categorized based on their relative system performance and transition readiness (Figure 7).

- **Leading countries:** 43 countries with well-performing energy systems and high transition readiness, indicating the ability to address the energy transition based on current performance
- **Leapfrog countries:** 14 countries with system performance below the mean, but relatively high transition readiness, indicating a position to leapfrog their development
- **Emerging countries:** 43 countries with system performance and transition readiness scores below the mean, indicating a challenging starting position to use transition opportunities
- **Countries with potential challenges:** 14 countries with above-average system performance but transition readiness below the mean, indicating the need for increased efforts to maintain and improve current performance levels

Countries show different improvement trajectories between 2013 and 2018, depending on their system performance and transition readiness. When assessing individual countries, it is important, however, to note that the classification of countries into these categories has its limitations, particularly for those close to the category boundaries.[66]

When looking into the indicators driving the performance improvement of the top 10 and bottom 10 performing countries between 2013 and 2018, they range across a variety of categories and combinations, providing a sample of different transition pathways. The analysis below shows systemic differences for country categories.

Leading countries

Leading countries were front runners in the advancement of environmental sustainability, with overproportionate improvements in the carbon emissions and energy intensity indicator categories (Figure 10). While their progress in environmental sustainability exceeded the other country categories, improvement in economic development and growth and security and access was lower than the global mean.[68] Further improvements have been driven by decreasing energy costs for industry and increasing the quality of electricity supply. In contrast to the other three categories, the removal of fossil fuel subsidies was not a driver of performance improvement for them since these countries did not have significant fossil fuel subsidies in the first place (Figure 8).

Regarding their readiness, these countries overcame the challenges from a comparatively high share of legacy energy infrastructure. They could serve as examples to other countries when it comes to policy and regulatory frameworks, infrastructure and business environments needed to incentivize consumer and business behaviour change to manage environmental impact. The availability of new technology, innovative business models, access to

Figure 7: Transition matrix[67]

Source: World Economic Forum with support from McKinsey & Company

capital and general infrastructure particularly exceed other country categories considerably, making this dimension a distinct strength to build on within their transition pathway (Figure 9).

Leapfrog countries

Leapfrog countries, which include countries from various geographical backgrounds, seem to have captured opportunities from not having legacy structures, limited locked-in investments and energy systems that are growing. In this context, they supported their energy transition through favourable regulation, attracting capital and improving infrastructure. While more than 80% of countries in the leapfrog category show scores in the top half for regulation and political commitment, only 40% score in the top half on the institutions and governance and human capital dimensions, indicating further improvement areas (Figure 9).

Leapfrog countries have similar scores to emerging countries in economic development and growth and environmental sustainability but outperform them in the security and access dimension. However, the progress made by both between 2013 and 2018 was similar due to a larger impact for emerging countries caused by subsidy removal and increased quality of supply.

Emerging countries

Average readiness scores for emerging countries indicate challenges in almost all areas (except energy system structure), particularly in human capital and regulation. Their results are considerably lower than leapfrog countries and leading countries (Figure 9).

A continued reduction of fossil fuel subsidies and improved energy access and quality of supply allowed these countries to start closing the gap to countries with higher performance scores in security and access and, to some extent, economic development and growth (Figure 8). The relative share of countries that decreased their performance is comparable with the leapfrog country category, but twice as high for countries ranking in the top half. The latter was mainly driven by the environmental sustainability dimension, which indicates a higher risk of performance fallbacks for countries in the two lower performance categories.

Countries with potential challenges

These countries have relatively well-performing energy systems with high scores in security and access and economic development and growth. Their major challenges lie in environmental sustainability. For the latter, the improvement between 2013 and 2018 underperformed vis-à-vis the other two dimensions.

The number of countries with decreasing performance scores within this category was 50% higher than for leading countries, indicating the beneficial impact of increased transition readiness, particularly in environmental sustainability – the dimension with the biggest difference between the two categories.

When compared to the leading group, these countries showed greater challenges in readiness in institutions and governance, infrastructure and innovative business environment, and capital and investment. However, when they accelerate their energy transition, these countries will have the advantage of a robust energy system and can learn from leading countries more mature in their energy transition.

Figure 8: Performance improvement per country category, 2013-2018

Source: World Economic Forum with support from McKinsey & Company

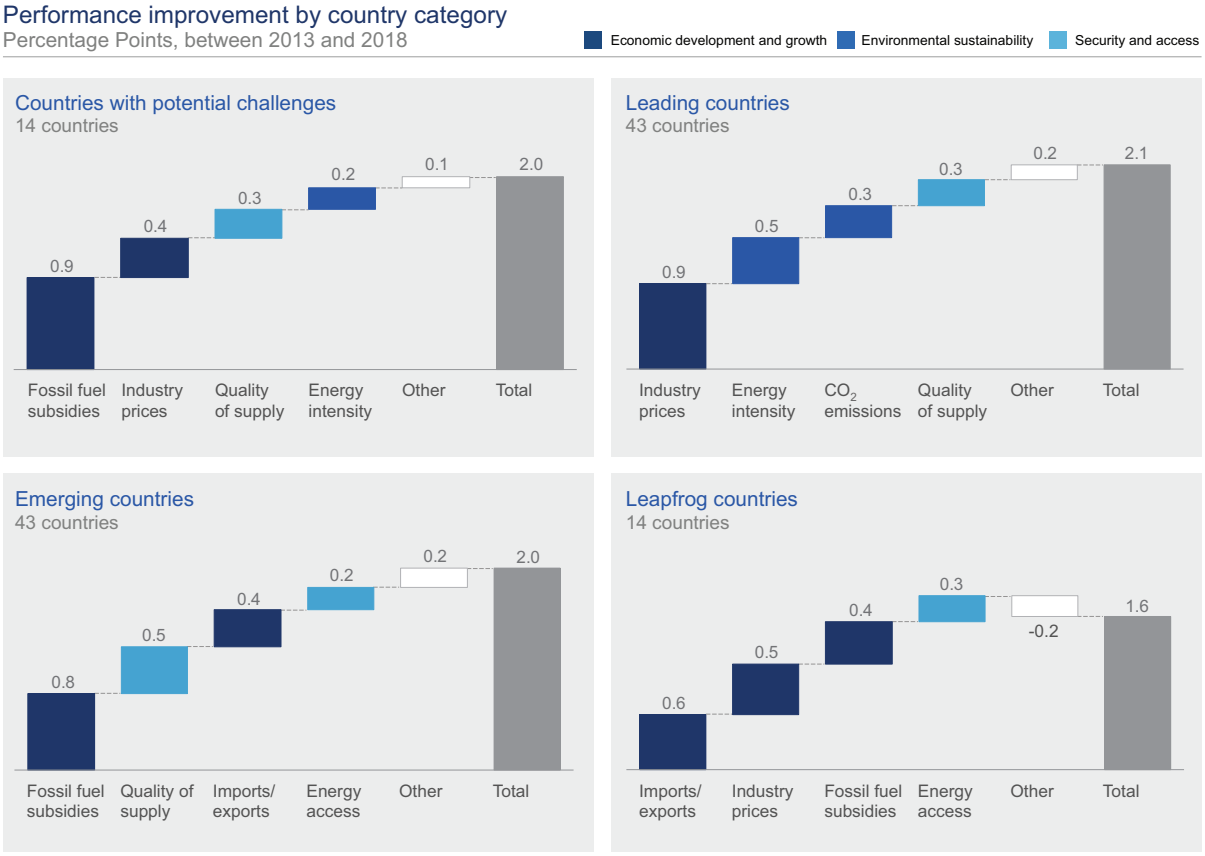
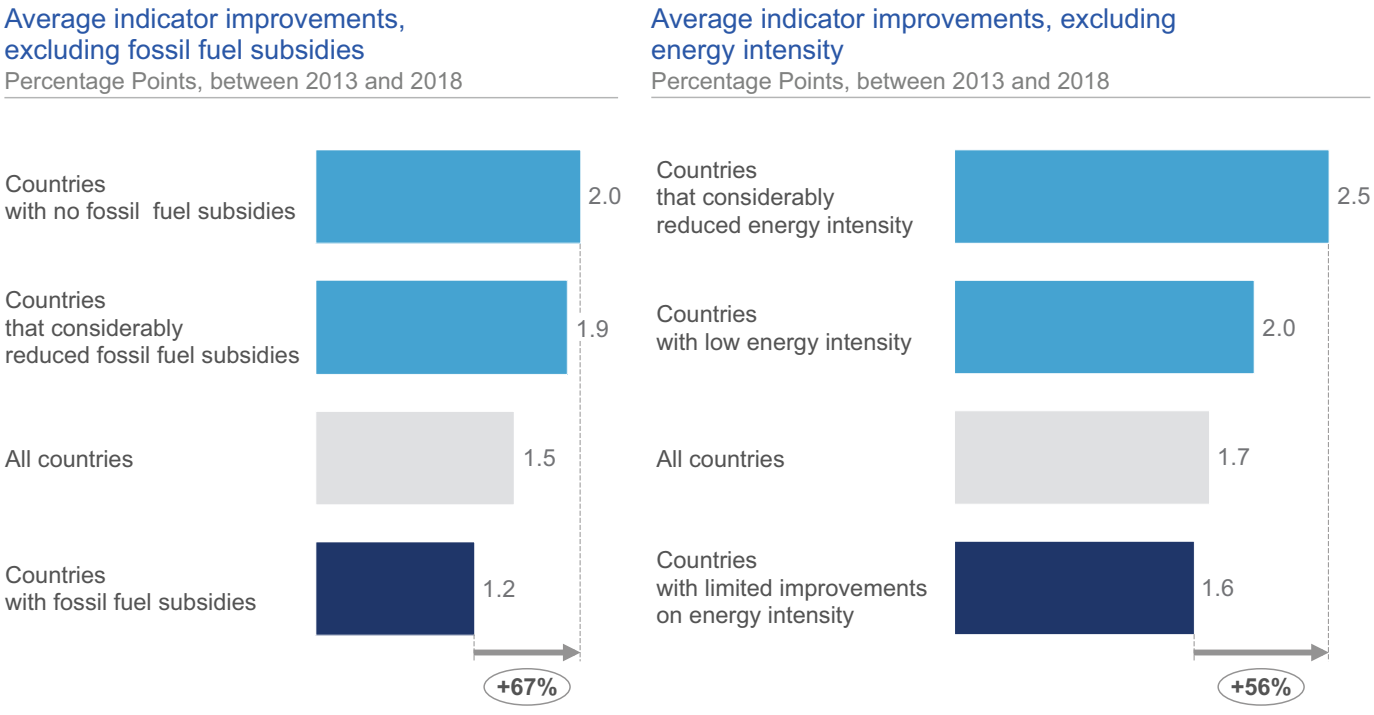


Figure 9: Transition readiness per country category

Source: World Economic Forum with support from McKinsey & Company



Balanced energy triangles

The three dimensions of the energy triangle are interdependent. This project's calculations show that countries tend to have similar levels of performance in each dimension, suggesting they reinforce each other. Of the more than 100 countries included in the calculations, only seven in the top half of the ranking are in the bottom quartile of one of the triangle dimensions. Countries with bottom quartile performance in one or two dimensions showed lower improvement rates in the other dimensions of the triangle. Moreover, countries with high performance scores are two times more likely to have improved in three dimensions of the triangle. They also show similar improvement rates in the three dimensions. These observations strengthen the argument for countries to improve their energy systems without prioritizing one of the three dimensions.

