Insight Report

Fostering Effective Energy Transition
2019 edition

March 2019

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Preface

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This report summarizes findings from the second edition of the Energy Transition Index (ETI, or the Index), part of the World Economic Forum Fostering Effective Energy Transition initiative. The ETI builds on the previous Energy Architecture Performance Index series (2013-2017) to establish a fact base rich with insights that enables decision-makers to benchmark against global peers, learn from best practices and prioritize necessary actions to support and encourage an effective energy transition in their countries.

The Index benchmarks countries on the performance of their energy system and their readiness for energy transition. It offers a framework for countries to design long-term energy transition roadmaps by considering current energy system performance and highlighting the necessary enablers that improve countries' readiness for energy transition.

Over the past year, developments across the three pillars of the energy triangle – economic development and growth, energy security and access, and environmental sustainability – have attested to the complexity of the energy system and highlighted the need to accelerate energy transition.

Ambition of the Energy Transition Index

The implications of the ongoing energy transition will reverberate across the established socio-economic, technological and geopolitical order. Although unprecedented in its scale and impact, the energy transition also offers an opportunity to shape the future of the energy system and ensure its sustainability, security, affordability and inclusiveness in the long term. Progress towards these goals requires supporting policies, technological innovation, large volumes of investment and a platform that encourages multistakeholder collaboration. The challenges faced by the energy system cannot be addressed by a single entity. Rather, a common understanding is required among all stakeholders on the long-term vision for energy transition and the near-term priorities.

The multidimensional nature of the ETI reflects the complexity of the energy system and the importance of achieving simultaneous progress on macroeconomic and social variables as well as on the regulatory environment impacting energy transition. However, energy systems across countries are unique to local circumstances, economic structure and socio-economic priorities, which highlight the multiple pathways to pursue an effective energy transition. Through these efforts, the World Economic Forum encourages the sharing of best practices and the use of its platform for effective public-private collaboration to facilitate energy transition planning in countries around the world.

This report examines progress and challenges on energy transition across countries grouped together based on shared characteristics that determine common objectives. Furthermore, it includes a section on the complexity of the energy transition, in an effort to highlight the true scale of the challenge.

Executive summary

The energy system, driven by factors such as rising demand, technological innovation, geopolitical shifts and environmental concerns, is undergoing a pivotal transformation. While energy systems have always been in transition, the current energy evolution is unprecedented due to the modern energy system's scale. Although faster than historic transitions, today's pace may not be fast enough. According to a 2018 special report of the Intergovernmental Panel on Climate Change,[1] global anthropogenic emissions will need to drop to net zero by 2050 to limit the global temperature increase to less than 1.5°C above the pre-industrial level. The energy system contributes two-thirds of global emissions and lies at the heart of this challenge. This is no trivial task, considering the size and inertia of the current energy architecture and the fragmented decision-making landscape.

Recent evidence highlights the complexity of transitioning to a lower-carbon energy system that fosters inclusive economic growth and provides affordable and secure supply. For example, even with the increased level of attention the Paris Agreement brought to this issue, global CO_2 emissions were expected to increase by more than 2% in 2018,[2] the highest in recent times. Coal consumption increased in 2018, after declining for three years.[3] And, with the average age of Asian coal plants at 11 years, it will be decades before they are retired.

Electrification, critical for decarbonization, makes up only 19% of the total final consumption of energy.[4] Investment in fossil fuels, as a share of total energy supply investment, grew in 2017 for the first time since 2014.[5] The share of fossil fuels in total primary energy supply has remained stable at 81% for the past three decades.[6] These trends cast a shadow of uncertainty on the effectiveness of energy transition efforts and underscore the need to accelerate them.

This document summarizes the findings from the second edition of the ETI, covering 40 indicators from 115 countries. Countries from Western and Northern Europe continue to lead the rankings. Sweden retains the top spot from last year, followed by Switzerland and Norway. The top 10 countries are diverse in their primary energy mix, energy system structure and natural resource endowments, which indicates the importance of country-specific circumstances in energy transition planning. However, a strong enabling environment is a common thread among top-ranked countries, evidenced by high scores on the transition readiness component. Laggards have poor energy system performance and transition readiness because of weak regulatory frameworks, lack of policy stability, ongoing geopolitical conflicts or strong path dependency from fossil fuel-powered energy systems.

Globally, energy transition has slowed. The year-on-year increase of the global average score on the Energy Transition Index was the lowest of the last five years. Three years after the global milestone of political commitment through the Paris Agreement, this lack of progress provides a reality check on the adequacy of ongoing efforts and the scale of the challenge.

Energy security and access continues to show greater improvement, driven by strong gains in access to electricity in Emerging and Developing Asia and by increasingly diversified import counterparts among fuel-importing countries. On average, 135 million people gained access to electricity each year between 2014 and 2016.[7] The scores on environmental sustainability increased only marginally, indicating the lack of progress consistent with the evidence cited above. Due to rising household electricity prices and fuel import bills, the average scores on the economic development and growth dimension declined compared to the previous year.

Stages of economic development, social development priorities, institutional arrangements and the role of fossil fuels in the economy vary across countries. Fossil fuels have a direct impact on countries' challenges and priorities relating to energy transition. In this report, countries with similar characteristics make up peer groups for analysis. Key insights from this analysis are:

– **Advanced Economies** rank high on the ETI, but still face the challenge of balancing economic growth and environmental sustainability. TThe rate of decline of the average energy intensity[8] of Advanced Economies slowed in 2017, with no significant improvement in the average carbon intensity of primary energy supply and per capita carbon emissions. Household electricity prices have been rising faster than electricity prices for industry, raising concerns about the equity considerations of energy transition, as evidenced by the recent Yellow Vest protests in France and the momentum of the Green New Deal in the United States.[9]

– Strong economic growth, urbanization and improving living standards are important factors driving the growth of energy demand in **Emerging and Developing Asia**. Coal maintains a significant share of the energy mix. Navigating the balance between growing the economy, meeting rising demand and improving environmental sustainability represents the key challenge for energy transition in this region.

– Apart from persistent gaps on universal access to electricity and clean cooking fuels in **Sub-Saharan Africa**, affordability and reliability of power supply are important challenges. A strong regulatory framework, policy stability and effective governance are essential to attract investment in capacity expansion and modernization, and to reap the economic dividends from the region's natural resource endowments.

- The **Latin America and the Caribbean** region has the highest environmental sustainability score among all peer groups due to large hydroelectric capacity and rapid progress made on installing renewable sources of electricity. With these characteristics, electrification of transport could unlock further improvement in environmental sustainability. Developing capacity for regional integration of electricity markets, improving operational efficiency of oil and gas extraction and harmonizing policies and standards could help improve other dimensions of the energy triangle.

- Energy transition in the **Middle East and North Africa** region requires that economies transform structurally so that gross domestic product does not have to rely as much on exports of fossil fuel. Diversifying the fuel mix, developing human capital for the future energy system and reducing fossil fuel subsidies are essential for an effective energy transition in this region.

Peer-group analysis shows that challenges and priorities are differentiated across country archetypes. A complex energy transition, which includes the interaction between different systems, leads to diverse challenges. Effective energy transition is not restricted to shifts in fuel mix or dominant technology for energy extraction, conversion or consumption. Rather, **accelerating the energy transition will require coordinated action across economic, technological and sociopolitical systems**:

- **Energy–economy system**: Economic growth in modern economies is closely associated with increasing energy consumption. Decoupling energy consumption from economic growth will require economic diversification to less energy-intensive industry sectors, energy efficiency in production processes and increased cooperation between developed and developing countries for technology transfer and capacity building.

- **Energy–technology system**: A wider toolkit of low-carbon technologies needs to be developed for widespread commercialization. Moreover, to keep up with society's requirement, this needs to be done at a faster pace. Policies and incentives for research and development, as well as an entrepreneurial environment, are essential to deploy new technologies more quickly. Overcoming technology lock-ins from legacy systems will require redesigning institutions and engaging consumers to ease adoption of new technologies.

- **Energy–society system**: Disruptive unintended consequences, such as distribution of the cost of energy transition in society, livelihood concerns of communities that depend on fossil fuel extraction or conversion, and stranded infrastructure will need to be managed to ensure equity of energy transition.

Accelerating energy transition will require faster progress on all fronts, including research on and deploying technology, large amounts of investment, consumer participation, and formulating and implementing policy. Given the scale and complexity of energy transition, and its interdependencies across different systems, no stakeholder group can unilaterally achieve faster and more impactful progress. Long-term roadmaps informed by a transparent fact base, reflecting country-specific circumstances and addressing interdependencies of energy transition with different parts of the society and economy, are required for an effective energy transition.

1. Introduction

Economic development and growth

According to the *World Energy Outlook 2018*, published by the Organisation for Economic Co-operation and Development and the International Energy Agency, global energy demand increased by 2.1% in 2017 and is expected to increase by another 25% by 2040. That most of the increase in demand comes from emerging economies underscores the close relationship between energy consumption and economic growth. The continued demand for coal to generate thermal power comes primarily from fast-growing Asian economies. While the demand for oil for passenger vehicles is expected to plateau in the short term due to improved fuel efficiency and electrification of transport, strong demand from sectors such as petrochemicals, freight transport and aviation suggest peak oil demand is further away than expected.

Energy transition also has wider societal implications, driven by signals of unequal distribution of its costs and benefits. This is particularly important for communities that depend on legacy energy infrastructure for their livelihoods. Rising fuel prices have driven protests in countries as diverse as Zimbabwe,[10] France, India[11] and Brazil.[12] Public discourse, such as over the Green New Deal in the United States, is reflecting the socio-economic ramifications of energy transition. Inclusiveness and affordability are critical for a just transition.

Energy security and access

Geopolitical shifts, such as the political crisis in Venezuela, trade sanctions against Iran and oil production cuts across OPEC countries, drove commodity price volatility in 2018 and resulted in rising fuel import bills for many countries. Thanks to continued technological advances and efficiency gains, the United States became the largest producer of crude oil,[13] with consequences that will reshape the international energy geopolitical order for years to come. The geopolitics of renewable energy is gradually growing in importance, according to "The Geopolitics of Renewable Energy", a 2017 paper of the Belfer Center for Science and International Affairs, Harvard Kennedy School, USA, as countries look to gain competitive advantage in technologies and materials required to develop renewable energy infrastructure.

Regarding energy access, the number of people without access to electricity fell below 1 billion due to substantial gains made in South and South-East Asia. The year 2018 was also a strong reminder about the need for resilience across the energy infrastructure. Blackouts from successive waves of tropical storms, as well as large-scale infrastructure disruptions from wildfires in the United States, argue strongly for redesigning resilience strategies for security of supply. Moreover, given increasing digitalization and interconnections in the power system, companies are integrating cyber-resilience as a core business issue, according to the World Economic Forum 2019 report, *Cyber Resilience in the Electricity Ecosystem: Principles and Guidance for Boards*.

Environmental sustainability

Global carbon emissions from fuel combustion grew at an accelerated rate in 2017, while investment in clean energy declined by 8% in 2018. Lower capital costs in solar photovoltaics partly explain this (lower costs caused by sharp price decreases due to oversupply); the other explanation is the tariffs imposed on solar panels imported to the United States.[14] Despite these headwinds and the financial pressure that lower solar prices have put on solar manufacturers, particularly in China,[15] 2018 was a record year for solar installations.

The increasing frequency and intensity of extreme weather events call for a quicker transition to a low-carbon world. In late 2018, scientists from around the world and on behalf of the Intergovernmental Panel on Climate Change reiterated the urgency of reducing emissions and limiting global warming to 1.5°C. Although feasible, the scale and pace of the economic, social and technological transformation required is unprecedented. Only 16 countries have laid out emission reduction targets consistent with their nationally determined contribution in the Paris Agreement.

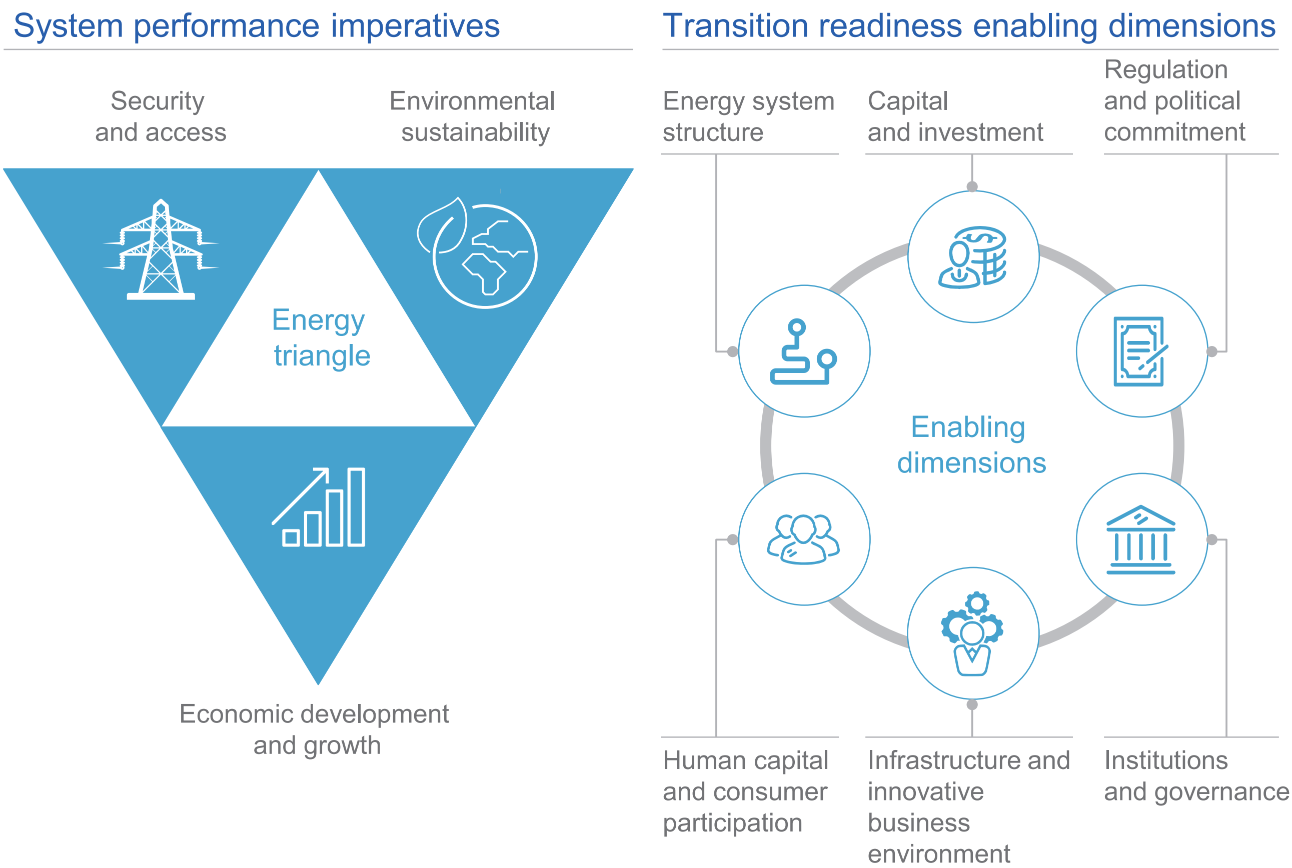
The World Health Organization, in its *COP24 Special Report: Health and Climate Change* of 2018, estimated that meeting global carbon reduction targets would save the equivalent of 1 million lives per year through related reductions in air pollution. Achieving these targets would also mitigate the negative economic and health impacts from increased sea levels, droughts and heat waves. In that light, accelerating the transition to a low-carbon energy system in a just and equitable manner, without limiting economic growth, is arguably the most important energy transition challenge today, underpinning the need for speed.

