WORLD ENERGY COUNCIL

World Energy Scenarios | 2019

Exploring Innovation Pathways to 2040

In Collaboration with Accenture Strategy and the Paul Scherrer Institute

ABOUT THE WORLD ENERGY COUNCIL

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

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

Further details at www.worldenergy.org and @WECouncil

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ABOUT THE REPORT

Scenarios provide an inclusive and strategic framework that enables big-picture thinking. They are designed to be used as a set to explore and navigate what might happen and support a better-quality global strategic dialogue on the future of energy systems.

In 2016, the World Energy Council and its scenarios partners, Accenture Strategy Energy and the Paul Scherrer Institute, introduced the World Energy Scenarios which explore three plausible pathways for energy transition to 2060.

Over the last three years this scenario framework has been validated by input from the Council's extensive energy expert member community. The three scenarios are perceived to be more relevant than ever.

In this scenarios refresh, the Council has adopted a medium-term time horizon of 2040 and focused on the implications of broader and disruptive innovation for the energy industry.

The report, "Exploring Innovation Pathways to 2040," presents three global storylines to 2040, with supporting systems thinking maps, comparative analysis and regional summaries. It includes a discussion of new insights, reflecting deeper shifts in the energy system innovation landscape, and provides a broader view on "how to use" the scenarios.

Refreshed scenarios were informed by insights from more than 100 deep-dive leadership interviews across 14 themes, regional workshops and wide experts' engagements.

Produced in collaboration with:
Accenture Strategy as Project Partner, Scenarios

Paul Scherrer Institute as Project Partner, Scenarios: Energy Modelling and Scenario Quantification

PREFACE

Welcome to the new and different futures of energy and an opportunity to better prepare for the challenges ahead!

The World Energy Council has been developing and using World Energy Scenarios for over a decade to support its global member network of energy leaders, to clarify complexity, and to realise new opportunities for successfully managing global energy transition.

Since introducing the World Energy Scenarios framework in 2016, our extensive global horizon scanning has detected signals in all three of our archetype scenarios – **Modern Jazz, Unfinished Symphony and Hard Rock** – in all regions of the world.

We have benchmarked the Council's scenarios with the energy future outlooks, scenarios, and visions that have been produced by a well-respected peer group, which includes global energy companies and international institutions.

Importantly, we continue to invest in effective use. We are supporting our members and their stakeholders in their use of the World Energy Scenarios, recognising that the added value of a scenarios-based leadership dialogue is different from simply discussing written reports. We have developed a variety of application processes, with an emphasis on interactive experiences to help governments and businesses use World Energy Scenarios in the drive to impact.

As a result, we are confident in providing assurances of the quality, relevance, and usefulness of this set of World Energy Scenarios to 2040.

This latest set of scenario narratives maintains the existing scenario framework and describes three potential pathways for energy system transition to 2040. At the request of our members we have focused these scenarios on helping energy leaders to grapple with the new realities of a disruptive landscape of innovation in energy transition, which is emerging faster and from beyond the energy sector.

In addition to the three scenario stories, there is a detailed comparative analysis of the implications for the energy system, eight regional perspectives, and a set of supporting energy systems dynamics maps. We encourage energy leaders to resist the temptation to flick directly to the numbers section and, instead, to immerse themselves in the stories in order to make better sense of the illustrative quantification.

In the journey of The Grand Transition, we have entered a new energy era, which promises clean energy abundance and the benefits of sustainable energy for all. It is a promise that still needs to be met. In order to succeed, we need to avoid the risk of fragmentation of bottom-up innovation and top-down ideological polarisation, which is characterising global energy dialogues. These scenarios are a tool to help guide leadership decisions through rapidly changing energy realities and a platform to realise the importance and benefits of a collaborative approach by energy transition leaders, within and beyond the energy sector.

Whatever your role – government minister, investor, technologist, entrepreneur, business leader, major resource holder, city mayor, policy maker/shaper, energy expert, or interested observer – we invite you to join us in using and further developing these scenarios in the drive to thrive in a successful world-wide energy system transition.

Younghoon David Kim
Chair, World Energy Council

Christoph Frei
Secretary General, World Energy Council

FOREWORD

We have entered the age of disruptions. Technological innovations, climate change and more tense geopolitics are reshaping the world of energy. The World Energy Scenarios provide the perfect tool for assessing these macro-uncertainties and crafting a strategic response, whether you are an energy leader, policy maker or innovator.

Following an intensive review of signals a decision was made to maintain the World Energy Scenarios 2016 framework, focus on medium-term pathways to 2040 and elaborate on regional developments. The three 2019 scenarios are, as before:

- **Modern Jazz.** A market-led, innovative, and digitally disrupted world with a faster paced and more uneven economic growth.
- **Unfinished Symphony.** A strong, coordinated, policy-led world, with long-term planning and united global action to address connected challenges, particularly a low-carbon future
- **Hard Rock.** A fragmented world with inward looking policies, lower growth and less global cooperation.

These scenarios were developed by World Energy Council members and produced with our collaborators, Accenture Strategy and the Paul Scherrer Institute.