Successful initiatives of countries with overproportionate improvements

Although there are different pathways to effective transition, this analysis suggests that improvement in some areas produces more than proportional benefits throughout the whole energy system. Two examples are the removal of fossil fuel subsidies and improvements in energy intensity.

Fossil fuel subsidies

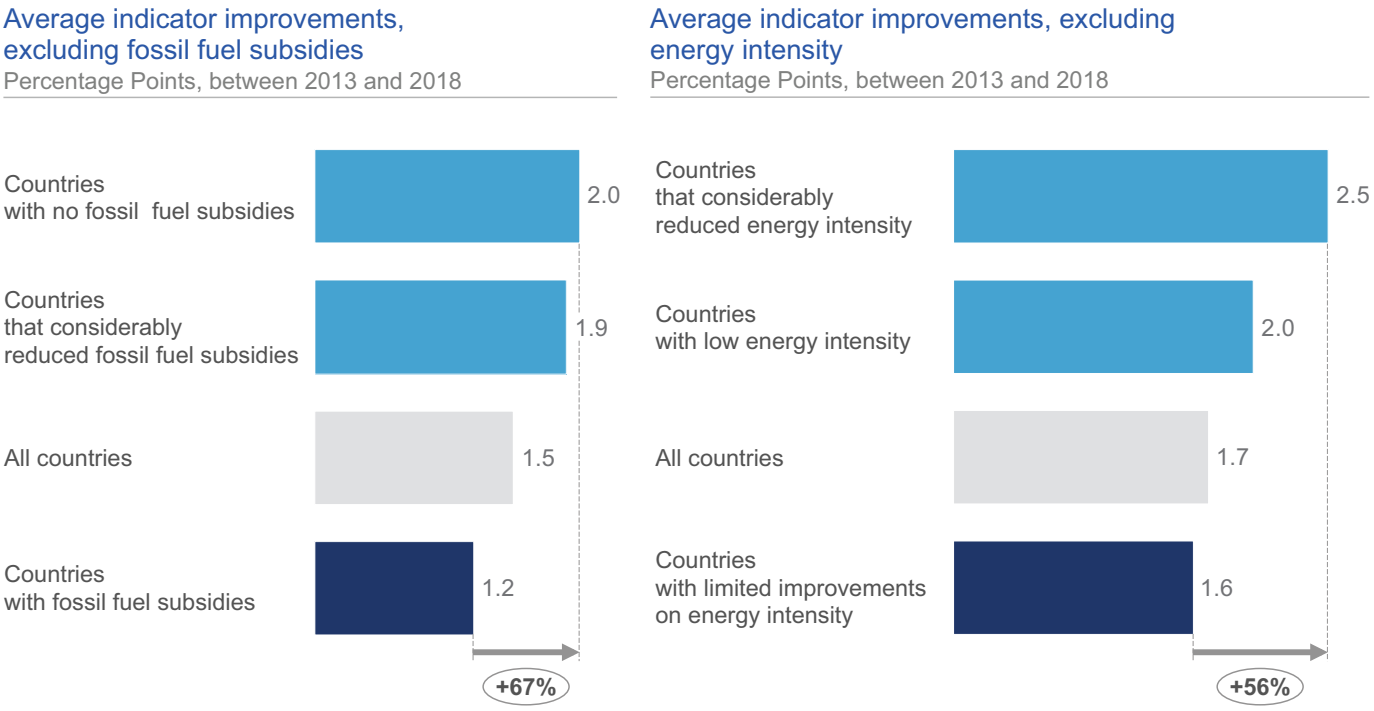
The index results are in line with the numerous analyses on fossil fuel subsidies.[70, 71, 72] Countries with no subsidies or that removed large amounts of fossil fuel subsidie[73] showed more than 50% higher improvement rates in other indicators (Figure 10). Generally, no country with fossil fuel subsidies exceeding 1% of GDP ranks in the top quartile of the index.[74] The latter suggests that the removal of fossil fuel subsidies can positively impact other dimensions of the energy triangle. Since 2013, several countries have reduced their fossil fuel subsidies, mainly due to fiscal pressures from reduced oil and gas prices. In some cases, this subsidy removal has been accompanied by favourable policies for renewable energy.[75]

Energy intensity

Countries that improved their energy intensity between 2013 and 2018 by at least 2.5 times higher than average[76] showed greater than 50% improvement in other indicators than countries with moderate or no improvements (Figure 10). Countries with already low energy intensity[77] also showed overproportionate improvement in the other indicators. Generally, improvements in energy intensity have been driven by the countries with high performance scores, further increasing the gap between top and bottom performers.

Figure 10: Indicator improvements with wider system implications

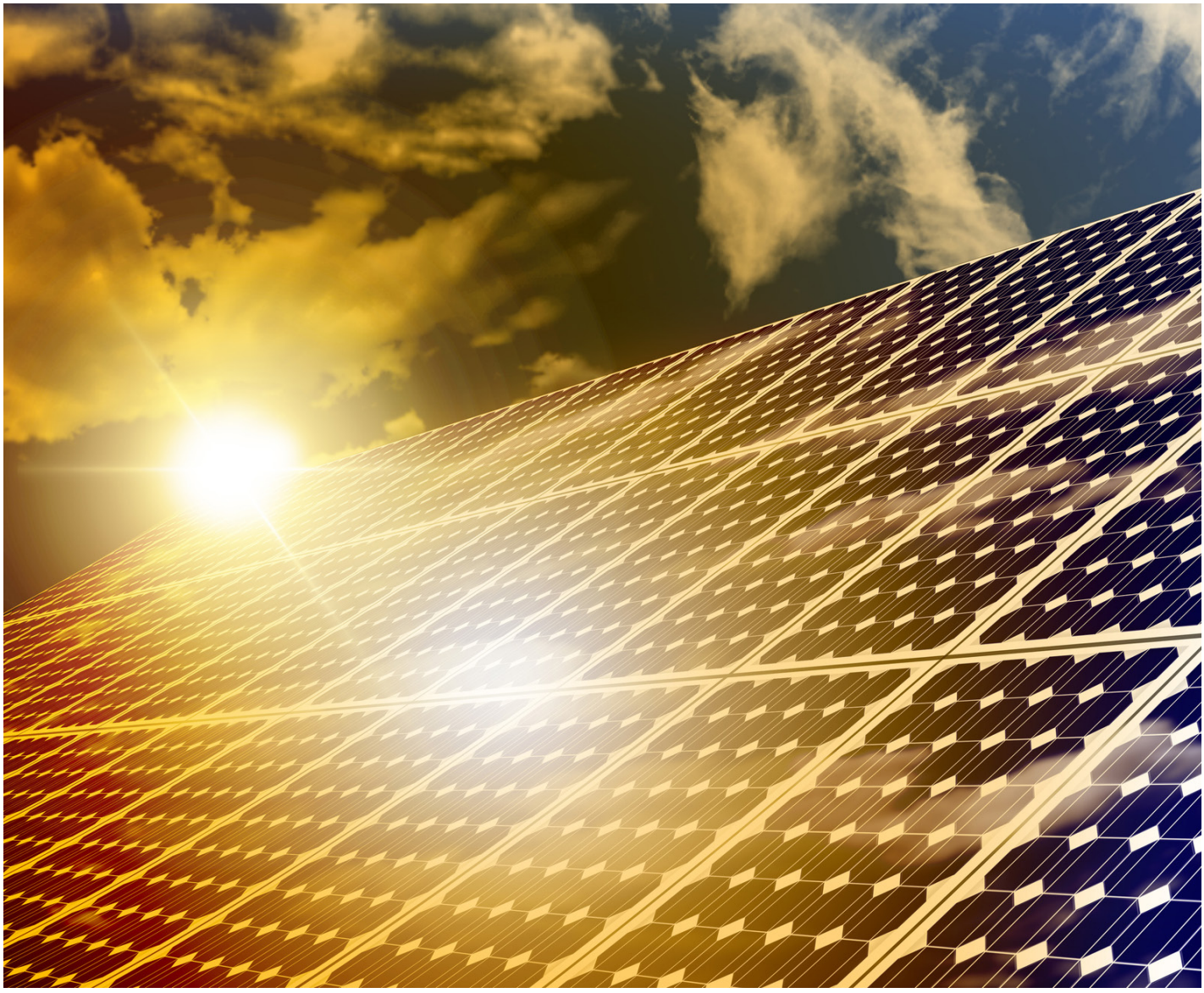
Source: World Economic Forum with support from McKinsey & Company



Box 6: Energy subsidies[79]

Globally, more than $600 billion p.a.[80] is allocated to energy subsidies, affecting the fiscal balances and policy behaviours of both energy consumers and producers. The reform or elimination of this type of policy is frequently referred to, particularly in low-price environments, as a win-win course of action that has the potential to positively impact the three corners of the energy triangle: sustainability, economic growth, and security and access.