2. Index overview

The Energy Transition Index's analytical framework is designed to track country-level energy transitions. It takes the energy sector's wide range of roles within a country's economy into account, along with its supporting regulations, markets and technologies.[16] This allows for following the evolving energy system performance as measured by the system's ability to support inclusive economic development and growth, secure and reliable access to energy, and environmental sustainability (the energy triangle).

Strong energy system performance is due to several energy transition readiness factors, including the availability of investment and capital, effective regulation and political commitment, stable institutions and governance, supportive infrastructure and innovative business environment, human capital, and the maturity and fixed assets that make up the existing energy system's structure. Figure 1 summarizes the energy system performance and transition readiness dimensions.

Figure 1: Energy system performance and transition readiness dimensions



Source: World Economic Forum. *Fostering Effective Energy Transition: A Fact-Based Framework to Support Decision-Making*, 2018

The 2019 Energy Transition Index (ETI) provides scores for 115 countries spanning the many dimensions of energy transition performance and enablers. The Index delivers country-level composite scores that aggregate 40 energy transition indicators over these dimensions; this includes integrating information from trustworthy data sources that describe country levels of energy pollution, prices, supply chains, infrastructure, political institutions, financial systems, human capital and more. Country-specific scores are derived by normalizing the individual indicators and applying a weighting framework (see Appendix 1). The country rankings are presented next, with scores on system performance and transition readiness rounded to the nearest whole number. A full list of indicator data sources is provided in Appendix 2.

3. Overall findings

Effective energy transition is the timely transition towards a more inclusive, sustainable, affordable and secure global energy system. That system provides solutions to global energy-related challenges while creating value for society, without compromising the balance of the energy triangle. While energy transition is a shared concern among countries, progress will be a function of decisions taken within national settings reflecting specific social, economic and political priorities.

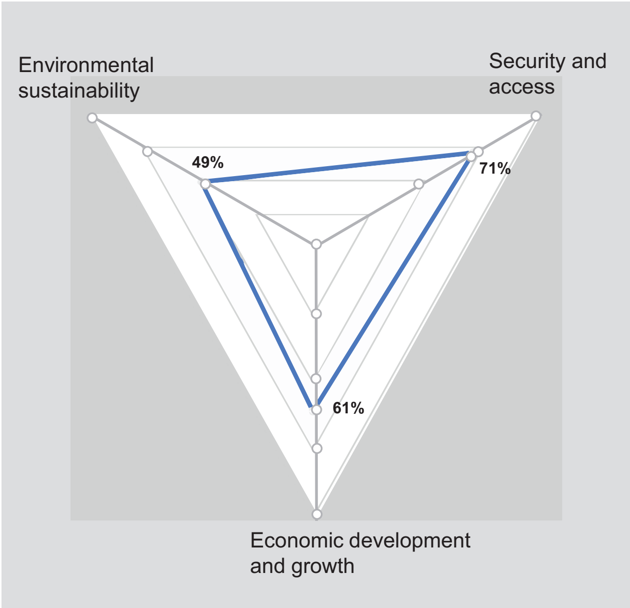
The ETI 2019 rankings (Table 1) did not change significantly from last year, especially at the top and bottom of the table. This indicates continued leadership by countries that have performed well historically, an outcome of both technological advances and effective policy-making and implementation. **Sweden** retains the top spot in the ranking, followed by **Switzerland** and **Norway**. All countries ranked in the top 10 are from Western and Northern Europe, and are diverse in their primary energy mix, energy system structure and natural resource endowments. High-ranking countries also show high scores on transition readiness due to their strong institutional and regulatory frameworks, ability to attract capital and investment at scale, innovative business environment and high-level of political commitment on energy transition.

Countries lagging in the rankings demonstrate the inertia of legacy systems and the need for a strong enabling environment. According to the data, fossil fuel-exporting countries, such as **Nigeria**, **Mozambique** and **Venezuela**, and countries consuming a disproportionate amount of coal, including **South Africa** and **Mongolia**, experience challenges in effective energy transition.

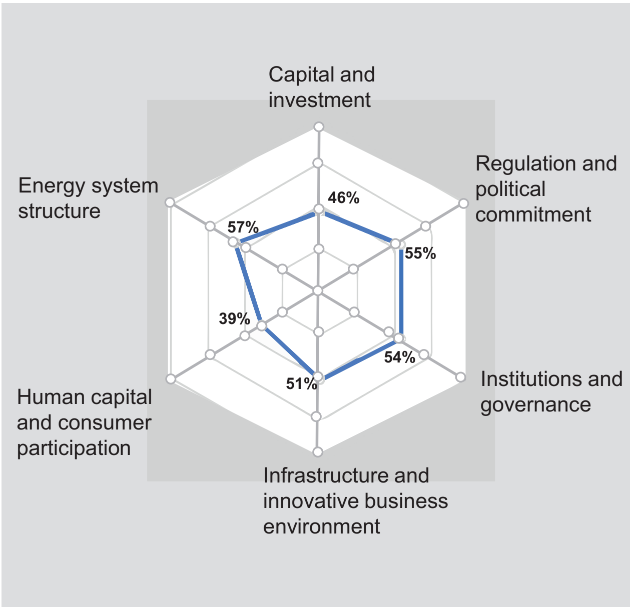
Figure 2 shows the global average scores on the dimensions of energy system performance and transition readiness. An analysis of the ETI indicates the pace of energy transition has slowed down. The year-on-year increase in the global average aggregate ETI score was the lowest of the last five years,[17] suggesting challenges in advancing on energy transition. The following section looks at the progress, or lack thereof, on dimensions of system performance and transition readiness.

Figure 2: Global aggregate system performance and transition readiness scores, 2019 (simple average)

System performance scores



Transition readiness scores



Source: World Economic Forum

Table 1: Energy Transition Index 2019[1] results

Rank	Country name	2019 ETI Score[2]	System Performance	Transition Readiness
1	Sweden	75%	81%	69%
2	Switzerland	74%	78%	71%
3	Norway	73%	82%	65%
4	Finland	73%	72%	74%
5	Denmark	72%	72%	73%
6	Austria	71%	71%	71%
7	United Kingdom	70%	74%	66%
8	France	69%	77%	60%
9	Netherlands	69%	71%	66%
10	Iceland	69%	75%	62%
11	Uruguay	67%	75%	60%
12	Ireland	67%	71%	63%
13	Singapore	67%	68%	65%
14	New Zealand	66%	73%	58%
15	Luxembourg	66%	64%	67%
16	Portugal	65%	71%	59%
17	Germany	65%	66%	64%
18	Japan	65%	67%	63%
19	Lithuania	65%	72%	57%
20	Estonia	64%	64%	64%
21	Costa Rica	64%	75%	54%
22	Belgium	64%	67%	61%
23	Latvia	64	69%	58%
24	Slovenia	64%	69%	58%
25	Spain	64%	71%	56%
26	Chile	63%	67%	59%
27	United States	63%	66%	59%
28	Malta	62%	70%	54%
29	Italy	62%	70%	54%
30	Israel	62%	67%	56%
31	Malaysia	61%	68%	55%
32	Georgia	61%	64%	58%
33	Slovak Republic	61%	68%	54%
34	Colombia	61%	71%	51%
35	Canada	61%	66%	56%
36	Panama	60%	69%	51%
37	Mexico	60%	69%	50%
38	Albania	60%	67%	52%
39	Brunei Darussalam	59%	67%	52%
40	Romania	59%	68%	50%
41	Hungary	59%	66%	52%
42	Croatia	59%	66%	52%
43	Australia	59%	64%	54%
44	Peru	59%	68%	49%
45	Cyprus	59%	66%	51%
46	Brazil	58%	70%	45%
47	Morocco	58%	67%	48%
48	Korea, Rep.	58%	60%	55%
49	Czech Republic	57%	61%	53%
50	Armenia	57%	65%	49%
51	Thailand	57%	63%	51%
52	Ecuador	57%	70%	43%
53	Paraguay	57%	64%	49%
54	Greece	56%	67%	46%
55	Montenegro	56%	56%	55%
56	Vietnam	55%	62%	49%
57	Azerbaijan	55%	63%	48%
58	Jamaica	55%	57%	53%
59	Philippines	55%	62%	49%
60	Sri Lanka	55%	65%	45%
61	Argentina	55%	67%	43%
62	Namibia	55%	58%	51%
63	Indonesia	55%	64%	46%
64	Turkey	55%	60%	49%
65	Qatar	54%	56%	52%
66	Jordan	53%	56%	50%
67	United Arab Emirates	53%	55%	50%
68	Oman	53%	55%	50%
69	Republic of Moldova	52%	61%	43%
70	Guatemala	52%	59%	45%
71	Kenya	52%	53%	51%
72	Tunisia	52%	59%	45%
73	Ghana	52%	54%	49%
74	El Salvador	51%	55%	48%
75	Poland	51%	57%	46%
76	India	51%	53%	49%
77	Bulgaria	51%	54%	48%
78	Dominican Republic	50%	56%	45%
79	Russian Federation	50%	61%	39%
80	Trinidad and Tobago	50%	54%	47%
81	Bolivia	50%	60%	41%
82	China	50%	48%	51%
83	Kazakhstan	50%	61%	38%
84	Tanzania	49%	51%	47%
85	Honduras	49%	50%	48%
86	Egypt, Arab Rep.	49%	55%	43%
87	Kuwait	49%	55%	43%
88	Tajikistan	49%	48%	49%
89	Algeria	48%	61%	36%
90	Bangladesh	48%	52%	43%
91	Senegal	47%	48%	47%
92	Bahrain	47%	44%	51%
93	Nepal	47%	47%	47%
94	Botswana	47%	49%	44%
95	Ethiopia	46%	46%	47%
96	Nicaragua	46%	50%	42%
97	Pakistan	46%	47%	46%
98	Saudi Arabia	46.2%	51%	41%
99	Serbia	46%	53%	39%
100	Cambodia	45%	46%	44%
101	Iran, Islamic Rep.	44%	54%	33%
102	Zambia	44%	41%	46%
103	Cameroon	43%	43%	43%
104	Bosnia and Herzegovina	43%	46%	40%
105	Benin	42%	42%	42%
106	Lebanon	42%	42%	41%
107	Ukraine	42%	48%	35%
108	Mongolia	41%	45%	38%
109	Nigeria	41%	46%	35%
110	Kyrgyz Republic	40%	37%	43%
111	Mozambique	40%	43%	37%
112	Venezuela	39%	50%	27%
113	Zimbabwe	39%	37%	40%
114	South Africa	37%	36%	37%
115	Haiti	36%	35%	37%

- Advanced Economies
- Commonwealth of Independent States
- Emerging and Developing Asia
- Emerging and Developing Europe
- Latin America and the Caribbean
- Middle East and North Africa
- Sub-Saharan Africa

For the ETI 2019 methodology, see the methodology addendum at the end of this report. Country figures are rounded to full PPT, but exact figures are used to determine rankings. Therefore, countries with the same ETI scores may have different rankings.

Note 1: The Energy Transition Index benchmarks countries on the performance of their energy system, as well as their readiness for transition to a secure, sustainable, affordable, and reliable energy future. ETI 2019 score on a scale from 0 to 100%.

Note 2: ETI 2019 score on a scale from 0% to 100%.

Source: Energy Transition Index Report 2019, World Economic Forum

Source: World Economic Forum

3.1. System performance

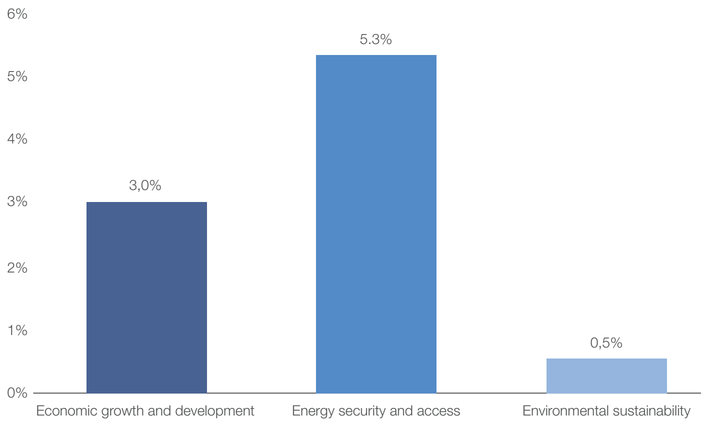
Energy system performance measures the ability of countries' current energy architecture to deliver across the three imperatives of the energy triangle: economic development and growth, energy security and access, and environmental sustainability.

The insights from the ETI 2019 highlight the persistent challenges in energy system performance. After increasing for four years since 2014, the average system performance score remained flat over the past year; the primary reasons were the continued use of coal for power generation in Asia, increasing commodity prices andthe lack of progress on reducing per capita emissions and the carbon intensity of primary energy supply in Advanced Economies. While energy security and access had the highest average score of the three dimensions, environmental sustainability had the lowest average score and improved the least over the last five years (Figure 3). The slow progress on environmental sustainability of the energy system, as suggested by the ETI, is consistent with the latest evidence of the increase in emissions from fuel combustion.