In practice, however, policies to eliminate subsidies face strong opposition from the groups that benefit from them, and experiences with subsidy reform are mixed. In addition to purely economic merits, proper consideration needs to be given to the political economy realities of reforming/eliminating subsidies. Recipients of energy subsidies frequently carry political weight and suppliers usually find that providing subsidies is politically cost-effective. Furthermore, once an energy subsidy is in place, economic and political actors concerned galvanize around it, making reform challenging.



4. Country energy transition roadmaps

The energy transition framework and the index support a call to action for policy-makers, businesses and society to improve the quality of life of their people by creating an enabling environment for effective energy transition.

Having all the enabling factors in place is not a trivial task and their establishment is sometimes a function of broader macroeconomic or political shifts. Moreover, stakeholders will need time to improve infrastructure gaps or address human capital challenges, as well as allocate resources to solve issues in areas like institution stability or market volatility.

However, stakeholders in all countries can create a vision for their energy transition, define actions and prioritize initiatives that maximize benefits for the overall system. The analytical framework and index can help them to identify good practice examples and construct an energy transition roadmap that effectively supports decision-making on a national level.

Peer group comparison

Countries approach energy transition from a variety of contexts, institutional arrangements, structural backgrounds and natural resource endowments. In that light, a "blind" comparative index analysis could yield limited benefits in terms of lessons learned or best practice identification.

It is therefore beneficial to compare countries by peer group, defined by geography, development status, other unique characteristics of countries' energy systems or economies – depending on the objective of the comparison. This will allow countries to recognize relative strengths and improvement areas and to prioritize relevant initiatives for their country-specific roadmaps. Figure 11 shows how selected peer groups compare on their system performance and transition readiness.

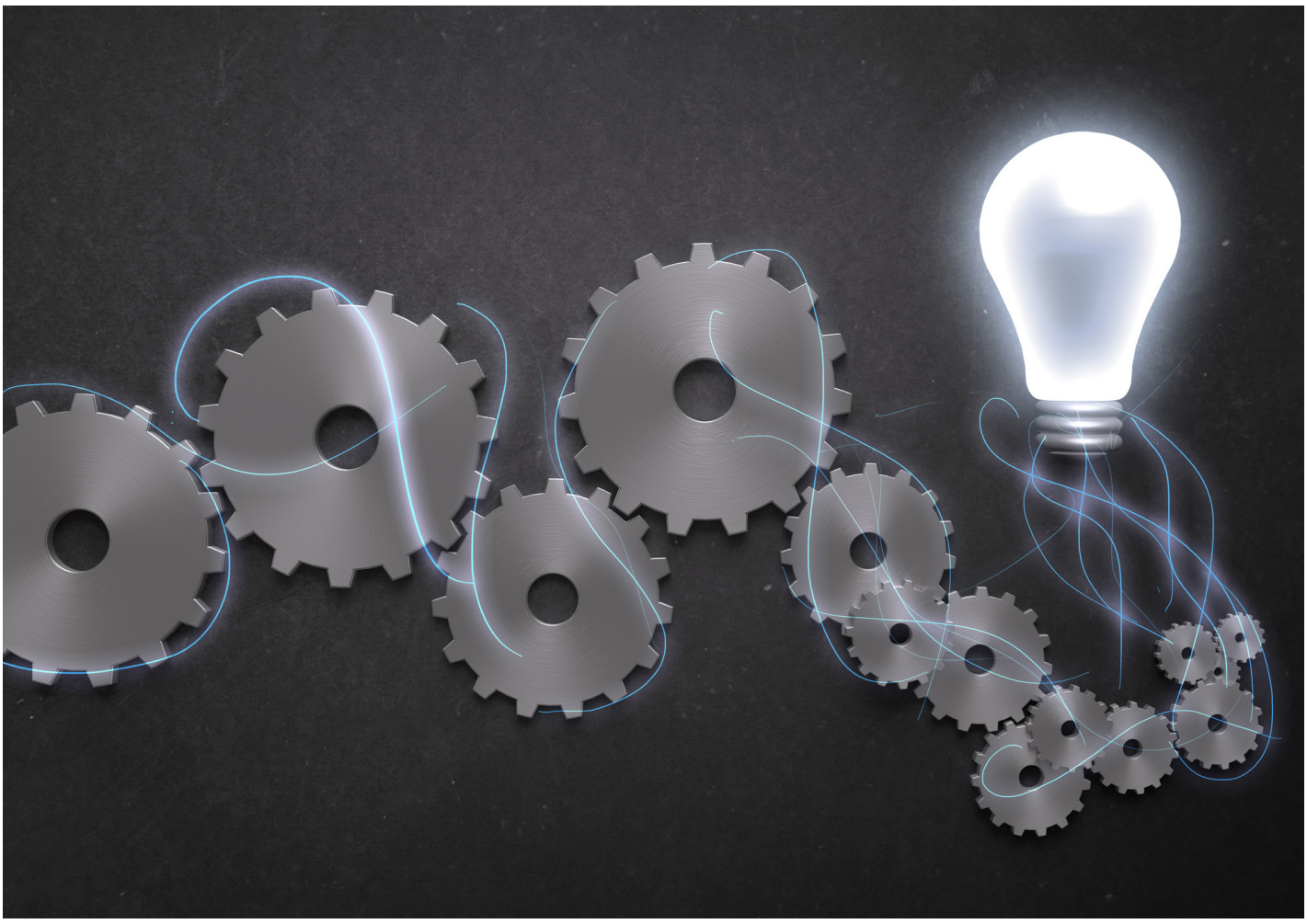


Figure 11: System performance and transition readiness per selected peer groups

Source: World Economic Forum with support from McKinsey & Company

Transition roadmaps

A country-specific transition roadmap is a tool to support timely, transparent and effective energy transition. It provides a long-term, cross-sectoral vision, comprising clear imperatives, goals and major milestones for the energy transition in a given country. Such a roadmap allows the establishment of the required enablers as outlined in the framework for effective energy transition, including integrated policy frameworks, stable policies and certainty for investors and consumers.

Developing an energy transition roadmap requires a systemic approach that considers all stakeholders, regional specificities and decision timing, and anticipates unintended consequences. If developed thoroughly, it provides several benefits for all stakeholders. These derive from a common understanding of the imperatives of the energy transition, transparency on timing, the extent of the expected changes, clarity on how to measure progress, prioritization of the most effective improvement initiatives, and increased predictability from consistent, yet agile policy frameworks. It is important that an energy transition roadmap, while defining a long-term vision and targets, maintain the flexibility to capture the full potential from innovation and fast-moving technologies.

Formulating a country transition strategy that enables economic growth is not straightforward. Several elements need to be taken into account, including:

- The impact on energy affordability, security and sustainability for different stakeholder groups
- The supply and demand of different energy sources
- The regional integration of energy infrastructures
- Capital requirements and cost allocation
- The (regional) impact on existing jobs
- Workforce requirements for potential new industries and the application of new technologies
- The impact on economic value added for existing businesses
- Timing implications and lead times for introducing new technologies
- New policies, regulatory and market design considerations
- Local, national and regional political constraints

Work conducted by McKinsey in the Netherlands,[81] a country with significant improvement potential in environmental sustainability, identified three specific considerations that other governments should keep in mind (see the Netherlands case example below):

- Use optimizing long-term value for the country as the main criterion for the transition roadmap
- When tackling decarbonization, develop specific plans per demand sector; a fact-based plan translates long-term goals into clear short- and medium-term decisions and targets
- Establish incentives, including tax policies, that consider the longer-term challenge ahead; remain agile to encourage citizens and major energy consumers to participate in the energy market overhaul

Case example: Netherlands

Even without abundant natural resources, it is possible to build a high-performing energy system. However, countries with top scores in the ETI still face major challenges. The major focus of McKinsey's work in the Netherlands lay on reducing carbon emissions while maintaining, and further improving, the contribution of the current energy system to economic development and growth as well as secure access to energy.

According to the International Energy Agency (IEA)'s report on CO_2 Emissions from Fuel Consumption, a limited number of cases exist where industrialized countries maintained high standards of living while reducing per capita and per GDP emissions. However, transforming the Dutch energy system to greatly reduce emissions will require significant investment. A crucial question for policy-makers and business leaders is whether there is a way to minimize investment and increase economic benefits through increased efficiency and the creation of new (export) sectors.
The study found that an accelerated but flexible approach to reducing greenhouse gas emissions will yield value in terms of GDP and employment. It was estimated that investing €10 billion per year between 2020 and 2040 in a low-carbon energy system (equivalent to 3% of GDP) would generate a positive GDP impact and potentially create tens of thousands of jobs in the long run, with a minimum of 45,000 installation jobs in the near term.

Positive growth was deemed possible through four main investment themes:

1. Creating nationwide economies of scale through large-scale, planned programmes for technologies that would benefit from central rollout. Attractive areas could include improving building insulation, expanding renewable energy supply and electric-vehicle charging

2. Avoiding investment in less efficient equipment that may need to be replaced with low- or zero-carbon equipment before reaching its economical or technical end-of-life in order to meet targets; leapfrogging to low-carbon or carbon-neutral technologies

3. Attracting and stimulating new economic activity in target sectors, increasing investment in those sectors and developing capabilities to competitively differentiate the Netherlands on a global level

4. Transforming adjacent economic sectors: an accelerated energy transition could spur more investment and innovation in supporting fields; this will require changes in technology, business models and financing, and could make the economy more competitive as a whole

The study estimates that investment and spending on goods and services required for the energy transition will generate GDP growth of 2% in the short to medium term. Over time, this direct effect will slowly fade but, in the

longer term, further upsides can be created. For example, a shift in economic activity away from sectors with lower economic multipliers (like large plants) towards sectors with higher economic and employment multipliers (like construction) will provide a further net boost to GDP. The Netherlands' trade balance could be affected positively as the country will need to import less fossil fuel. The biggest and longest-lasting economic benefits are likely to come from investment in sectors that may generate substantial economic growth and jobs.

5. Way forward

Even in today's environment of fast-paced technological advancement, successful energy transition and system improvement will not happen overnight. Many policy and business decisions made now will not show their full impact immediately. Therefore, if countries want to increase the probability of meeting their mid- and long-term objectives, they must embark on their individual journeys with a sense of urgency independently from their starting positions and transition pathways.

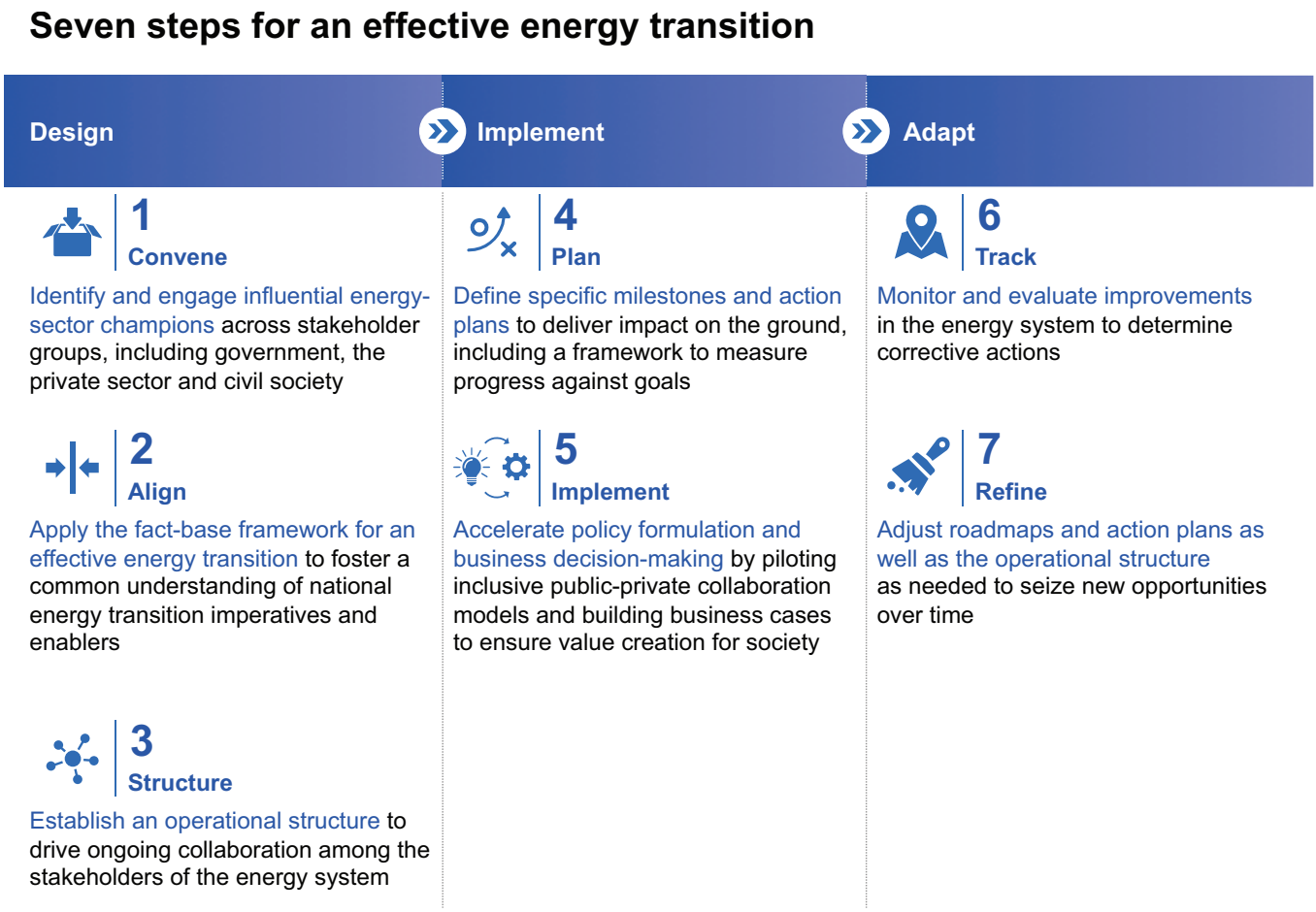
The Forum aims to publish the Energy Transition Index on a regular basis, to provide continuous transparency on individual countries' energy system performance, and for countries to inform their national and regional energy transition assessments. Outcomes from these assessments could feed back into the ETI and contribute to its refinement.

Moreover, the Forum aims to actively work with countries committed to define their transition visions and roadmaps. As the International Organization for Public-Private Cooperation, the Forum supports country-level transition efforts. It can serve as a catalyst and facilitator with its supportive platform to create inclusive engagement from stakeholders across the entire energy system and to foster good practice exchanges by connecting transition efforts globally.

In-country transition efforts can draw from successful experiences and tested frameworks, adapted for energy system challenges (Figure 12). The coordination of country-specific transition efforts should be led by and fully owned by local champions, to ensure full implementation and long-term success. The Forum is confident that locally-owned, country-level action, built from inclusive, public-private cooperation and rooted in a common fact base will create value for stakeholders throughout the energy system and help accelerate an effective energy transition.

Figure 12: Seven steps for an effective energy transition

Source: World Economic Forum with support from McKinsey & Company



Appendices

Complementary efforts

A rich body of work from various organizations complements the framework presented in this document and facilitates a holistic perspective on pathways to foster an effective energy transition. The following is a (non-exhaustive) list of examples:

The Energy Transitions Commission (ETC) aims to accelerate change towards low-carbon energy systems that enable robust economic development and limit the rise in global temperature to well below 2°C.[82]

The World Energy Council's Energy Trilemma Index provides an assessment of countries' ability to balance the trade-offs between energy security, energy equity (accessibility and affordability) and environmental sustainability. It also provides comprehensive country profiles for the three dimensions of the trilemma.[83]

The Energy Security Risk Index of the Global Energy Institute provides detailed insights into energy security risks for major energy consuming countries in absolute terms as well as relative to the OECD average.[84]

Sustainable Energy for All (SEforALL) aims to empower leaders to broker partnerships and unlock finance to achieve universal access to sustainable energy. Its objective is to ensure universal access to modern energy services, doubling the global rate of improvement in energy efficiency, and doubling the share of renewable energy in the global energy mix by 2030.[85]

Regulatory Indicators for Sustainable Energy (RISE) benchmarks national policies and regulatory frameworks on energy access, energy efficiency and renewable energy.[86]

The IEA Policy and Measures databases offer access to information on energy-related policies and measures taken or planned to reduce greenhouse gas emissions, improve energy efficiency and support renewable energy development and deployment.[87]

The PBL Netherlands Environmental Assessment Agency provides the Climate Pledge Nationally Determined Contribution (NDC) tool, which projects country-level emissions to 2030, under the scenario of full implementation of Paris Agreement NDCs, and under the trajectory of current national climate and energy policies.[88]

The Climate Action Tracker tracks the emission commitments and actions of countries and provides an up-to-date assessment of individual national pledges, targets and NDCs as well as currently implemented policy to reduce their greenhouse gas emissions.[89]

Addendum on the methodology

This section presents the methodology for the global Energy Transition Index (ETI) 2018, a composite index that measures two main elements:

- A country's energy system performance across the three imperatives of the energy triangle: 1) economic development and growth; 2) environmental sustainability; and 3) energy access and security
- A country's energy transition readiness across six main areas that enable energy system improvement as part of the energy transition: 1) capital and investment; 2) regulation and political commitment; 3) stable institutions; 4) infrastructure and innovative business environment; 5) human capital and consumer participation; and 6) energy system structure

Methodology overview

The ETI focuses on tracking specific indicators to measure the energy system performance of a variety of countries. The overall ETI score and rank is the average of two scores (Figure A1).

System performance score[90]

Seventeen indicators are aggregated into three categories, one for each of the imperatives, to both score and rank the performance of each country's energy system performance. These three category sub-scores are then averaged to generate the system performance score. The three sub-scores are:

- **Environmental sustainability:** The extent to which the energy system has been constructed to minimize negative environmental externalities
- **Economic development and growth:** The extent to which the energy system supports, rather than detracts from, economic development and growth
- **Energy access and security:** The extent to which the energy system places energy security at risk, and whether adequate access to energy is provided to all parts of the population