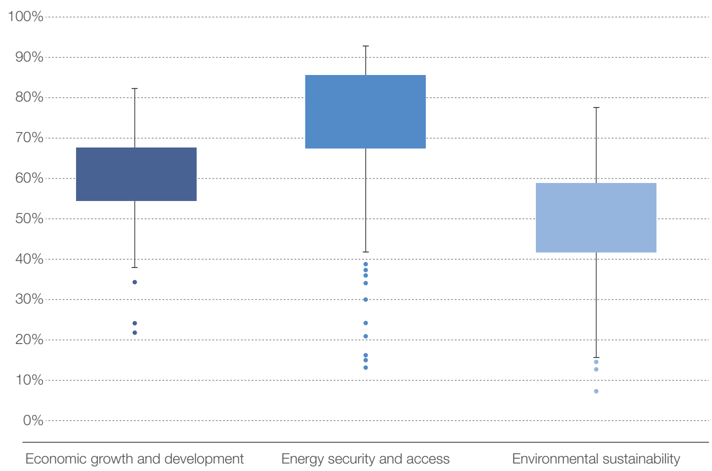
For an effective energy transition, countries should pursue a balance between the three imperatives of energy system performance. Achieving this is complex, however, due to the competing priorities in countries, as well as economic and geopolitical uncertainties. Though they sustain higher than average scores on individual dimensions, economies with high scores on energy system performance tend to overprioritize improvements along select dimensions instead of targeting a balanced approach (Table 2). This might be a consequence of the energy system's structure and suggests that energy transition is a complex process. Even leading countries have yet to determine a comprehensive roadmap for a secure, sustainable, inclusive and affordable future energy system.

Figure 3: Change in and distribution of energy system performance dimension scores

Change in scores, 2014-2019



Distribution of scores, 2019



Source: World Economic Forum

Table 2: Top 10 countries on energy system performance and their ranking on dimension scores

System performance		Economic growth and development		Energy security and access		Environmental sustainability	
Rank	Country	Score	Rank	Score	Rank	Score	Rank
1	Norway	89%	1	87%	28	70%	6
2	Sweden	74%	10	92%	2	78%	1
3	Switzerland	73%	12	87%	25	74%	3
4	France	70%	23	92%	4	69%	9
5	Uruguay	67%	35	81%	46	76%	2
6	Costa Rica	74%	9	81%	49	70%	5
7	Iceland	81%	5	84%	37	59%	28
8	United Kingdom	68%	29	91%	10	64%	18
9	New Zealand	69%	27	88%	23	63%	21
10	Lithuania	63%	55	90%	18	64%	20

Source: World Economic Forum

Economic development and growth

This dimension measures the extent to which energy contributes towards economic development and growth in a country in terms of affordability of energy services to households, cost-competitive supply of energy to industries and impact on gross domestic product (GDP) through exports, imports or energy subsidies.[18] The distribution of scores on economic development and growth is the narrowest among the three dimensions (Figure 3), implying that countries exhibit relatively less difference on this dimension. This indicates the importance of country-specific circumstances in energy policy-making, such as the structure of the economy, the stages of development, and social and political priorities.

Wholesale energy prices dropped worldwide, but household electricity prices rose in many countries, a cause for concern regarding energy affordability and equity. Moreover, this reflects a challenging trade-off in energy transition. For example, decreasing costs of solar photovoltaics, storage technologies and electric vehicles have enabled consumers to produce, store and sell electricity. While this is an incentive for investing in modern and cleaner forms of energy services, distributed generation increases the costs of the network, which is reflected in consumers' electricity bills.[19]

Countries that rely heavily on revenues from fuel exports score highly on affordability of energy services and on energy security and access. However, their ranking in the bottom quartile of the transition readiness component signals challenges in creating an enabling environment for energy transition. While increasing export revenue from fuels indicates the energy sector's positive contribution to a country's economic development and growth, it also highlights the need for structural reforms to protect against shocks from energy transition, such as electrification and the mainstreaming of decentralized renewable energy sources. Cheaper renewable energy and efficiency gains from digitalization offer competitive advantage on manufacturing that can stimulate economic growth and generate new sources of employment.

Additionally, the fuel import bill as a percentage of GDP increased in almost all fuel-importing countries in 2017, largely due to an increase in commodity prices. However, and primarily in emerging economies, the increasing fuel import bill is also the result of rising demand across all end-use sectors. Energy services generally become less affordable in such a scenario or affect economic growth indirectly through higher fuel subsidies.

Environmental sustainability

This dimension measures the sustainability of the energy system in a country by considering the energy intensity of GDP, the system's emission intensity and the level of pollutants. Producing an accurate measurement of the environmental footprint across the energy value chain is challenging due to the lack of data on the effect of emissions on public health and the implications of the energy system on land and water use, among others. Scores on this dimension have been consistently low, with no significant signs of improvement. This is alarming considering the availability of low-carbon technology alternatives and the amount invested in low-carbon energy sources over the past five years. It demonstrates the persistent nature of the environmental sustainability challenge, as well as the strong path dependency of economic growth on energy consumption.

In 2017, global CO_2 emissions grew after remaining flat for three years.[20] CO_2 emissions from fuel combustion grew in more than half of the countries as demand increased from the residential and transportation sectors. Reversing the trend from the previous two years, global coal consumption grew in 2017 due to an increase in demand in the Asia-Pacific region, including in India and China. Moreover, the International Energy Agency (IEA) expects CO_2 emissions from advanced economies to increase in 2018 partly because of economic growth, reversing five years of successive declines in net emissions from these countries.[21]

Urgent and accelerated measures are required to have a noticeable effect on environmental sustainability. Beyond enabling policies and investments in alternative power generation and electrification of transport, deep decarbonization strategies of economic sectors with higher abatement costs than other sectors, such as aviation, shipping and heavy industries including steel and cement production, need to be pursued through energy efficiency and demand management.[22] Employing Fourth Industrial Revolution technologies that offer pathways to enhance productivity and efficiency is important for faster progress on environmental sustainability. Negative emissions options, such as carbon capture and sequestration and natural carbon sinks, must be prioritized to buy more time. Moreover, given the scale of the challenge and the urgency of expedited action, a common understanding among policy-makers and the private sector is required on the priorities and pathways for environmental sustainability.

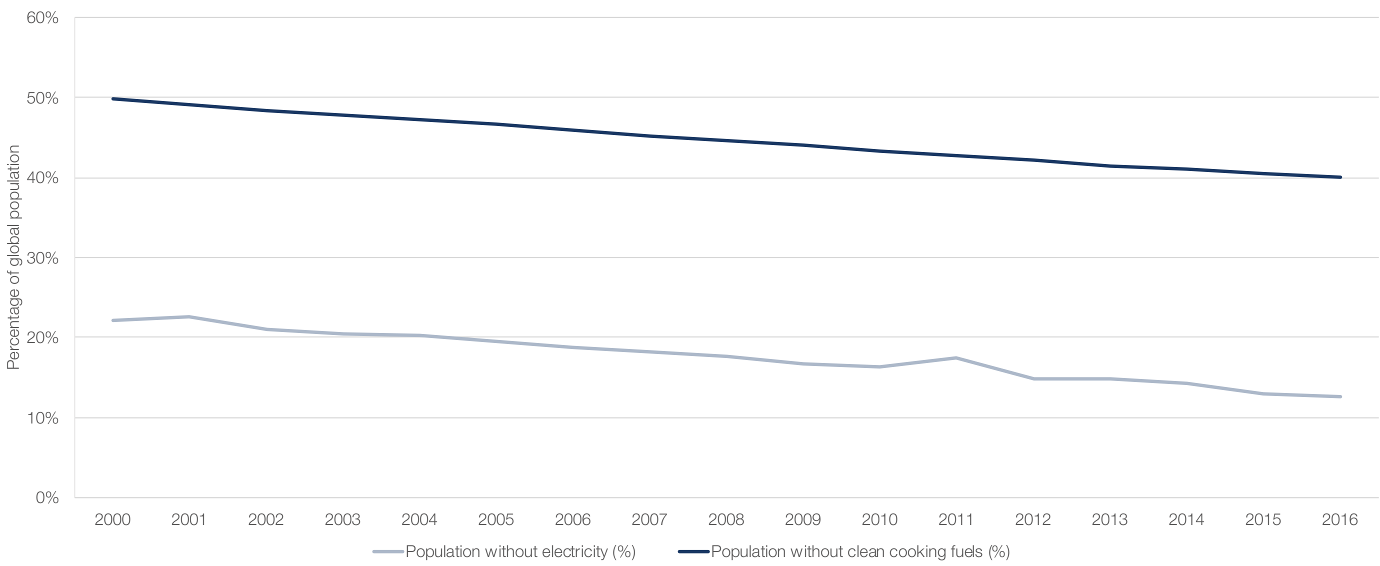
Energy security and access

On average, countries have improved on energy security indicators, determined by countries' ability to ensure "uninterrupted availability of energy sources at affordable prices".[23] More than half of the economies improved the diversity of both their fuel supply sources and their import counterparts. Reducing concentration in the fuel supply mix and import partners is critical to hedging against fuel price volatility and geopolitical shifts. High-ranking countries that depend on imports have approached energy security through diversification, as well as through demand-side strategies to enhance self-sufficiency. This is relevant for emerging economies, especially those in Asia, which are importing more fuel to meet the rising demand for energy.

Ensuring reliable and secure access to modern energy services is a key objective of energy transition. Countries have made strong improvements in energy access, as demonstrated by increasing levels of access to electricity and improving the quality of its supply. Between 2014 and 2016, more than 400 million people have gained access to electricity, reducing the total number of people globally who lack access to electricity to under 1 billion for the first time ever.[24] Since 2000, the number of countries with universal access to electricity increased from 70 to 118.[25] The gains in electrification are due to large-scale programmes in South and South-East Asian countries, where a mix of grid expansion and decentralized generation sources were used to increased access to electricity. The progress in Sub-Saharan Africa, where more than 600 million people lack access to electricity, remains slow.[26] To realize the Sustainable Development Goal (SDG) of universal access by 2030, the rate of electrification needs to increase. In fact, the percentage of the global population lacking access to electricity and clean cooking fuels has declined over time (Figure 4).

Electrification, however, should not be considered a binary objective measured by the presence of grid connection. Rather, the quality and level of access to electricity are critically important to ensure it makes a meaningful difference in improving living conditions and creating economic opportunities. Recent data indicate the reliability of electricity and the per-capita energy consumption levels in access-deficit countries of Sub-Saharan Africa are low. Moreover, about 40% of the global population still use solid fuels for cooking. Apart from being important in mitigating emissions, clean cooking fuels and access to them are crucial for improved public health outcomes and for gender equality.[27]

Figure 4: Global population without access to electricity or clean cooking fuels, 2000-2016



Source: World Bank, World Development Indicators, Sustainable Energy for All database. “Access to electricity (% of population)”, https://data.worldbank.org/indicator/eg.elc.accs.zs; “Access to clean fuels and technologies for cooking (% of population)”, https://data.worldbank.org/indicator/EG.CFT.ACCS.ZS

3.2. Transition readiness

The ETI captures the readiness of a country through six enabling dimensions: energy system structure, regulation and political commitment, capital and investment, human capital and consumer participation, infrastructure and innovative business environment, and institutions and governance. The 10 top-ranked countries for transition readiness can be shown with their scores for each of the six dimensions (Table 3).

Energy system structure

The existing energy system structure’s effect on readiness is measured through the country’s current level of energy consumption per capita, the share of power generation from coal, and the share of generation from renewables and carbon content within the country’s fossil fuel reserves. This dimension is important for transition readiness because the existing energy infrastructure or resource endowment could affect the decision-making processes and political priorities for some countries. Developing transition policies within fossil fuel-rich countries would demand stronger political will and may require lengthier stakeholder engagement. High consumption per capita indicates a certain level of energy affluency among consumers and will vary depending on the structure of the economy in other cases.

This year’s analysis shows that the 10 countries with the highest scores in readiness all score low in energy system structure. This applies to most of the countries within the larger group of Advanced Economies. In many cases, this was due either to the high energy consumption per capita resulting from the high level of income and development in these countries or to the share of coal in their energy systems. While per-capita demand for energy is relatively high for many Advanced Economies, reduction is anticipated over time given these countries are strongly committed to energy efficiency. This is captured in the regulation and political commitment dimension of the Index, with Advanced Economies scoring 75% on average in the World Bank Regulatory Indicators for Sustainable Energy (RISE) efficiency indicators compared to an average of 50% for the countries analysed in the Index.

Regulation and political commitment

This dimension measures countries' dedication to the energy transition through their commitment to nationally determined contributions to emissions reduction and through their policy stability as indicated in the World Economic Forum *Global Competitiveness Report*, as well as through World Bank RISE scores for energy efficiency, renewables and energy access. Improvement in energy efficiency and renewables policies have been driving the improvement across this dimension; Italy, Canada and South Korea were the top three countries in energy efficiency policies in 2017, while Germany, India and the United Kingdom were the top performers in renewables policies.

Infrastructure and innovative business environment

As expected, the data shows positive correlation between regulatory indicators and the infrastructure and innovative business environment. This dimension is measured through the innovative business environment index, the availability of technology index, and the quality of logistics and transportation infrastructure indices. The availability of technologies encourages the development of ambitious energy programmes. At the same time, energy policies provide certainty and opportunities for businesses to innovate. Out of the top 30 countries in innovative business environment, 24 are also among the top 30 in regulatory and business environment.

Institutions and governance

The institutions and governance dimension attempts to measure the perception of credibility in countries' institutions, an important factor in building investor confidence and mobilizing financing for the energy transition. This composite index builds on indices for the rule of law, perception of corruption and a country's credit rating. The data show positive correlation between this dimension and the one for regulation and political commitment.

Capital and investment

The IEA estimates the average annual investment required to meet the Intergovernmental Panel on Climate Change's 2°C scenario at $3.7 trillion between 2016 and 2050.[28] Many sources of finance will need to be mobilized for the sustainable energy sector, and policy-makers must be open to new and innovative forms of financing and business models for energy firms. This dimension considers a country's investment freedom, access to credit and change in annual renewable capacity built, as well as the proportion of energy investments directed toward energy efficiency, as a measure of its ability to attract capital and investment. Investment freedom is critical in mobilizing financing for the energy transition. The data from 2018 show that the top 10 countries in readiness consistently scored high in this indicator.

Human capital and consumer participation

A bidirectional relationship exists between the energy transition and society. The transition can create shared growth through increased job opportunities. The magnitude and impact depend on the energy system's current state and whether jobs could be lost during the transition. Moreover, as energy systems change, human capital development will need to be prioritized to foster know-how for the management and operation of the future energy system.

Table 3: Top 10 countries in transition readiness, scored and ranked for the six readiness enabling dimensions, 2018

Transition readiness		Capital and investment		Regulation and political commitment		Institutions and governance		Infrastructure and innovative business environment		Human capital and consumer participation		Energy system structure	
Rank	Country	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	Finland	76%	4	69%	11	82%	10	81%	7	83%	1	52%	69
2	Denmark	73%	7	68%	12	85%	3	78%	9	81%	2	49%	75
3	Austria	73%	8	67%	14	82%	12	75%	12	67%	8	60%	52
4	Switzerland	69%	12	75%	2	83%	9	83%	3	55%	18	58%	55
5	Sweden	62%	24	66%	18	84%	7	81%	6	62%	10	57%	57
6	Luxembourg	64%	20	67%	15	85%	5	73%	14	57%	16	56%	59
7	United Kingdom	82%	1	66%	16	80%	14	77%	10	46%	36	46%	83
8	Netherlands	63%	22	71%	5	81%	13	83%	1	51%	25	44%	85
9	Singapore	52%	41	71%	6	89%	1	81%	5	43%	41	55%	61
10	Norway	61%	26	69%	10	89%	2	71%	17	47%	31	55%	63

Source: World Economic Forum

The analysis for 2018 shows a high level of readiness is concentrated among nations that have a comparatively lower impact on the pace of the global energy transition. In some cases, this is merely due to the size of a country's energy system; in others, the country has already evolved to where incremental benefits are less impactful on a global scale. The latter argument is supported by a trend analysis of the readiness score, which indicates that Advanced Economies have had the least improvement over the past five years given their mature ecosystems for the energy transition.

This point is illustrated by plotting each country group's transition readiness score with its annual emissions (total CO_2 emissions from fuel combustion in 2016) as a percentage of all emissions (Figure 5), which indicates:

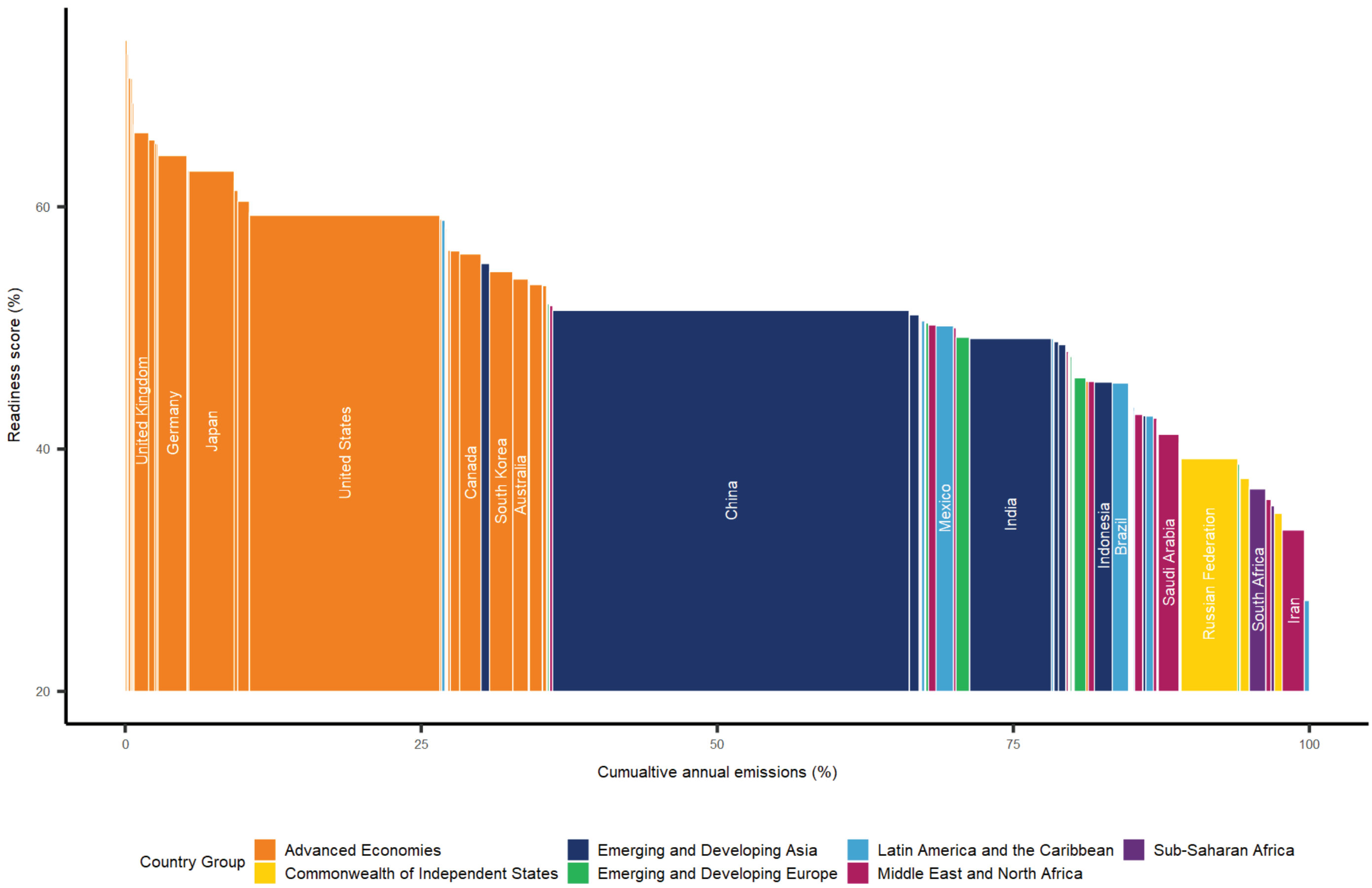
1. The 10 countries scoring highest in readiness for transition have only 2.6% of global annual emissions

2. Almost 65% of global fuel burning-related carbon emissions are in countries that score 55% or less on readiness

The focus on emissions demonstrates the concern, while understanding that the ETI measures the transition beyond emissions to cover environmental sustainability, economic development and growth, and energy security and access.

While countries with evolved energy systems may have only a small impact from changes within their systems, those countries could have great potential in advancing the transition in less developed economies. Countries with evolved systems experimented greatly and learned lessons that resulted in their current systems. For example, the evolution of energy markets in California (USA), the success of green energy transition in Germany and the sophisticated integrated energy planning processes in Japan offer many lessons for developing nations.

Figure 5: Transition readiness scores vs annual emissions per country



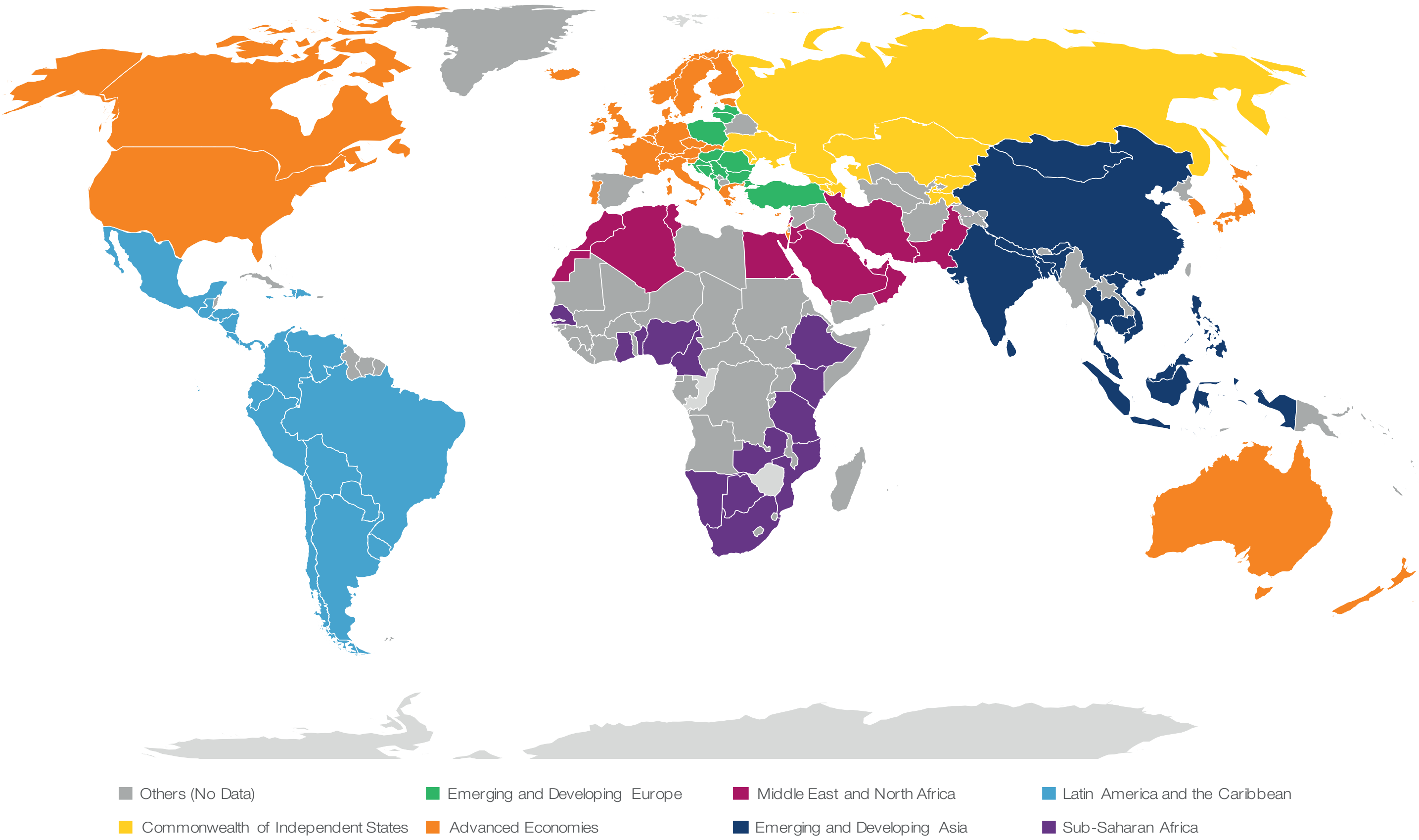
Source: World Economic Forum

4. Insights from peer-group analysis

Countries approach energy transition with different starting points and various structural, economic, social and institutional particularities. This implies that instead of straightforward comparisons based on scores in the ETI, countries should be compared to a peer group with similar structural characteristics. This section describes insights from a peer-group analysis of assigned groupings (Figure 6).

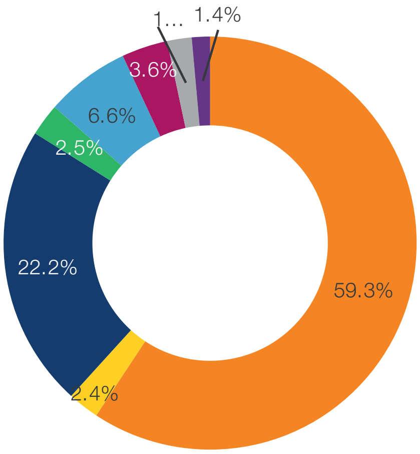
To provide perspective on the country groups, a series of macro variables are illustrated to show the share of global GDP, global population, CO_2 emissions and primary energy supply (Figures 7 through 10). This section concludes with a readiness matrix (Figure 11) with the positionings of countries along the system performance and transition readiness measures.

Figure 6: Countries selected for ETI analysis, with peer groups



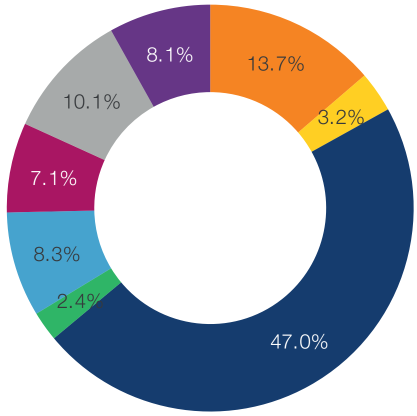
This map has been created for illustrative purposes only, using publicly available sources. The boundaries shown do not imply any opinion on the part of the World Economic Forum. No citation or use of this map is allowed without the written consent of the World Economic Forum.
Source: World Economic Forum

Figure 7: Share of global GDP (nominal, 2017)



Source: World Bank. World Development Indicators, "GDP (current US$)", https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?page=

Figure 8: Share of global population, 2017



Source: World Bank. World Development Indicators, "Population, total", https://data.worldbank.org/indicator/sp.pop.totl

Figure 9: Share of global CO_2 emissions from fuel combustion, 2016

Source: IEA. *CO_2 emissions from fuel combustion*, 2018 edition

Figure 10: Share of global total primary energy supply, 2016

Source: IEA, *World Energy Balances Database*, 2018

Advanced Economies
Commonwealth of Independent States
Emerging and Developing Asia
Emerging and Developing Europe
Latin America and the Caribbean
Middle East and North Africa
Others (No Data)
Sub-Saharan Africa

4.1. Advanced Economies

Advanced Economies rank high on the ETI due to well-developed and modern energy systems coupled with a robust supportive environment with transition readiness enablers. Of the top 25 countries ranked in the ETI, 21 are Advanced Economies. This group's relatively high score on energy system performance confirms both the importance of pursuing a balance between energy security, environmental sustainability and economic growth, and the synergistic effect with transition readiness enablers.

The group's average score of 88/100 on the energy security and access dimension is noteworthy considering most countries in this group are net energy importers (except Norway, Canada and Australia). Diversification of the fuel mix and a sufficient pool of import partners have been instrumental in ensuring reliability and security of energy supply in Advanced Economies.

The key challenges for energy transition in these economies relate to affordability and environmental sustainability. Average scores for economic development and growth and energy security and access for Advanced Economies are higher than for all other groups. However, on environmental sustainability, the group lags behind the Latin America and Caribbean region, primarily because of comparatively higher emissions per capita and higher carbon intensity of the fuel mix. High retail electricity prices in high-ranking countries, such as Denmark, Germany, Belgium, Spain and Portugal, highlight the complexity of keeping energy prices affordable while investing in energy transition. Recent evidence[29,30] suggests rising electricity prices are affecting households and small business more than large industrial energy consumers, which affects the equity and inclusiveness in sharing the costs of energy transition.