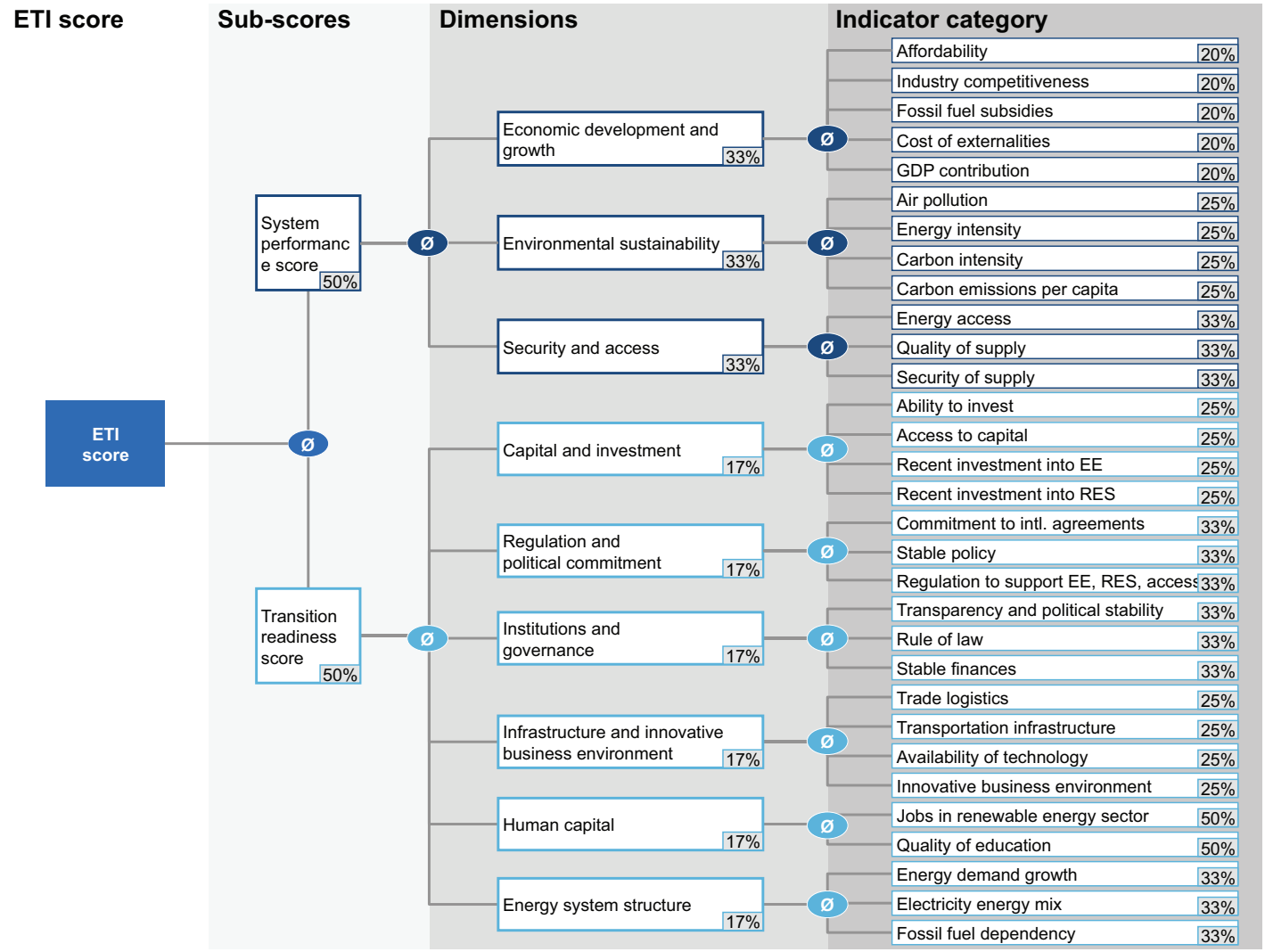
Transition readiness score

Twenty-three indicators are aggregated into six categories, one for each of the enabling dimensions, to both score and rank the transition readiness of each country's energy system. These category sub-scores are averaged to generate the transition readiness score. The six sub-scores are:

- Capital and investment
- Regulation and political commitment
- Institutions and governance
- Infrastructure and innovative business environment
- Human capital and consumer participation
- Energy system structure

Figure A1: Energy Transition Index indicators

Source: World Economic Forum with support from McKinsey & Company



Indicators: Selection criteria and profiles

Where possible, the ETI team aimed to select indicators using the following criteria:

- **Reliability:** Using reliable source data from renowned institutions
- **Quality:** Selecting data that represents the best measure available given constraints; all potential data sets were reviewed by the expert panel for quality and verifiability, and those that did not meet these basic quality standards were discarded
- **Completeness:** Using data of adequate global and temporal coverage
- **Reusability:** Sourcing data from providers with which the ETI can work on a regular basis, thus allowing for data to be updated with ease

Where data is missing for a particular year, the latest available data point is extrapolated forwards.

Indicators profile

Figure A2 details each of the indicators selected to calculate the system performance score, the weight attributed to it within its category, what it measures and the energy system objective that it contributes to, either positively or negatively.

Figure A3 details each of the indicators selected to calculate the transition readiness score, the weight attributed to it within its category, what it measures and the enabling dimension that it contributes to, either positively or negatively.

Figure A2: System performance score indicators

Source: World Economic Forum with support from McKinsey & Company

Imperative	Measure (of)	Indicator name	Weighting
Economic development and growth	Affordability	Household electricity prices (PPP $c/kWh)	0.20
	Cost competitiveness	Industry electricity prices ($c/kWh)	0.10
		Wholesale gas price ($/mmbtu)	0.10
	Cost-reflective prices	Fossil fuel subsidies (% of GDP)	0.20
	Externalities	Unpriced cost of externalities (% of GDP)	0.20
	Supports/detracts from growth	Value of energy exports (% of GDP)	0.10
		Cost of energy imports (% of GDP)	0.10
Environmental sustainability	Air pollution	PM2.5 ($\mu g/m^3$)	0.25
	Energy intensity	Energy intensity (MJ/$2011 PPP GDP)	0.25
	Carbon intensity	CO_2 intensity (kg/GJ TPES)	0.25
	Carbon emissions per capita	CO_2 emissions per capita (tonnes/capita)	0.25
Energy access and security	Energy access	Electrification rate (% of population)	0.17
		Solid fuels use (% of population)	0.17
	Supply security	Energy imports (% of energy use)	0.11
		Import counterpart diversification (HHI)	0.11
		Diversity of TPES (HHI)	0.11
	Supply quality	Quality of electricity supply (Index)	0.33

Figure A3: Transition readiness score indicators

Source: World Economic Forum with support from McKinsey & Company

Enabler dimension	Measure (of)	Indicator name	Weighting
Capital and investment	Ability to invest	Investment Freedom (Index)	0.25
	Capital availability	Access to Credit (Index)	0.25
	Investment	Investment in energy efficiency (% of total)	0.25
		Renewable capacity buildout (% of total)	0.25
Regulation and policy	Commitment to international contracts	Commitment to COP21 NDCs (Index)	0.33
	Policy stability	Stability of Policy (Index)	0.33
	Regulatory support	Regulatory Indicators for Sustainable Energy (Index)	0.33
Stable institutions	Transparency	Corruption Perception (Index)	0.33
	Rule of law	Rule of Law (Index)	0.33
	Credit rating	Credit Rating (Index)	0.33
Infrastructure and innovative business environment	Trade logistics	Logistics Performance (Index)	0.25
	Transportation	Quality of Transportation Infrastructure (Index)	0.25
	Technology	Availability of Technology (Index)	0.25
	Business environment	Innovative Business Environment (Index)	0.25
Human capital and consumer participation	Workforce impact	Jobs in low-carbon industries (%)	0.50
	Qualifications	Quality of Education (Index)	0.50
Energy system structure	Maturity of energy system	Energy per capita (GJ/capita)	0.33
	Power generation mix	Share of electricity from renewable generation (%)	0.11
		Share of electricity from coal generation (%)	0.11
		Flexible electricity supply (%)	0.11
	Fossil fuel dependency	Fossil fuel reserves (CO_2 emissions, billion Mt)	0.33

Selected country examples

Of the peer groups mentioned previously, selected examples of countries and regions are provided below, based on ETI results and dialogues with key stakeholders in their respective energy systems:

- **China**: a G20 member within the leapfrog category. It has the largest population globally, the highest primary energy consumption (125,000 PJ)[92] and the highest carbon emissions from the energy system (9,100 Mt CO_2).[93]
- **India**: a G20 member within the emerging category. It has the largest share of people globally who lack electricity access (approximately 240 million)[94] and, together with China, it is expected to be the largest contributor to GDP and energy demand growth over the next two decades.[95] It has also been the biggest driver of incremental CO_2 emissions over the last three years.[96]
- **Europe**: a region that comprises a large number of high-income countries primarily part of the leading countries category. It includes many countries with high GDP per capita, and as a region accounts for the third highest primary energy consumption (71,500 PJ) and carbon emissions (3,400 Mt) globally.[97]
- **Saudi Arabia**: a G20 member within the emerging category. It embarked on its transition journey recently, is the largest oil exporter globally and a prominent member of OPEC.
- **Kenya**: a country within the leapfrog category. It shows the highest readiness scores among Sub-Saharan countries, whose population faces energy access challenges.

China

China accounts for 15% of global GDP, 18% of the global population, 30% of global carbon emissions and has been the biggest driver of global energy demand growth over the last 10 years.[98] Within the ETI, China ranks in the bottom performance quartile and second readiness quartile, making it part of the leapfrog category.

Between 2013 and 2018, China improved its performance score by 2.5 percentage points, mainly through better energy intensity, increased diversity of its primary energy supply through more natural gas, hydro, nuclear and renewables, and reduced import costs.

China's security and access score ranks 5 percentage points above the global average, its economic development and growth score is 10 percentage points below average and its environmental sustainability score is 30 percentage points below average, making the latter the biggest improvement area. The low environmental sustainability score is mainly due to China's dependency on coal as the primary energy source (73% of electricity generation), which results in low performance of its CO_2 intensity and particle emissions.[99]

China's transition readiness (rank: 46/114) indicates that it has made large efforts to prepare itself for the energy transition, despite its relatively unfavourable energy system structure (rank: 109/114). Of special note are its systematic regulation and political commitment (rank: 2/114) – reflected in an ambitious five-year plan – and large financial investments to support the improvement of energy efficiency and development of renewable energy (rank: 51/114). China is already investing over $100 billion domestically in renewables every year and has become the largest investor in renewable energy overseas, strengthening its position among the leading countries in renewable energy supply chains.[100] In 2016, China accounted for more than 40% of global employment in the renewable energy industry.[101]

However, the rapid development of renewable energy has outpaced electricity demand and led to inefficiencies in China's power system, creating challenges for the different market participants.[102] Countries that faced similar challenges in the past could serve as case examples of how to adapt market design and business models.

India

India is one of the largest consumers of energy (36,000 PJ),[103] and its demand is projected to grow. India's energy needs are primarily met by fossil fuels (74% of TPES),[104] with implications for environmental sustainability (score: 40%) and increasing energy import costs. Furthermore, a considerable share of India's population still lacks access to electricity and clean cooking fuel. In the ETI, India ranks in the third performance quartile and third readiness quartile, making it an emerging country that is approaching the leapfrog category.

Between 2013 and 2018, India improved its performance score by 5.6 percentage points, mainly with improved energy access, reduced subsidies and reduced import costs. India's economic development and growth score ranks 15 percentage points below average, its environmental sustainability score ranks 9 percentage points and its security and access score ranks within the average.