Analysis of Advanced Economies' data underscores the challenge of ensuring energy security and economic growth while improving environmental sustainability. Scores on environmental sustainability are the lowest of the three when considering the three corners of the energy triangle. Moreover, while the average score on environmental sustainability for Advanced Economies improved over the years, the rate of improvement has slowed over the past year. The Advanced Economies demonstrate challenges in reducing the energy intensity of their economies, as the rate of energy intensity improvement in 2017 was slower than in previous years across many countries in this group. Canada, Australia and South Korea are the only large economies in this group with scores below the top quartile on the ETI, which is primarily due to their low scores on environmental sustainability. Although ranking high on economic growth and energy security, the three economies are among those with the highest carbon intensity of fuel mix, per-capita energy consumption and carbon emissions in the world.

Sweden, the top-ranked country on the ETI, also has the highest scores on environmental sustainability. Its energy intensity and greenhouse gas emissions per capita, while higher than half the countries ranked in the Index, have been declining over the past few years. Sweden has a low-carbon power generation mix, generating more than half its electricity from renewable energy sources and the remaining portion from nuclear energy.[31] The country's energy transition is supported by an effective institutional and regulatory framework, and by political commitment. For example, the Climate Act, which entered into force in 2018, introduced legally binding commitments to achieve net zero greenhouse gas emissions by 2045. It also requires an annual climate report with its budget bill each year to ensure cross-party commitment, stability of policy and continued progress on implementing reforms across political cycles.[32]

4.2. Emerging and Developing Asia

With nearly 50% of the world's population, Emerging and Developing Asia has the largest share of the world's energy consumers among the regions analysed in this report. Most of the growth in energy demand comes from this group of countries, and data shows its total primary energy supply grew by 28% over the past eight years, which underscores the region's relevance when considering energy transition. While the group's 13 countries are diverse, for example in their income levels, institutional arrangements and economic structures, they share common challenges related to their energy system.

With the exception of Malaysia, Mongolia, Cambodia and Brunei Darussalam, the countries are net energy importers. Rising income levels, the increasing rate of urbanization and energy security concerns have been leading factors in the development of their respective energy policies. As a result, several countries have opted for an energy mix with an important role for coal, an abundant resource in many Asian economies. This has compromised the region's environmental sustainability score, which averages 49% (below the Advanced Economies' average of 54%). Relatively high industry electricity prices and wholesale gas prices, given the region's many energy importers, have led to lower rankings in the economic development and growth indicators.

Malaysia is the highest-ranked country from the region in the Index, and also scores highest in system performance. Its energy security and access score is among the top 20 of the 115 countries surveyed in the ETI, thanks to its high electrification rate, low usage of solid fuels, diverse fuel mix and high quality of electricity supply. On the environmental front, however, its carbon intensity and per-capita carbon emissions are over 20% above the global average, leading to a lower score on this dimension. To tackle the challenge of carbon emissions, Malaysia has pledged to increase the installed capacity of renewables from 21% to 30% and will require new coal plants to employ technologies with higher efficiency and lower emissions.[33] Given the country's strategic priority to maintain affordable energy,[34] using these technologies could present a challenge as they are among the most expensive means of reducing carbon emissions compared to employing renewable energy sources.[35] This confirms the challenge of achieving a balanced transition across the energy triangle's three dimensions.

The difficulty of balancing across the triangle's three imperatives is also observed in China. Although the country has a relatively high score in energy transition readiness, its system performance ranking remains low, driven by its low score on environmental sustainability. China's high level of pollution at PM2.5, with a pollutants level of 56.3 micrograms per m^3 , is almost double the average of the countries analysed in the Index. Additionally, the carbon intensity of the country's energy mix, at 73 kg of CO_2 per gigajoule, ranks it among the highest three countries in the ETI; this is no surprise given that China consumes 51% of the world's coal demand,[36] and that coal constitutes more than 60% of the country's primary energy mix. Over the years, China has implemented several ambitious air quality plans and regulations with varying degrees of success. In 2013, it enacted the Air Pollution Action Plan, which set targets for particulates in key regions and resulted in an over 30% reduction in the PM2.5 level in Beijing over its five-year implementation. This led to the closure of several coal-fired power stations in the city and a ban on using coal for heat. Despite the success in the key regions covered by the policy, the mean levels of exposure to particulate matter in 2016 improved by only 3% over 2010 levels.[37] The Plan expired in 2017 and was followed by the Three-Year Action Plan for Winning the Blue Sky, which expands the coverage of regulations on air quality to additional regions. It is viewed by some critics, however, as having relaxed requirements over regions that have achieved or exceeded the initial plan targets.[38]

4.3. Sub-Saharan Africa

Sub-Saharan Africa has the lowest levels of per-capita energy consumption, with about 600 million people lacking access to electricity and many more without access to clean cooking fuels. The region's energy demand, representing 3.4% of global demand (per the IEA), is expected to grow three-fold by 2060[39] driven by a rising population, improved access to energy and economic growth. Due to unresolved challenges on energy access and environmental sustainability, and the lack of enablers such as policy stability, a strong institutional framework and supporting infrastructure, countries in Sub-Saharan Africa rank low on the ETI.

The analysis of ETI subcomponents and their dimensions reveals the complexity of energy transition challenges in the region. The average scores on energy system performance have improved over the past five years, but all Sub-Saharan countries score lower than the global average on energy system performance. The scores on the economic development and growth dimension are closer to the global average, largely driven by increasing exports of oil and gas. As the region is rich in natural resources, fossil fuel production and export are key contributors to economic growth and job creation. Modernization and digitalization of exploration and production infrastructure to increase productivity and operational efficiency, as well as reskilling of the workforce,[40] can help unlock further improvements. Effective institutions are critical, however, in ensuring the available natural resources are used optimally.

The region's average scores on the energy security and access dimension are the lowest among the energy triangle's three dimensions. While electrification across Sub-Saharan Africa has been steadily increasing, it has struggled to keep pace with the rising population.[41] Moreover, the pace of electrification is slow compared to Emerging and Developing Asia.[42] India, Indonesia and Bangladesh have made fast progress towards universal electrification due to strong political commitment, a stable policy regime, use of grid expansion and decentralized generation sources, and a supportive environment for investment in infrastructure. In Sub-Saharan Africa, the Last Mile Connectivity Project[43] in Kenya and the National Electrification Program in Ethiopia[44] are steps in the right direction. Ensuring affordability is critical, however, to making progress on electrification goals; average household electricity prices in real terms are higher in Sub-Saharan Africa than in all other regions. The affordability challenge is a result of low per-capita income levels and high costs of electricity supply due to system losses and inefficient operations. Modernizing utilities to make the power supply more reliable can result in further tariff hikes, and introducing cost-recovery tariffs can further exacerbate concerns about affordability. Thus, better targeting of energy subsidies to low-income households is required,[45] as is prioritizing decentralized sources of generation.

Despite relatively low CO_2 emissions per capita and average carbon intensity of primary energy supply, the average scores on environmental sustainability dimensions are on par with the global average and have declined consistently over the past few years. Apart from Namibia, Ghana and Botswana, countries in this region have among the highest energy intensities in the world. Due to recent discoveries of oil and gas, and abundant coal in Botswana and South Africa, the share of renewable energy in the power generation mix declined in 2018.[46] Leveraging domestic resources is essential for growth, which shows the link between environmental sustainability and economic growth in Sub-Saharan Africa.

The challenge on environmental sustainability is also closely linked to energy security and access concerns. Due to the lack of access to reliable and affordable electricity, industries and households increasingly use diesel generators to supply power. Moreover, limited access to clean cooking fuels leads to the use of traditional biomass for cooking purposes. As a result, countries in the region have high PM2.5 concentration in the atmosphere. Sub-Saharan Africa has abundant potential in renewable energy, including hydro, solar and wind. Given the significant power deficit and strong forecasted growth in generation capacity, the region could avoid carbon lock-in and the risk of stranded assets by increasing the share of renewable energy and decentralized sources in the generation mix.

Namibia is the highest-ranking country in the region, with a combined aggregate score of 55/100, while the region's two largest energy consumers, Nigeria and South Africa, rank in the bottom 10 percentile. Nigeria has high scores on economic development and growth due to large fossil fuel reserves, but the overall scores are affected by low scores on the remaining system performance dimensions, as well as a lack of enabling infrastructure, regulatory framework and governance of energy transition. In South Africa, the energy transition challenge relates to shifting away from coal as the dominant source of power supply, as well as reforming the energy market to improve the reliability of this supply.[47]

4.4. Latin America and the Caribbean

Latin America and the Caribbean has 8.3% of the world's population and accounts for almost 6% of the global energy demand. The IEA estimates demand will increase by almost 40% by 2040.[48] The region shows great disparity in per-capita energy demand where, for example, Chile, Argentina and Venezuela have four times the per-capita energy demand of Honduras, Nicaragua or Haiti. To a certain degree, the disparity coincides with both the level of income and energy access of these countries. The heterogeneity in the distribution of natural and economic resources and income levels carries over to the ETI rankings, where the countries are scattered between the 11th and 115th rank with no concentration.

Looking at the ETI's subcomponents, and particularly system performance, most of the countries in this group scored consistently well over the past several years, buoyed by strong environmental sustainability scores with low levels of pollution, emissions per capita and carbon intensity. This results from having the highest share of renewables and second-lowest share of oil, gas and coal within its energy mix compared to other country groups; renewables' share was 8% in 2016 while Advanced Economies had only a 2% share in their energy mix. The impact of renewable energy production on the environmental scoring is even more evident for Uruguay, Costa Rica and Brazil, who are among the 10 highest-scoring countries in the ETI's environmental sustainability dimension with large shares of renewables in their total primary energy supply.

While hydropower is the primary renewable source of electricity for many of the region's countries, it also increases the electricity system's vulnerability to the amount of rainfall over the year. Tougher regulations on dam construction in some countries has further exacerbated this, allowing only run-of-the-river plants to be constructed. By design, those plants have less storage and increase the risk of supply shortages during droughts. Fossil fuel-based plants are built to diversify power sources and to ensure sufficient reserve capacity is available at all times. The IEA anticipates a 2.5% average annual increase in the region's gas-based power production until 2040.[49] Concerns over unexpected, prolonged droughts can lead to increased production of power from non-hydro power plants, resulting in increased carbon emissions. Despite having one of the lowest-carbon-intensive energy systems, Brazil has seen carbon emissions per unit of power production nearly double between 2006 and 2015;[50] the increase was due to growing reliance on backup power sources to maintain high levels of water storage in dams and to overcome the risk of prolonged drought conditions.[51] The costs of addressing capacity shortages through thermal power production facilities were estimated at over $11 billion in 2014.[52]

The less-diverse energy supply infrastructure has contributed to lowering this region's scores along the energy security and access dimension. The impact is partially offset, however, by continuous improvement in energy access over the years; electricity access increased from 91.7% in 2000 to 97.7% in 2016.[53] With the exception of the smaller countries of Honduras and Haiti, all nations in the region have enacted efficient access to modern energy policies and programmes.[54]

Along the economic development and growth dimension, this group's scores are close to the global average. The most influential factor within this dimension has been the high industrial electricity prices and their impact on energy affordability. Of the group's 21 countries, only five have prices lower than the global average: Chile, Mexico, Trinidad and Tobago, Ecuador and Paraguay. Deepening the integration of energy systems through regional electrical networks will likely help to increase competition and lower energy prices within the region. It could also facilitate further integration of renewable power capacity and improve the security of supply and resilience of the grid by adding diversity to the power mix.

Uruguay and Costa Rica are the highest-ranking countries in this region with combined aggregate scores of 67/100 and 64/100, respectively. Both scores are driven by strong performance along the environmental dimension. The group's lowest-ranking country, Haiti, is also the lowest-ranking this year in both energy system performance and transition readiness.

4.5. Middle East and North Africa

The Middle East and North Africa group accounts for 6.8% of the global energy demand and 7.1% of the world's population. The region is well endowed with fossil fuel resources that have greatly influenced its energy mix, with 92% of its primary energy supply provided by oil and gas. Geopolitical tensions and instability in these countries affects political priorities, opportunities for energy systems integration and the ability to attract investments required for the energy transition. While the average score of system performance within the region is closer to the global average, analysis of the three dimensions reveals imbalance in meeting the three objectives of the energy triangle.

The group has consistently registered the lowest average score in the environmental sustainability dimension compared to other groups. Outdoor air pollution, measured by the level of airborne PM2.5, is the highest in the world, the result of relaxed requirements where, within the region, only Iran and Israel have adopted laws that set limits on particulate matter and air pollution.[55] These counties also have the highest carbon intensity at double the world average, a direct result of the high concentration of oil and gas in their energy mix. Significant plans are under way to diversify the fuel mix. Earlier this year, Saudi Arabia announced the tripling of its renewable energy targets to have over 60 gigawatts of installed capacity by 2030, thereby increasing the share significantly to displace oil consumption in the power sector.[56] The United Arab Emirates is targeting a shift in its energy mix to have 44% sourced from clean energy sources.[57]

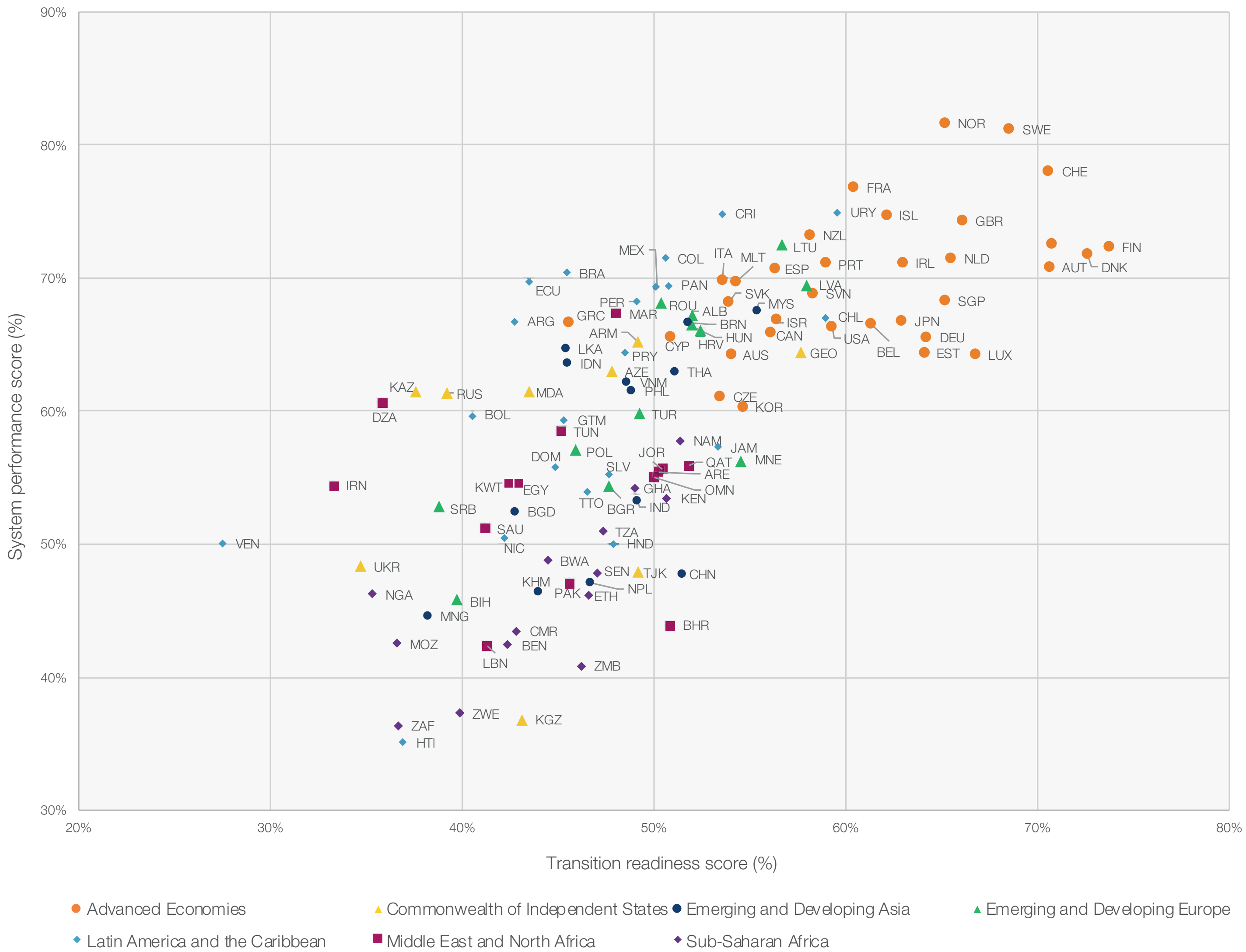
Analysis of the underlying data reveals the region has the lowest average household and industry electricity prices and the lowest wholesale gas prices. The positive impact of low prices on the economic development dimension, however, is offset by the negative impact of having the highest level of energy subsidies in the world, calculated as the share of a country's GDP. Significant efforts are under way within these countries to reform energy prices. Nine countries, at a minimum, have imposed certain forms or levels of energy price reforms over the past few years: Saudi Arabia, United Arab Emirates, Oman, Qatar, Kuwait, Bahrain, Algeria, Iran and Egypt.[58] In Saudi Arabia, some fuel product prices have increased up to 200% compared to 2015 levels. Some of these efforts are not captured in the Index because data was unavailable at the time of publishing.

On the energy security and access dimension, the region scores high in electrification with an average of 98%. This is offset by the lower score in the energy security dimension resulting from the concentration of oil and gas within the energy mix. On both energy security and economic growth, the region can greatly benefit from further integration of the energy supply infrastructure. One notable effort is in Egypt, where a 3,000-megawatt power transmission line has been approved to link the power grid to Saudi Arabia to improve the country's energy security. Two other connections exist with Jordan and Libya, and studies are under way to evaluate a potential connection with Cyprus.[59]

In terms of ranking, Morocco ranks highest and is followed by Qatar, which is driven by a strong performance score supported through low energy prices and significant fuel exports. Lebanon ranks lowest, driven by low performance in the energy security dimension due to import diversity, low quality of electricity supply and high energy subsidies.

Finally, a readiness matrix (Figure 11) can show the positionings of countries along the system performance and transition readiness measures, which can prove helpful for benchmarking.

Figure 11: ETI 2019 Performance/Readiness matrix (by country groups)



Source: World Economic Forum

5. The scale and complexity of energy transition

The transition journey is far from finished. Substantial change is required on several fronts: increasing sustainable sources in the composition of the primary energy supply, reaching near-universal access to affordable and reliable energy, minimizing carbon emissions and pollutants that result from energy production, and having a combination of technologies, infrastructure and sustainable practices for efficient energy use. Two mutually reinforcing challenges in energy transition – complexity and scale – determine the speed of energy transition.

The complexity of energy transition results from the diverse components within the system itself, as well as their interdependencies with components outside the energy sector. The energy system's boundaries include different fuel sources, extraction and conversion processes, and infrastructure, workers, investors, innovators and different end-use sectors. Beyond the boundaries, energy is a commodity traded between countries and a key component of public policy within them. The volatility of energy markets and trade flows influences countries' fiscal and monetary policies. The energy system also enables economic growth by fuelling industrial activity, providing employment and creating national income through exports. Universal access to energy is important to alleviating poverty and improving outcomes on social objectives, such as education, health and gender equality.

The large scale of the energy transition is evident by the size of the installed base, the volume of invested capital, the vast expanse of the supply chain, and the fragmented decision-making landscape across global, national, local and individual levels.

The intersection of technological systems with economic fundamentals, geopolitical and security considerations, individual and collective behavioural patterns, and political sensitivities contributes to the transition's slow pace. The steering of the current system towards a sustainable future cannot afford the luxury of decades, given the state of the energy system and the urgency of climate change warnings. At the same time, the transition will need to avoid creating economic disruptions or social inequalities.

To accelerate energy transition, countries must take a balanced approach across the three imperatives of the energy triangle while leveraging the potential of the Fourth Industrial Revolution and enhanced public-private collaboration. Prioritizing one of these imperatives at the expense of the others could reverse some of the progress made towards a fully transitioned system. Energy transition has complex implications that go beyond first-order shifts in fuel supply mix or dominant technology used to extract energy from nature.

The dominant discourse and public policy tend to emphasize changes in energy technologies or fuel source as an objective of the transition, instead of lasting changes in the energy system that reflect across the balance between established economic, social and political systems. The need for greater speed in energy transition may also be due to limited awareness, political will, investment or the availability of technologies. A comprehensive understanding of the scale and complexity of energy transition is required to make informed and efficient decisions that can accelerate the transition.

Subsequent sections of this report explore the different dimensions, narratives and perspectives to help foster a greater understanding of what determines the speed of energy transition. This includes borrowing from recent academic literature that breaks the energy system into three co-evolving and interacting systems.[60] Each has its own scope, key players, priorities and challenges (Figure 12). Grand energy transition is the result of significant changes within each of those systems and their interactions. Energy transition can thus be viewed as a change on the scale of a "system of systems".

Figure 12: The energy system: three co-evolving and interacting systems

System	Energy-related scope	Key players	Challenges
Energy–economy	Focused on understanding the current and future demand for energy and the optimization of supply infrastructure	Energy analysts, planners, economists and energy market regulators	Limited view on the impact of innovation and technology diffusion on demand growth and supply infrastructure
Energy–technology	Focused on understanding the impact of innovation, technology development and diffusion on the energy system	Scientists, engineers, economists, R&D institutions, and consumers	Focused on incremental improvements rather than breakthrough innovations or encouragement for wider adoption
Energy–society	Collection of energy policies related to efficiency, security and energy equity/ justice	Policy-makers, consumers and workers	Competing priorities within different political parties and governments, and changes in priorities over different time frames

Source: World Economic Forum

5.1. The energy–economy system

The energy–economy system operates through market forces that determine the volume, direction and distribution of energy flows. At any given point in time, energy supply and demand are in a global and national equilibrium through production, consumption and trade activity. Increases in energy demand are balanced with supply increases and, recently, with alternative energy sources that compete with incumbent fuels and technologies.

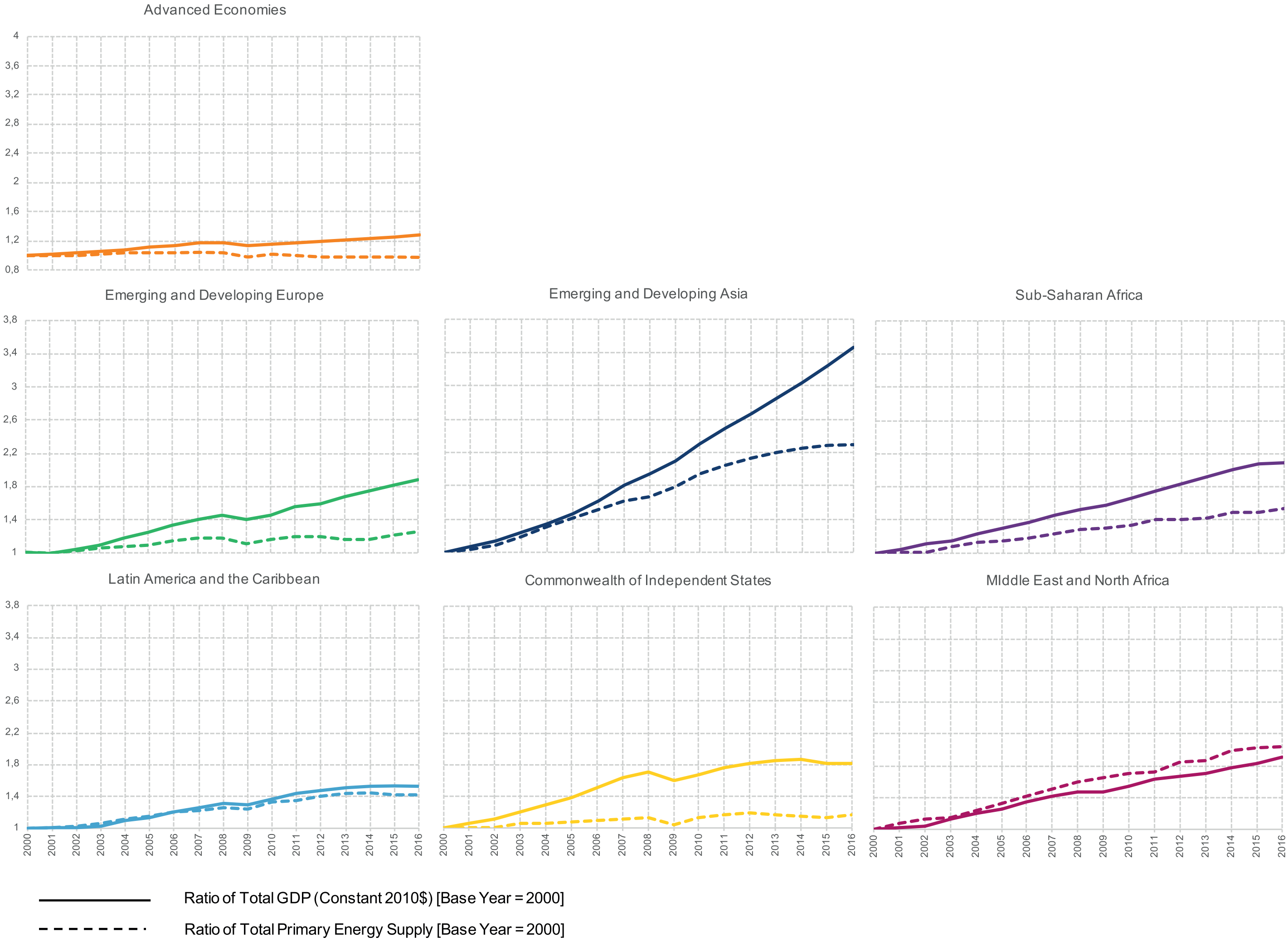
In addition to market forces of supply and demand, energy transition is driven by resource depletion, income levels, population, geopolitical considerations and environmental externalities. Hence, the economic definition of energy transition tracks progress in quantitative terms, such as shifts in fuel supply mix, energy intensity of the economy, energy consumption per capita, emissions intensity of energy supply, costs of energy production, trade balance and levels of investment. Policies tend to promote a particular fuel or technology, primarily by addressing market failures through incentives or technology mandates. The economic effects of energy transition are evident in recent events, including the cost competitiveness of renewable sources of energy, the rapid growth of shale exploration to produce oil and gas in the United States, and oil supply adjustments from OPEC and Russia.

This perspective of energy transition tends to dominate current discourse because it is tangible and measurable. It views the primary goal of a country's energy transition as the dual challenge of addressing rising energy demand and environmental sustainability while maintaining economic growth. The economic perspective of energy transition, however, does not consider system inertia and lock-in effects from dominant carbon-based technology systems, which limit the scale and speed of diffusion of innovations in the energy system. The economic perspective also does not consider politically driven changes, such as rural electrification or the provision of cheaper energy through subsidies, and the distributional and equity considerations arising from sharing the costs and benefits of energy transition.

As describe above, the key challenge for energy transition in the energy–economy system is for countries to decouple economic growth from energy consumption and to manage rising energy demand while ensuring growth and environmental sustainability. The extent to which energy consumption can be decoupled from economic growth depends on the stage of an economy's growth and its development pathway.

Recent trends in energy consumption and real GDP in different country groups can be shown using ratios between the yearly aggregate values of all countries in the respective groups and the aggregate values in the year 2000 (Figure 13). The trends highlight that total energy consumption in Advanced Economies has declined since 2000 even as the total real GDP for this group increased. This trend, consistent across high-income countries, is an effect of the combination of investment in technological and economic efficiency and the larger contribution to the economy from the less-energy-intensive services sector.