Considerable challenges remain in India's transition towards a secure, sustainable, affordable and reliable energy future. Recent initiatives to improve electricity access have experienced some success and the outlook is positive;[105] however, the road to continuous access to power and clean cooking fuel for all is long. Also, challenges from technical and commercial losses remain. The results of recent initiatives on separating feeders for agricultural supply and reviving the fiscal health of distribution companies are still pending.

India has the largest government-mandated renewable energy programme, with a target of 175 GW renewable energy capacity by 2022, and it announced plans to shift completely to electric vehicles by 2030. Along with significant measures on domestic energy efficiency, these initiatives can also target environmental sustainability and import independence.

The Indian renewable energy landscape shows promise, with subsequent renewable energy auctions clearing at prices lower than those in long-term thermal power purchase contracts. However, this has also cast uncertainty

on the economic viability of thermal power plants, which account for 58% of India's primary energy supply.[106] Significant investment in evacuation infrastructure and strong regulatory frameworks are needed for better grid stability and improved performance.

Europe

The EU, Norway and Switzerland demonstrate how a region can improve an energy system through the deployment of new technology and collaboration. Approximately 75% of European countries are part of the leading country category, and 15 of the top 20 countries in the ETI are European. Between 2013 and 2018, all European countries improved their performance scores, resulting in an average economic development and growth score of 63%, an environmental sustainability score of 54%, and a security and access score of 84%.

Since 2010, EU28 greenhouse gas emissions were reduced by 9%[107] and the energy intensity of European OECD countries ranges 27% lower than the OECD average.[108] Europe's power mix has a larger share of zero-carbon emitting generation technologies (>50%) than other large industrial nations.[109]

However, with an environmental sustainability score of 54%, European countries still have improvement potential. Reaching the ambitious COP21 decarbonization targets will require further effort (see the Netherlands case example). Moreover, energy prices are already among the highest globally and Europe remains dependent on fossil fuels and scarce resources from abroad.[110]

In the *New Concept for Europe* progress report, the World Economic Forum identified several opportunities for Europe to capture opportunities from the energy transition by empowering digitally enabled consumers and citizens and by using Fourth Industrial Revolution digital tools to optimize and balance electricity, heating, transport and other energy networks. The goal described is for Europe to power itself in a green, affordable and secure manner to achieve the Paris Climate Agreement targets by developing an integrated, connected and sustainable energy supply and by enabling smart energy and resource consumption. Concrete methods mentioned include the acceleration of the phaseout of subsidies for high-emission energy sources, integrated and more efficient heating, the introduction of policies and standards promoting zero-emission buildings by 2030, and open access to energy data to foster new energy business models.

Saudi Arabia

Saudi Arabia is the largest oil exporter globally and possesses around 22% of the world's petroleum reserves. Around 85% of its export earnings come from the oil and gas sector, which also accounts for about 50% of its GDP.[111] For Saudi Arabia and countries whose economies are reliant on the energy sector, an effective energy transition is important, as they are expected to face economic, fiscal and employment challenges as a result of the global push towards emission reductions.

Although many countries have realized they can improve their readiness by diversifying their energy mix and shifting capital to avoid exposure to uncertainty in oil demand and oil price volatility, they are at different stages in their preparations for energy transition.

In the ETI, Saudi Arabia ranks in the third quartile for system performance and transition readiness. Security and access (rank: 29/114) and economic development and growth (rank: 40/114) are driving performance, while the biggest challenges lie within environmental sustainability (rank: 111/114). High carbon intensity, per capita emissions and high particle emissions are major challenges.

To prepare for the transition, the Kingdom has established ambitious targets as part of its Vision 2030, including a clear roadmap for renewable energy development, the diversification of its economic activity and the participation of foreign stakeholders in the energy system. However, it will take time for the results of their energy transition to be fully reflected in the ETI scores.

Box 7: Employment in fossil fuel industries and transition readiness

According to the International Labour Organization statistical division, ILOSTAT, countries with a higher share of employment in fossil fuel industries[112] show lower levels of transition readiness in the Energy Transition Index. A higher share in fossil fuel employment is expected to create further transition challenges in the form of additional stakeholder engagement requirements and potential long-term labour market implications. Such challenges seem to impact the overall transition readiness for some countries.

However, the correlation is weak overall and shows three major outliers (Norway, Qatar and Brunei). Also, China, the country with the highest absolute number of people employed in fossil fuel industries, has the biggest share of jobs in renewable energy, which shows that it is possible for a fossil fuel energy sector and a new energy sector to complement each other.

Kenya

Kenya is the fourth largest economy in Sub-Saharan Africa and has progressed in providing access to electricity for its people in recent years.[113]

Within the ETI, Kenya ranks in the bottom performance quartile and top readiness quartile. While Kenya scores 15 percentage points higher than average on environmental sustainability (rank: 20/114), it shows 14 percentage points lower performance on economic development and growth and 39 percentage points lower performance on security and access (rank: 108/114). Its comparatively high performance in environmental sustainability is driven by the low-carbon intensity of its energy consumption, supported by a rich source of low-carbon energy in the form of geothermal, hydro and, increasingly, solar and wind power. Challenges within security and access are mainly driven by the energy access and quality of supply categories.

However, the trajectory is promising: between 2011 and 2014, Kenya managed to almost double electricity access from 25% to 46%. For countries with similar challenges, Kenya can be viewed as a good example of strong regulatory frameworks supporting energy access policy,[114] which incentivize private stakeholders to invest. Mini-grid deployment is supported by clear standards and last-mile connectivity by a grid densification programme, which is funded through connection fee subsidies.[115]

Box 8: Using solar home systems to improve electricity access in rural areas

Improving access to modern forms of energy has a positive impact on the entire energy system, not only the security and access dimension. For instance, replacing kerosene, candles or biomass with cleaner forms of energy reduces the per-unit cost, addresses health implications for its users and supports economic development.

Solar home systems offer a quick and relatively cheap solution to provide access to remote rural areas. McKinsey identified key elements to describe countries' attractiveness for a solar home system rollout: 1) off-grid regulations; 2) a business enabling environment; 3) logistics and channels; 4) affordability and willingness to pay; and 5) ease of payment.

Weights, measures and abbreviations

$	All $ in US$ unless otherwise noted
CCUS	carbon capture utilization storage
CH_4	methane
CO_2	carbon dioxide
COP21	United Nations 21st Conference of the Parties
EEA	European Energy Agency
ETC	Energy Transitions Commission
ETI	Energy Transition Index
EU	European Union
EU28	28 Member States of the European Union
g	gram
G20	Group of governments and central bank governors from 20 leading economies
GDP	gross domestic product
GHG	greenhouse gas
GJ	gigajoule
GW	gigawatt
HHI	Herfindahl-Hirschman Index
IEA	International Energy Agency
IEF	International Energy Forum
IISD	International Institute for Sustainable Development
IMF	International Monetary Fund
IRENA	International Renewable Energy Agency
kg	kilogram
kWh	kilowatt hour
LNG	liquefied natural gas
MJ	megajoule
mmbtu	1 million British Thermal Units (BTU)
Mt	metric ton
NDC	nationally determined contribution
OECD	Organisation for Economic Co-operation and Development
PJ	petajoule
PM2.5	particulate matter less than 2.5 micrometers in diameter (also called fine particles)
PPP	purchasing power parity
SEforALL	Sustainable Energy for All initiative (co-chaired by the United Nations and World Bank Group)
TPES	total primary energy supply
UNFCCC	United Nations Framework Convention on Climate Change
WB2C	world below 2 degrees

Acknowledgements

The World Economic Forum is pleased to acknowledge and thank the individuals and partners listed here, without whom the work on the Fostering Effective Energy Transition Energy System Initiative would not have been possible.

We thank Woodrow Wilson Center for International Scholars (Washington DC), Chatham House (London) and KAPSARC (Riyadh) for supporting the project's dialogue series. In addition to the named contributors below, acknowledgement and sincere gratitude go to a broad community of others in the private, government, civil society and academic sectors for their participation in the project. These participants remain anonymous because all roundtable discussions and expert interviews were held under the Chatham House Rule.

McKinsey & Company
Knowledge Partner, providing expertise and analytical support
Thomas Seitz, Senior Partner
Sebastien Leger, Partner
Arnout de Pee, Partner
Kassia Yanosek, Partner

Chief expert advisers
Morgan Bazilian, Lead Energy Specialist, World Bank, USA
Alesandro Blasi, Lead Program Manager, International Energy Agency, Paris
Dominic Emery, Vice-President, Long-Term Planning, BP, United Kingdom
Lin Boqiang, Dean, China Institute for Studies in Energy Policy, Xiamen University, People's Republic of China
Bertrand Magne, Senior Economist and Energy Specialist, SEforALL, Austria
Davide Puglielli, Senior Manager, Strategy and Mergers and Acquisitions, Enel, Italy
David Turk, Head, Energy and Climate Division, International Energy Agency, Paris
David Victor, Professor, University of California, San Diego (UCSD), USA
Eirik Waerness, Senior Vice-President and Chief Economist, Statoil, Norway
Rigoberto Ariel Yepez-Garcia, Chief, Energy Division, Inter-American Development Bank, Washington DC

Data partners
Climate Action Tracker, Fitch Ratings, Heritage Foundation, International Energy Agency, International Gas Union, International Monetary Fund, International Renewable Energy Agency, Moody's, PBL Netherlands Environmental Assessment Agency, Standard & Poor's, Transparency International, UN SEforALL, UN Statistics Division and UNCTADstat, World Bank Group, World Trade Organization

Contributors
Roberto Bocca, Head of Energy and Basic Industries, Member of the Executive Committee
Thierry Geiger, Head of Analytics and Quantitative Research, Global Competitiveness and Risks
Pedro G. Gómez Pensado, Head of Oil and Gas Industry
Daniel Hund, Project Collaborator seconded to the Forum by McKinsey & Company - Lead Author
Bandar Al-Khamies, Knowledge Lead, Future of Energy System Initiative
Espen Mehlum, Head of Knowledge Management and Integration, Energy Industries
Harsh Vijay Singh, Project Lead, System Initiative on Shaping the Future of Energy