Figure 13: Evolution of total GDP and total primary energy supply across country groups, 2000-2016



Note: The figure shows yearly ratios of quantities to their values in 2000.
Sources: For GDP: Constant 2010 US$, World Bank, 2017, https://data.worldbank.org/indicator/NY.GDP.MKTP.KD?page= ; for total primary energy supply: IEA, *World Energy Balances*, 2018

However, in country groups with faster economic growth, such as Emerging and Developing Asia, Sub-Saharan Africa, and the Middle East and North Africa, energy consumption has increased considerably since 2000. As countries move up the development curve towards higher income levels. early stages of economic growth are typically associated with increased levels of energy consumption and carbon emissions.[61]

Given the urgency of the climate challenge, an important question is how governments of Advanced Economies can work with developing countries to promote sustainable growth in emerging economies. Technology transfer has always been one important element, though success stories in this sphere are limited. Successful technology transfer goes beyond transferring the hardware; it entails enabling the recipient country to replicate and innovate this technology. This requires tackling technology diffusion inhibitors, which range from diversity in the recipient nation's objectives for technology development to concerns over intellectual property rights, weak domestic demand, high levels of subsidies and a weak investment climate.[62]

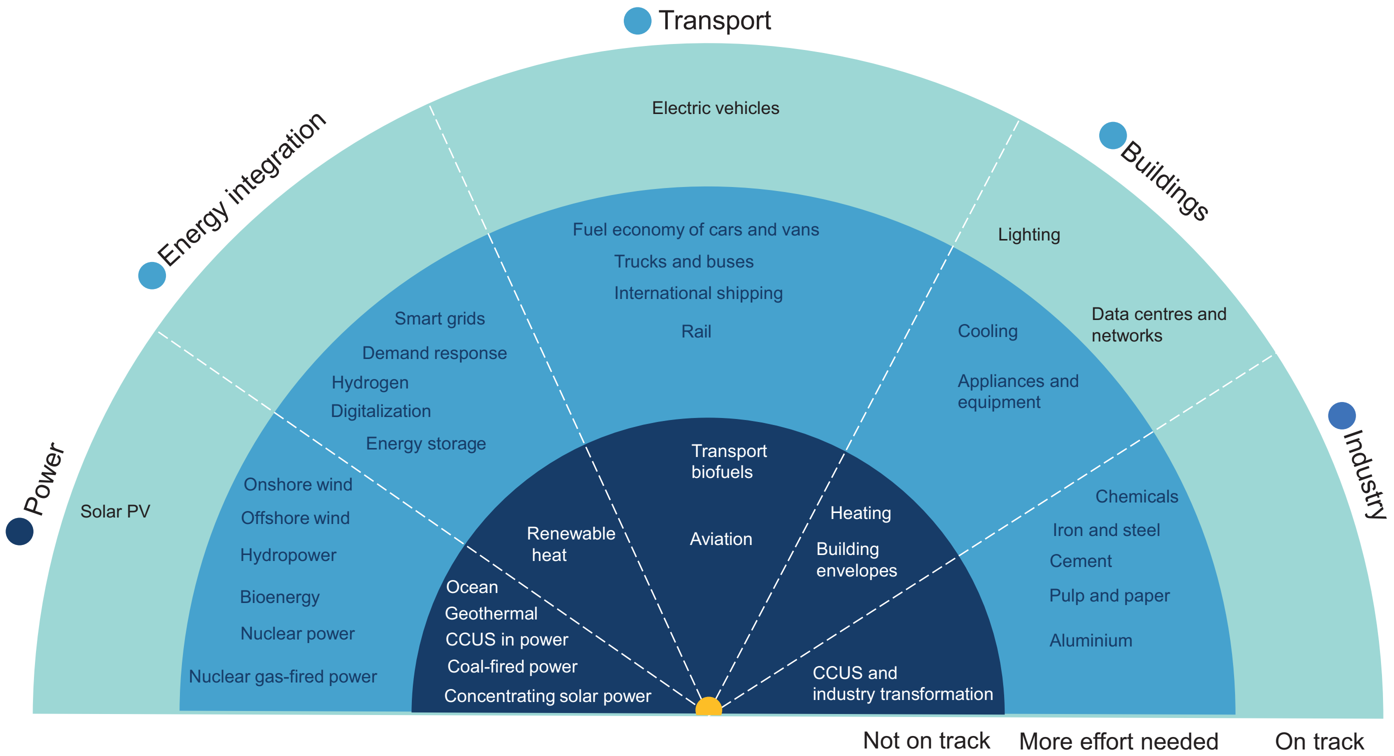
5.2. The energy–technology system

The current energy architecture evolved to serve social needs such as lighting, mobility, heating and safety, and to fuel economic growth. Ensuring a secure, affordable and reliable energy supply to meet these socio-economic objectives requires a vast array of technologies for energy extraction, conversion and end use, and an enabling infrastructure to integrate these activities. From a technology perspective, energy transition is driven by innovating across different technological areas and adopting this innovation in the energy value chain. The key objective of energy transition, from the technology perspective, is to substitute the prevalent fossil fuel-based technologies dominating the energy system with more efficient and low-carbon alternatives. One important avenue to achieve this is through developing and quickly diffusing innovative technologies and solutions.

Innovations in the energy system are either incremental or breakthrough. Incremental innovations, such as those benefiting from digitalization, artificial intelligence and machine learning, have helped the energy system become more efficient and productive. In addition to optimizing processes and the use of assets, they have also enabled new business models that have significantly altered the landscape of the energy system.

But accelerating the speed of energy transition requires breakthrough innovations. In contrast to incremental ones, breakthrough innovations cannot materialize in shorter timescales with less upfront capital; they are inherently time- and capital-intensive and are vulnerable to the uncertainties of energy markets and the political climate. According to the IEA,[63] only four of 38 energy technology areas were on track in 2018 to meet its Sustainable Development Scenario, which the agency describes as "a major transformation of the global energy system, showing how the world can change course to deliver on the three main energy-related SDGs simultaneously".[64] From a technology perspective, a broader set of technology options will need to mature for widespread adoption at an accelerated pace. This includes breakthrough innovation not just in power generation or energy extraction, but also in carriers, such as hydrogen, biofuels and energy storage, and in carbon removal options, such as carbon capture, utilization and storage and deep decarbonization of hard-to-abate end-use sectors (for example, aviation, shipping, cement and steel production) (Figure 14).

Figure 14: IEA radar of energy technology areas



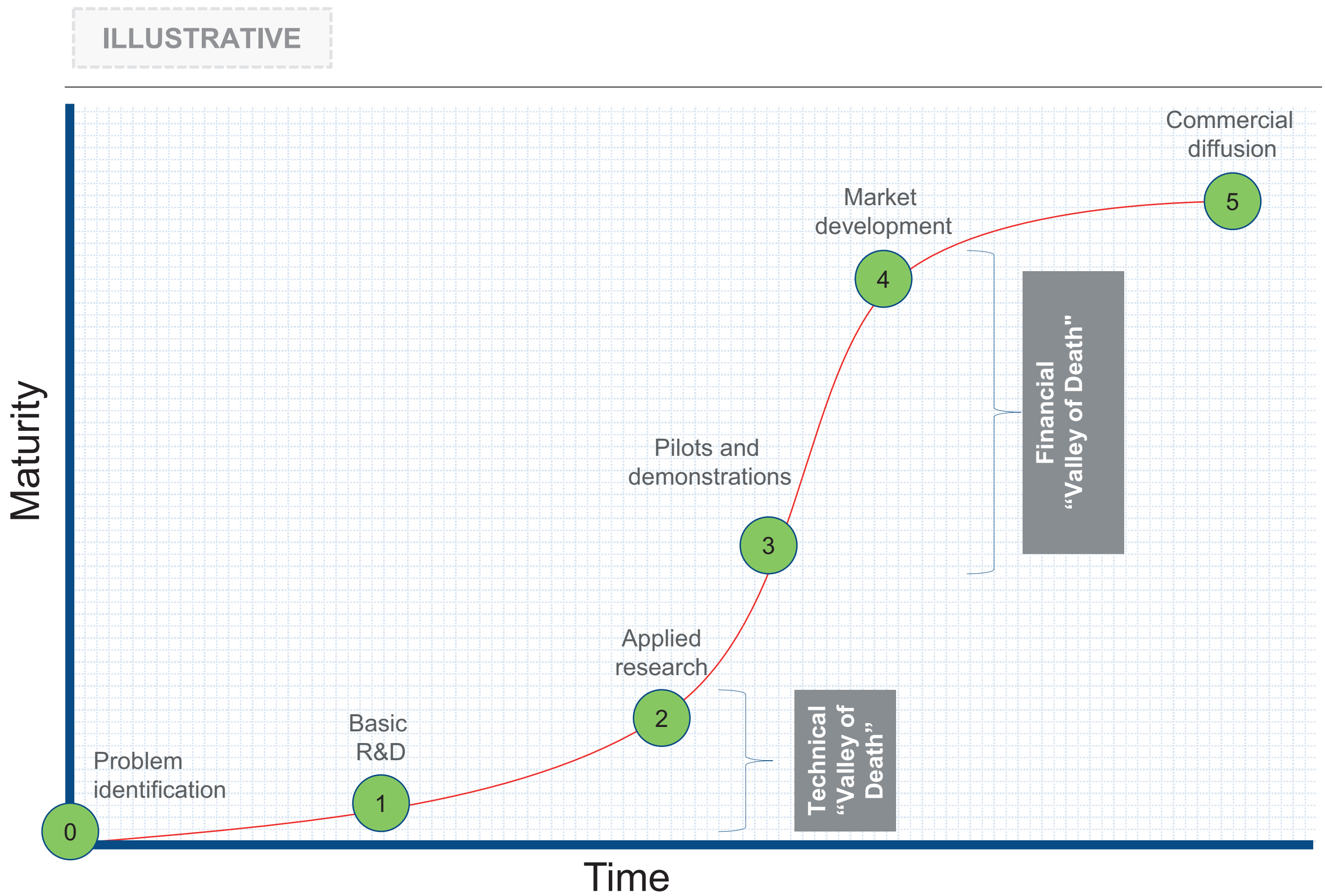
Note: CCUS = carbon capture, utilization and storage.
Sources: IEA, *Energy Technology Perspectives 2018*; KPMG International Cooperative, https://assets.kpmg/content/dam/kpmg/xx/pdf/2018/10/radar-of-ieas-clean-energy-technologies-and-sectors-infographic.pdf

Technology areas advance through different stages of innovation, from idea or product identification to commercial diffusion (Figure 15). Accelerated progression of a technology area through successive stages of innovation relies largely on the presence of a vibrant innovation ecosystem, an entrepreneurial culture and timely access to finance. It also needs a mix of policies that balance supply push (such as R&D incentives, collaborative research between universities and the private sector, test beds for demonstration) and demand pull (including public procurement, technology mandates, consumer preferences and early-adopter incentives). The barriers to technological diffusion, however, are not restricted to the lack of access to capital or enabling policies. For example, even after a decade of sustained capital investment and a policy environment conducive to renewable energy sources and electric vehicles, renewable energy supply (solar photovoltaic and onshore wind) amounts to only 1.6% of global primary energy supply. Moreover, the stock of electric vehicles in 2017 was only 0.2% of light duty vehicles on the road. Innovative technologies interact with existing energy systems; they face path-dependency from technological lock-in and from existing institutional frameworks and end-use behaviours that evolved in sync with the technological system.[65]

The technological lock-in is created by the high fixed costs of the installed base, long lifetimes of physical infrastructure, and economies of scale that encourage maintaining the current course rather than pursuing other technology options. Furthermore, the inertia is aggravated through network effects that increase the existing system's value through interconnected physical infrastructure, uniform technology standards, interoperability features, standardized training modules and regulatory structures. Additionally, the existing technological system is deeply embedded in institutional structures that were designed to ensure the security, reliability and affordability of energy supply. The existing institutional frameworks governing energy systems operate on least-cost principles to minimize the cost to consumers and on risk aversion, and promote business models that need scale and high levels of consumption for financial viability. Given the long lifetimes and essential nature of energy systems, these attributes are critical to ensuring reliable and affordable energy services, though they create strong barriers to entry for disruptive technologies through institutional lock-in.

Lastly, the extent to which innovation diffuses in the system depends on the level of end-user adoption. The behavioural lock-in is a consequence of established individual lifestyle preferences, habits and routines, social norms, and cultural

Figure 15: Stages of Innovation



Note: "Valley of Death" refers to the barriers innovations face before they are commercialized.
Source: Adapted from Sims Gallagher, K., Holdren, J.P. and Sagar, A.D. "Energy-Technology Innovation", *Annual Review of Environment and Resources*, Vol. 31, November 2006, pp. 193-237, http://seg.fsu.edu/Library/Energy-Technology%20Innovation.pdf

values. Moreover, given the large scale of the energy system, shifts in individual consumption patterns do not significantly affect the systemic level, leading to the problem of collective action. That is, the impacts of energy reforms on consumers are spread over billions of people around the world, while the supply-side effects are concentrated on a much smaller number of influential stakeholders, such as industries, multinationals and producers.

The above-mentioned phenomena demonstrate a strong path dependency in favour of the existing energy system, which significantly limits the pace of diffusion of innovative energy technologies and solutions. Established technological, institutional and behavioural components are interdependent; thus, a mix of policy interventions are required that can simultaneously target them and the coordination between political, economic and social actors to foster energy transition through accelerated innovation and deployment of low-carbon technologies.

5.3. The energy–society system

Energy policies are not formulated in isolation but rather are strongly interdependent with what occurs in the energy-economy and energy-technology systems. What happens in any of these determines the course of energy policies, and vice versa.

In the energy–economy system, for example, energy policies frequently attempt to optimize the fuel and technology mix to promote greater energy security and economic growth. In the energy–technology system, energy policies are instrumental in furthering innovation and an environment that allows for disseminating technologies. Effective design and formulation of energy policy needs to do these things while pursuing equity and justice when distributing socio-economic costs.

The road to achieving energy transition comes with collective action challenges, such as when transitioning to a lower-carbon system. The benefits from carbon reduction, in the form of avoided climate change on the general population, are diffused relative to the concentrated costs borne by business owners in fossil fuel-intensive industries. Owners in these industries, for example, experience greater risks of carbon costs eroding the long-term value of their business.[66] For this reason, effective energy transition policy ought to address the effects on vulnerable sectors of the economy.

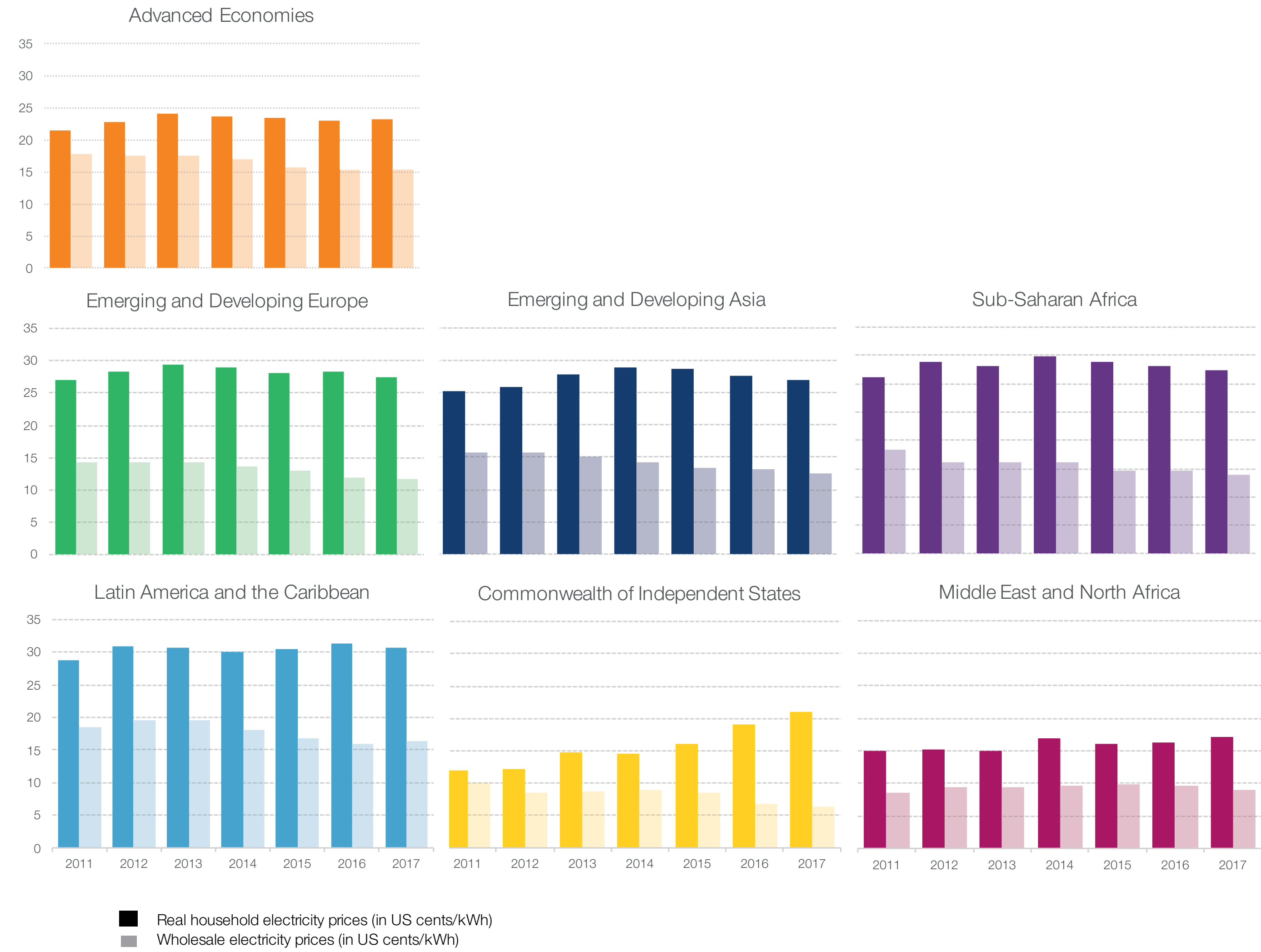
The role of civil society is particularly important to achieving a just and equitable transition. Throughout the process, the question of who wins, who loses, how and why should be at the centre of the dialogue. This includes those who live with the side effects of energy extraction, production and generation, and who will bear the social costs of decarbonizing energy sources and economies.[67]

Failure to adequately address negative impacts and provide support for individuals adversely affected can lead to political resistance and social unrest. The recent Yellow Vest movement in France, which started in response to multiple increases in fuel taxes (*la contribution climat énergie*), exemplifies the need for inclusiveness and equity in energy transition.

Simply answering the question by identifying winners and losers is not enough. Policy design and implementation should extend to answering the question of what to do with those who are adversely affected; effective policies can only be implemented by answering this. Unless policy design addresses the potential negative socio-economic effects of the low-carbon transition, society will continue to face fierce opposition from fossil fuel-dependent communities that could hinder the energy system's decarbonization.[68] Recent resistance from the Australian government to abandoning coal, along with calls by the US administration to revise the previous administration's clean power plan, sheds light on the complexity of developing stable policies. Both governments have presented counterarguments to abandoning coal that are linked primarily to the effect on localized economies or communities.

In addition to considerations on equitable distribution of costs and the benefit of energy transition, policies need to promote inclusive growth. Given the essential nature of energy services, affordability of energy supply directly affects households' well-being. The gap between wholesale and household electricity prices has been increasing in almost all country groups (Figure 16), signalling concerns about affordability and inequality. Moreover, on average across countries at different income levels, real average household electricity prices increased in more than 60% of the countries monitored. Energy poverty, defined as the inability of households "to consume adequate amounts of energy to maintain a decent standard of living at a reasonable cost",[69] is a concern not restricted to developing countries. The effect of the costs of energy transition, as reflected by rising energy bills, is increasingly being felt in high-income countries, which are generally considered further advanced in the energy transition process. For example, one in three US households struggled to pay energy bills in 2015, according to a survey by the U.S. Energy Information Administration.[70] In the United Kingdom, household energy debt rose by 24% in 2018 alone because of multiple revisions to energy prices during the year.[71] Across countries in the European Union, 16.3% of households reported disproportionately high expenditures on energy services in 2016.[72]

Figure 16: Household and wholesale electricity price trends (by country group), 2010-2017



Note: kWh = kilowatt hour
Sources: For household electricity prices – Enerdata (normalized using price level ratio of purchasing power parity conversion factor [GDP] to market exchange rate [World Bank, International Comparison Program database, https://data.worldbank.org/indicator/pa.nus.pppc.rf]); for wholesale electricity prices – World Bank Group. *Doing Business 2019: Training for Reform*

The challenges of equity and justice on energy transition require close scrutiny of the distribution aspects of the disruptive effects – in terms of cost sharing and the effects on local communities. To foster inclusiveness, energy transition policies will need to be tailored according to income and spatial distributions. This requires reskilling of workers at risk of losing livelihoods, and transparency in environmental or carbon taxes. Environmental taxes have been more effective when the tax burden is proportional to the individual consumption levels, and when the taxation is revenue-neutral overall.[73]

6. The way forward

The results of the Energy Transition Index 2019 establish the need for speed in energy transition. Given the scale and complexity of the challenge and the urgency of collective action, it is not a trivial task. Energy transition is not restricted to shifts in the fuel mix or dominant technologies used in energy extraction, conversion or consumption. A fundamental transformation in the way the world harnesses and consumes energy has far reaching economic, technological and political implications across multiple systems. Accelerating energy transition will require coordinated efforts that address the interconnections of the energy system with different elements of the economy and society.

Analysis of peer-economy groups highlights the differences in strengths and priorities for energy transition across countries. Multiple pathways, driven by country-specific circumstances, can lead to a future energy system that is secure, sustainable, affordable and inclusive. Leveraging the potential of the Fourth Industrial Revolution and enhanced public-private collaboration will be critical to these efforts.

Through this effort, the World Economic Forum intends to increase the transparency on energy transition. The Energy Transition Index offers a fact-based framework that can help decision-makers in prioritizing measures for an effective energy transition in their countries. Making fast progress on energy transition requires common understanding among all stakeholder groups in a given country, and a long-term roadmap that identifies the vision, destination and major milestones for energy transition. Figure 17 offers a framework for pursuing long-term energy transition roadmaps through multistakeholder collaboration.

As the International Organization for Public-Private Cooperation, the Forum aims to leverage its multistakeholder platform to encourage action on energy transition in countries. The forward-looking framework for energy transition has received positive feedback from stakeholders, particularly among those in the Association of Southeast Asian Nations and in Latin American countries. The Forum is exploring opportunities to best support ongoing energy transition efforts in these countries, encouraging public-private collaboration.

Figure 17: Seven-step framework for effective energy transition

Design

1 Convene

Identify and engage influential energy-sector champions across stakeholder groups, including government, the private sector and civil society

2 Align

Apply the fact-based framework for an effective energy transition to foster a common understanding of national energy transition imperatives and enablers

3 Structure

Establish an operational structure to drive ongoing collaboration among the stakeholders of the energy system

Implement

4 Plan

Define specific milestones and action plans to deliver impact on the ground, including a framework to measure progress against goals

5 Implement

Accelerate policy formulation and business decision-making by piloting inclusive public-private collaboration models and building business cases to ensure value creation for society

Adapt

6 Track

Monitor and evaluate improvements in the energy system to determine corrective actions

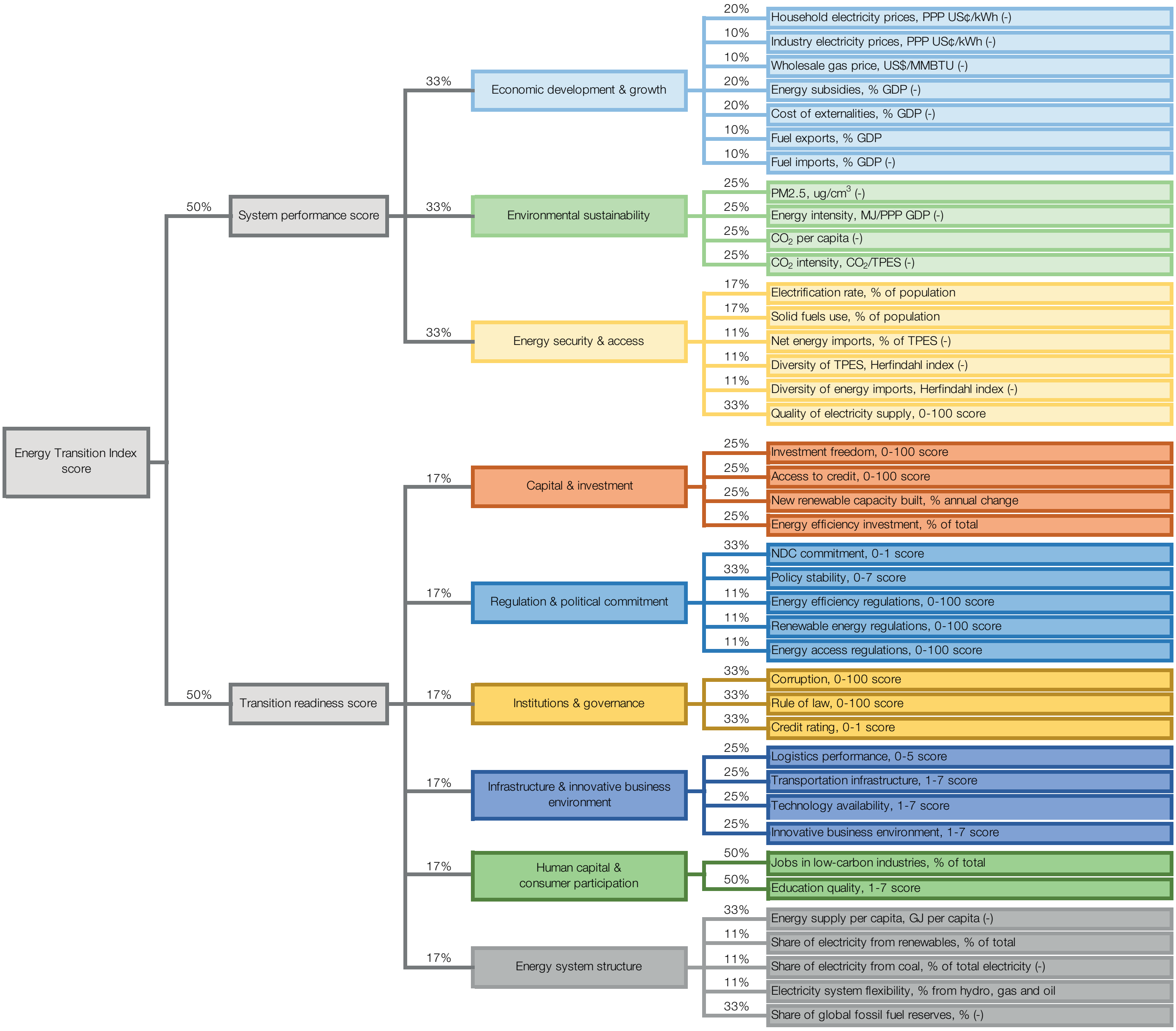
7 Refine

Adjust roadmaps and action plans as wel as the operational structure as needed to seize new opportunities over time

Source: World Economic Forum. *Fostering Effective Energy Transition: A Fact-Based Framework to Support Decision-Making*, 2018

Appendices

1. Energy Transition Index indicators and weighting framework



Notes: "(-)" means the indicator is negatively associated with the Index score. For example, an increase in household electricity prices lowers that country's economic development and growth score. Indicator values for each country are normalized according to threshold values determined by the indicator-specific distributions, and aggregated according to the weighting framework to determine country-level scores.
TPES = total primary energy supply; PPP = purchasing power parity; US¢ = US cents; MMBTU = million metric British thermal unit; ug/cm^3 = micrograms per cubic centimetre; MJ = megajoule; GJ = gigajoule; kWh = kilowatt hour.
Source: World Economic Forum

2. **Data sources**

Data source	Indicator
Enerdata	Household electricity price
World Bank, Doing Business indicators	Industry electricity price, quality of electricity supply, rule of law, access to credit
International Gas Union	Wholesale gas price
International Monetary Fund	Energy subsidies, externalities
World Trade Organization	Fuel imports and exports
World Bank, World Development Indicators	PM 2.5, electrification, use of solid fuels, share of electricity from renewables/coal/gas/hydro
International Energy Agency, *World Energy Balances*	Energy intensity, energy imports, energy diversity, energy per capita
International Energy Agency, *CO_2 emissions from fuel combustion*	CO_2 per capita, CO_2 intensity
United Nations Conference on Trade and Development	Import diversity
United Nations Framework Convention on Climate Change	Nationally determined contributions (NDC) commitment
World Economic Forum Global Competitiveness Index	Policy stability, transportation infrastructure, availability of technology, quality of education
World Bank, Regulatory Indicators for Sustainable Energy	Energy efficiency regulations, renewable energy regulations, energy access regulations
Transparency International Corruption Perceptions Index	Corruption
Moody's, S&P and Fitch	Credit ratings
The Heritage Foundation	Investment freedom
International Renewable Energy Agency	New renewable capacity built, low-carbon industry jobs
World Bank, Logistics Performance Index	Logistics
BP Statistical Review of World Energy	Fossil fuel reserves

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The World Economic Forum acknowledges and thanks the individuals and organizations without whose support the *Fostering Effective Energy Transition* 2019 report would not have been possible.

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Data partners

Climate Action Tracker, Enerdata, 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

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