Endnotes

1. For further details see “Game Changers in the Energy System”, World Economic Forum, 2017, available at http://www3.weforum.org/docs/WEF_Game_Changers_in_the_Energy_System.pdf.
2. World Economic Forum, *Global Energy Architecture Performance Index Report 2017*, available at www.weforum.org/reports/global-energy-architecture-performance-index-report-2017.
3. United Nations, *World Population Prospects: The 2017 Revision*, available at www.un.org/development/desa/publications/world-population-prospects-the-2017-revision.html.
4. Energy Transitions Commission, “Better Energy, Greater Prosperity”, available at www.energy-transitions.org/better-energy-greater-prosperity.
5. International Energy Agency, *Energy Access Outlook 2017: From Poverty to Prosperity,* World Energy Outlook Special Report, available at www.iea.org/publications/freepublications/publication/WEO2017SpecialReport_EnergyAccessOutlook.pdf.
6. Purchase power adjusted.
7. Savings of $290-390 million in yearly productivity improvements in the oil and gas and mining industry, $310-540 million in energy efficiency savings and $150-280 million in transportation efficiency savings; see “How technology is reshaping supply and demand for natural resources”, McKinsey Global Institute, February 2017, available at https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/how-technology-is-reshaping-supply-and-demand-for-natural-resources.
8. International Renewable Energy Agency (IRENA); McKinsey; The cost of wind, solar and storage technology between 2010 and 2016 reduced by approximately 30%, 70% and 75%, respectively.
9. International Renewable Energy Agency (IRENA), *Renewable Energy and Jobs: Annual Review 2017*, available at https://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Jobs_Annual_Review_2017.pdf.
10. U.S. Energy Information Administration, “Henry Hub Natural Gas Spot Price” (dollars per million BTU), 2010-2016, available at https://www.eia.gov/dnav/ng/hist/rngwhhdA.htm.
11. Share of electricity net production from coal in the United States declined from 45% to 30% while net production from natural gas increased from 24% to 34%; U.S. Energy Information Administration, “Net generation for United States, monthly, 2002-2016, available at https://www.eia.gov/electricity/data/browser/#/topic/0?agg=2.
12. See also the World Economic Forum report, *The Future of Electricity: New Technologies Transforming the Grid Edge*, available at www.weforum.org/reports/the-future-of-electricity-new-technologies-transforming-the-grid-edge.
13. Bloomberg New Energy Finance; by 2015, more than 20 million pico solar products had been sold to off-grid consumers, providing basic energy access to people otherwise disconnected to clean and affordable energy.
14. In combination with the decarbonization of the electricity generation mix.
15. In the United States alone, a combination of policy changes (e.g. BEV subsidies, tax incentives) and shifting consumer preferences resulted in sales of 160,000 electric vehicles; McKinsey, “Dynamics in the global electric-vehicle market”, July 2017, available at https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/dynamics-in-the-global-electric-vehicle-market#0.
16. Australia can serve as an example for the rise of the “prosumer”, where more than 20% of households produce their own electricity through rooftop PV installations and use new digital technologies to reverse the flow of electrons and sell back to the grid; RenewEconomy, “One-quarter of Australian homes now have solar”, available at http://reneweconomy.com.au/one-quarter-of-australian-homes-now-have-solar-70886/.
17. BP, “BP Statistical Review of World Energy”, June 2017, available at https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review-2017/bp-statistical-review-of-world-energy-2017-full-report.pdf.
18. International Energy Agency, *Energy Efficiency 2017*, available at https://www.iea.org/publications/freepublications/publication/Energy_Efficiency_2017.pdf.
19. NBCNews, “(Incandescent) lights to go out in China”, November 2011, available at http://www.nbcnews.com/id/45166535/ns/world_news-asia_pacific/t/incandescent-lights-go-out-china/#.WeEUOFuPKMI.
20. United Nations Framework Convention on Climate Change (UNFCCC), “UN Climate Change”, available at http://newsroom.unfccc.int/about; 166 countries ratified the treaty. Syria and Nicaragua did not sign the agreement, and the United States announced their intention to leave the agreement in 2020.
21. India cancelled plans to build 14 GW of new coal generation capacity; CleanTechnica, “India Cancels Nearly 14 Gigawatts Of Proposed Coal Plants”, May 2017, available at https://cleantechnica.com/2017/05/25/india-cancels-nearly-14-gw-proposed-coal-plants/.

22. In January 2017, China's National Energy Administration announced it is cancelling the construction of 85 coal-fired power plants and will invest $350 billion in renewable energy sources; Independent, "China scraps construction of 85 planned coal power plants", January 2017, available at http://www.independent.co.uk/news/world/asia/china-scraps-construction-85-coal-power-plants-renewable-energy-national-energy-administration-paris-a7530571.html.

23. The New York Times, "Britain to Ban New Diesel and Gas Cars by 2040", July 2017, available at https://www.nytimes.com/2017/07/26/world/europe/uk-diesel-petrol-emissions.html.

24. International Energy Agency, *World Energy Investment 2017* report, available at https://www.iea.org/publications/wei2017/.

25. Sustainable Energy for All, available at http://www.se4all.org/; Global LEAP, available at http://globalleap.org/.

26. RE100, see http://there100.org/; ICLEI – Local Governments for Sustainability (International Council for Local Environmental Initiatives), "100% Renewable Energy Cities & Regions Network", available at http://www.iclei.org/activities/agendas/low-carbon-city/iclei-100re-cities-regions-network.html; Renewable Energy Buyers Alliance (REBA), available at http://rebuyers.org/.

27. EP100, see www.theclimategroup.org/project/ep100; Alliance to Save Energy, *Energy Productivity Playbook*, available at http://www.ase.org/sites/ase.org/files/gaep_playbook-energy-productivity_alliance-to-save-energy.pdf.

28. Global Tracking Framework, see http://gtf.esmap.org/.

29. In Europe, the Roadmap 2050 project evaluates the continent's readiness for transition, the near- and long-term prioritization of key actions, and the technical, economic and policy implications. For a general overview of policy on sustainable energy regulation, see World Bank, *Regulatory Indicators for Sustainable Energy: A Global Scorecard for Policy Makers*, 2016, available at http://documents.worldbank.org/curated/en/538181487106403375/pdf/112828-REVISED-PUBLIC-RISE-2016-Report.pdf.

30. European Climate Foundation, *Roadmap 2050*, available at http://www.roadmap2050.eu/attachments/files/Volume1_ExecutiveSummary.pdf.

31. United Nations Sustainable Development Goals, "Goal 7: Affordable and clean energy", available at http://www.un.org/sustainabledevelopment/energy/ and http://www.un.org/sustainabledevelopment/wp-content/uploads/2016/08/7_Why-it-Matters_Goal-7_CleanEnergy_2p.pdf.

32. World Bank, *Doing Business 2017: Equal Opportunity for All*, 2017, available at http://www.doingbusiness.org/~/media/WBG/DoingBusiness/Documents/Annual-Reports/English/DB17-Report.pdf.

33. World Bank, "Affordable and clean energy", available at datatopics.worldbank.org/sdgatlas/SDG-07-affordable-and-clean-energy.html.

34. Stern, N., *Stern Review on the Economics of Climate Change*, Summary of Conclusions, HM Treasury, 2006.

35. International Energy Agency, *CO_2 Emissions From Fuel Combustion Highlights* (2016 edition), available at https://www.iea.org/publications/freepublications/publication/CO2EmissionsfromFuelCombustion_Highlights_2016.pdf

36. International Energy Agency, *Energy Efficiency 2017*, available at https://www.iea.org/publications/freepublications/publication/Energy_Efficiency_2017.pdf.

37. CNBC, "Governments are getting lax about improving energy efficiency, putting climate progress at risk, top policy advisor warns", October 2017, available at https://www.cnbc.com/2017/10/04/nations-are-getting-lax-about-improving-energy-efficiency-iea-warns.html.

38. International Energy Agency, *Energy Efficiency 2017*.

39. Ibid.

40. McKinsey & Company Sustainability & Resource Productivity, "Pathways to a low-carbon economy: Version 2 of the global greenhouse gas abatement cost curve", September 2013, available at https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/pathways-to-a-low-carbon-economy.

41. International Monetary Fund (IMF), "Energy Subsidies in the Middle East and North Africa: Lessons for Reform", March 2014, available at https://www.imf.org/external/np/fad/subsidies/pdf/menanote.pdf.

42. McKinsey Sustainability & Resource Productivity, *Energy efficiency: A compelling global resource*, March 2010, available at file:///C:/Users/EP-FST/Downloads/A_Compelling_Global_Resource%20(1).pdf.

43. For example, the shift from internal combustion engines to electric vehicles, International Council on Clean Transportation, "Literature review of electric vehicle consumer awareness and outreach activities", March 2017, available at http://www.theicct.org/sites/default/files/publications/Consumer-EV-Awareness_ICCT_Working-Paper_23032017_vF.pdf.

44. International Energy Agency, *Energy efficiency indicators: Highlights*, December 2016, available at https://www.iea.org/publications/freepublications/publication/EnergyEfficiencyIndicatorsHighlights_2016.pdf.

45. McKinsey Sustainability & Resource Productivity, *Energy efficiency: A compelling global resource.*

46. World Bank, *Regulatory Indicators for Sustainable Energy: A Global Scorecard for Policy Makers*, 2016, available at http://documents.worldbank.org/curated/en/538181487106403375/pdf/112828-REVISED-PUBLIC-RISE-2016-Report.pdf.

47. Years for comparison (2013 and 2018) refer to the respective ETI results and 2013 data is backdated and used for trajectory analysis only.

48. Quartiles are defined as: first (75th to top), second (50th to 75th), third (25th to 50th), fourth (bottom to 25th).

49. Sustainable Energy for All, see http://www.se4all.org/our-mission.

50. Average score of countries in the top performance quartile: 84%; average score in the bottom performance quartile: 40%.

51. International Energy Agency, *World Energy Outlook 2017*, November 2017, available at www.iea.org/media/workshops/2017/cop23/presentations/16NovWEOSDSGuel.pdf.

52. Energy Transitions Commission, "Better Energy, Greater Prosperity", available at www.energy-transitions.org/better-energy-greater-prosperity.

53. Estimates suggest that energy efficiency investment would need to increase by a factor of 3-6 from current levels of $250 billion a year to reach the 2030 objective; The Beam, "5 Things We Learned From The Newly Updated 'Heat Maps' Developed By Sustainable Energy For All", September 2017, available at https://cleantechnica.com/2017/09/21/5-things-learned-newly-updated-heat-maps-developed-sustainable-energy/.

54. BP, "BP Statistical Review of World Energy", June 2017, available at www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review-2017/bp-statistical-review-of-world-energy-2017-full-report.pdf.

55. International Energy Agency, *CO_2 emissions from fuel combustion: Overview* (2017 edition), available at https://www.iea.org/publications/freepublications/publication/CO2EmissionsFromFuelCombustion2017Overview.pdf.

56. Emissions from electricity are all allocated to heat and electricity and not the end consumer.

57. Examples for coal-heavy systems are China and Mongolia with >70 kg CO_2 per gigajoule (GJ) of primary energy consumed. Examples of low-carbon intensive energy systems are Switzerland, Norway, France, Iceland and several Sub-Saharan African countries.

58. Energy Transitions Commission, "Better Energy, Greater Prosperity".

59. McKinsey & Company, "Electric Vehicle Index (EVI)", available at www.mckinsey.de/elektromobilitaet.

60. Museum of the City, "Air Pollution in Chinese Cities", available at http://www.museumofthecity.org/project/urban-air-pollution-in-chinese-cities/.

61. CNN, "These countries want to ban gas and diesel cars", September 2017, available at http://money.cnn.com/2017/09/11/autos/countries-banning-diesel-gas-cars/index.html.

62. Only countries with >10 metric tons CO_2 emissions were included in the analysis.

63. International Energy Agency, *World Energy Investment 2017* report, available at www.iea.org/publications/wei2017.

64. Between 2010 and 2014, the United States reduced carbon emissions from fuel combustion by 170 million tons.

65. U.S. Energy Information Administration, "Today in Energy, Power sector carbon dioxide emissions fall below transportation sector emissions" January 2017, available at www.eia.gov/todayinenergy/detail.php?id=29612.

66. Category boundaries are defined by above and below median transition readiness and system performance scores.

67. Absolute score improvement in security and access is lower than global mean improvement, as the performance in this dimension is already comparatively high. When comparing relative improvement towards the frontier of a 100% score, improvement rates across all country categories are similar.

68. Given the dependence among system performance objectives and limited substitutability across them, using a geometric average rather than an arithmetic average to compute ETI scores would have been the conceptually more attractive choice. However, as differences in rankings are small for most countries, the Energy Transition Index is computed based on an arithmetic average methodology for simplicity reasons. See the methodology appendix for more details.

69. International Energy Agency, *World Energy Outlook 2017*, November 2017, available at http://www.worldenergyoutlook.org/energyclimate/.

70. International Institute for Sustainable Development, Global Subsidies Initiative, "Placing a Spotlight on Subsidies", available at https://www.iisd.org/gsi/what-we-do.

71. International Monetary Fund, "IMF Survey: Counting the Cost of Energy Subsidies", July 2015, available at http://www.imf.org/en/News/Articles/2015/09/28/04/53/sonew070215a.

72. Indicated as an improvement in the fossil fuel subsidies score of greater than 20 percentage points between 2013 and 2017.

73. This cannot be explained by the absence of energy-rich countries in the top quartile, as several energy-rich countries with no/limited subsidies manage to rank in the top quartile, e.g. Canada, Australia, Norway.

74. One example is Oman, Authority for Electricity Regulation, "Renewable Energy", available at www.aer-oman.org/aer/RenewableEnergy.jsp?heading=0.

75. Indicated as an improvement in the energy intensity score by more than 10 percentage points between 2013 and 2017 (>10% score improvement).

76. Indicated as indicator scores of greater than 80%.

77. The average energy intensity score of top half countries was 67% vs 38% for bottom half countries. The improvement rate between 2013 and 2017 was +4.8 percentage points vs +2.8% percentage points.

78. Energy subsidies refer to both subsidies for fossil fuels and for renewable energy.

79. According to the IEA, in 2014, countries spent $490 billion on fossil fuels and $135 billion on renewable energy technologies and biofuels. See *Financial Times*, "A world map of subsidies for renewable energy and fossil fuels", July 2016, available at www.ft.com/content/fb264f96-5088-11e6-8172-e39ecd3b86fc?mhq5j=e7.

80. McKinsey & Company, "Accelerating the energy transition: cost or opportunity?", September 2016, available at www.mckinsey.com/global-themes/europe/accelerating-the-energy-transition-cost-or-opportunity.

81. For information on the Energy Transitions Commission, see http://www.energy-transitions.org/who-we-are.

82. See the World Energy Council "Energy Trilemma Index", available at https://trilemma.worldenergy.org/.

83. See the Global Energy Institute "Energy Security Risk Index", available at https://www.globalenergyinstitute.org/energy-security-risk-index.

84. For information on Sustainable Energy for All, see http://www.se4all.org/our-mission.

85. See the World Bank Regulatory Indicators for Sustainable Energy, available at http://rise.esmap.org/.

86. See the International Energy Agency Policies & Measures Databases, available at https://www.iea.org/policiesandmeasures/.

87. See the PBL Netherlands Environmental Assessment Agency "PBL Climate Pledge NDC tool", available at http://themasites.pbl.nl/climate-ndc-policies-tool/.

88. For information on the Climate Action Tracker, see http://climateactiontracker.org/about.html.

89. For further details on the objectives of effective energy architecture, see the World Economic Forum *Global Energy Architecture Performance Index Report* for 2013 to 2017.

90. Countries' commitment to NDCs is evaluated based on their participation in the Paris Agreement, the ratification of the agreement, the ambition level of the NDC (based on Carbon Action Tracker data) and the countries' current trajectories to meet the 2030 targets (based on PBL data).

91. International Energy Agency, *World Energy Balances 2017*, available at http://www.iea.org/bookshop/753-World_Energy_Balances_2017.

92. International Energy Agency, *CO_2 emissions from fuel combustion: Overview* (2017 edition).

93. Bloomberg, "Living in the Dark: 240 Million Indians Have No Electricity", January 2017, available at www.bloomberg.com/news/features/2017-01-24/living-in-the-dark-240-million-indians-have-no-electricity.

94. BP, "BP Energy Outlook, 2017 edition", available at www.bp.com/content/dam/bp/pdf/energy-economics/energy-outlook-2017/bp-energy-outlook-2017.pdf.

95. BP, "CO_2 emissions", available at www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/co2-emissions.html.

96. Number listed for OECD Europe, International Energy Agency, *World Energy Balances 2017*; International Energy Agency, *CO_2 emissions from fuel combustion: Overview* (2017 edition).

97. BP, "BP Statistical Review of World Energy", June 2017, available at www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review-2017/bp-statistical-review-of-world-energy-2017-full-report.pdf.

98. Rank (CO_2 intensity): 113 out of 114; rank (PM2.5 emissions): 97 out of 107.

99. McKinsey & Company, "China's renewable energy revolution", August 2017, available at https://www.mckinsey.com/mgi/overview/in-the-news/china-renewable-energy-revolution.

100. International Renewable Energy Agency (IRENA), *Renewable Energy and Jobs: Annual Review 2017*, available at https://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Jobs_Annual_Review_2017.pdf.

101. In 2016, the load factor of China's coal plants was only 48% according to China's National Energy Administration.

102. International Energy Agency, *World Energy Balances 2017.*

103. Ibid.

104. International Energy Agency, *World Energy Outlook 2017*.

105. Government of India, Ministry of Power, Central Electricity Authority, "All India Installed Capacity (in MW) of Power Stations (as of 30.11.2017)", available at http://www.cea.nic.in/reports/monthly/installedcapacity/2017/installed_capacity-11.pdf.

106. European Energy Agency, "EEA greenhouse gas – data viewer", June 2017, available at http://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

107. Organisation for Economic Co-operation and Development, "Greenhouse gas emissions", December 2017, available at https://stats.oecd.org/Index.aspx?DataSetCode=AIR_GHG.

108. Energy Transitions Commission, *Pathways from Paris: Assessing the INDC Opportunity*, April 2016, available at http://www.energy-transitions.org/sites/default/files/20160426%20INDC%20analysis%20vF.pdf.

109. McKinsey Center for Business and Environment and the Ellen MacArthur Foundation, *Growth Within: A Circular Economy Vision for a Competitive Europe*, June 2015, available at https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf.

110. Organization of the Petroleum Exporting Countries, "Saudi Arabia facts and figures", available at www.opec.org/opec_web/en/about_us/169.htm.

111. Fossil fuel industries are defined in this context as oil and gas production and services and coal mining.

112. Power Africa, *Development of Kenya's power sector 2015-2020*, May 2016, available at www.usaid.gov/sites/default/files/documents/1860/Kenya_Power_Sector_report.pdf.

113. See the World Bank "RISE - Regulatory Indicators for Sustainable Energy", RISE access scores: Kenya = 82.

114. The Beam, "5 Things We Learned From The Newly Updated 'Heat Maps' Developed By Sustainable Energy For All", September 2017, available at https://cleantechnica.com/2017/09/21/5-things-learned-newly-updated-heat-maps-developed-sustainable-energy/.

115. Several of the countries that are not covered in the analysis due to data constraints are expected to rank in the bottom half of the matrix.

WORLD ECONOMIC FORUM

COMMITTED TO IMPROVING THE STATE OF THE WORLD

The World Economic Forum, committed to improving the state of the world, is the International Organization for Public-Private Cooperation.

The Forum engages the foremost political, business and other leaders of society to shape global, regional and industry agendas.

World Economic Forum
91–93 route de la Capite
CH-1223 Cologny/Geneva
Switzerland

Tel.: +41 (0) 22 869 1212
Fax: +41 (0) 22 786 2744

contact@weforum.org
www.weforum.org