The process included 100 expert interviews and several workshops building the scenario narratives, both in London and other locations. We offer thanks to those Member Committees that hosted workshops in France, Estonia, Germany and UAE; and to those who attended most of the workshops: Andreia Severiano, Angel Landa Ugarte, Burkhard von Kienitz, Christoph Menzel, François Cattier, François Dassa, Hans-Wilhelm Schiffer, Jean-Eudes Moncomble, John M. Roberts, Julian Jansen, Priit Mändmaa, Rafael Cayuela, Ryo Fukushima, Stefan Gheorghe, and Wolfgang Ernst.

The ability to incorporate the wide range of perspectives from multiple sources was only possible thanks to a talented core team. I would like to thank those who have contributed to this project. This includes from Accenture Strategy, Albert Howard, James Collins, Muqsit Ashraf and Richard Kho whose critical analyses have enhanced the report; from the Paul Scherrer Institute, Tom Kober, Martin Densing and Evangelos Panos, who led the modelling, and from the World Energy Council's Secretariat, Angela Wilkinson and Anastasia Belostotskaya, whose leadership and coordination was central to the success of the project; and Betty Sue Flowers, our report editor.

The launch of the World Energy Scenarios in Abu Dhabi is a platform for possible applications across the world. Many possible uses of scenarios are outlined in the report and are recommended for a broad range of users.

What I have learned from this process is:

- The need to get a better understanding of combinatorial disruptions, and the promise of the "constellation of disruptions" tool.
- The sharply different formulation of regional challenges across the world that questions our desire to work together to address global concerns.
- There are no certainties about the exact nature and form of the energy transition. We need inspired leadership and the courage to create the energy world we need and want.

Finally, I take full responsibility for any omissions or inaccuracies in the report.

Ged Davis - Executive Chair, World Energy Scenarios, World Energy Council

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EXECUTIVE SUMMARY

The world of energy is being reshaped by a set of fundamental drivers, which we term the "Grand Transition". These drivers provide the broader context for determining global energy pathways to 2040.

Since the World Energy Council last published its World Energy Scenarios in 2016, we have experienced three years of comparatively high, carbon-centric energy demand and a marked acceleration in renewable energy developments. A new pattern of geostrategic competition is emerging that is further straining the multilateral system and impacting global trade. What has changed most, however, is the speed and volatility of changes and unevenness of impacts. Fragmentation and polarisation of leadership and poor economic returns limiting the license to invest for market players are emerging as some of the biggest risks in managing successful energy transition. Meanwhile, energy leaders are also challenged to make sense of the fast-shifting landscape of innovation and the new spirt of entrepreneurialism in energy. A fresh focus on energy systems innovation and the emerging phenomenon of "disruption-as-usual" is both timely and relevant to energy transition leaders within and beyond the energy sector.

The energy system implications of this 2019 scenario-based update include:

1. **ALL THREE WORLD ENERGY SCENARIOS HAVE BEEN VALIDATED** by signals in all regions and are perceived as more relevant than ever.
2. **GLOBAL PRIMARY ENERGY DEMAND MOMENTUM REMAINS** in line with the 2016 scenario modelling, with per capita energy consumption projected to peak in the 2020s.
3. **ELECTRIFICATION EXTENDS TO MORE USES AND USERS,** driving decarbonisation rates; however, the question of hard-to-abate sectors and non-electrified uses remains open.
4. **A NEW MOBILITY REVOLUTION,** which is dependent on infrastructure, is gathering momentum, with the potential to disrupt the entire energy landscape in the longer term.
5. **ENERGY EFFICIENCY GAINS ARE CRITICAL** to manage energy demand from industrial, residential and commercial sectors and to avoid reducing climate change momentum.
6. **NEW OPPORTUNITIES ARE EMERGING** to provide energy-plus services in an increasingly consumer-centric energy system.
7. **INFRASTRUCTURE INNOVATION AND INVESTMENT,** and proactive policies are necessary to secure affordable decarbonisation and socially just energy transitions.
8. **NEW NET-ZERO CARBON TECHNOLOGIES PATHWAYS** (including hydrogen) and carbon abatement mechanisms (including Carbon Capture, Usage and Storage (CCUS)) emerge and start to scale by 2040.
9. **ACHIEVING PARIS AGREEMENT TARGETS REMAINS ELUSIVE,** with none of the 2019 scenarios meeting the 2°C target agreed to in the UNFCCC Paris Agreement.

Recommendations for business leaders and policy makers are presented with a clear call to avoid complacency and fragmented action, to address connected challenges and to intensify collaborative innovation.

THREE SCENARIOS FOR FUTURE ENERGY PATHWAYS

In 2016, the World Energy Council (the "Council") and its scenarios partners, Accenture Strategy Energy and the Paul Scherrer Institute, published a new set of World Energy Scenarios describing three different plausible pathways for energy transition. The scenarios adopted a time horizon to 2060 to focus on the responses to the challenge of global climate change.

Over the last three years, this scenario framework has been validated by input from the Council's extensive energy expert member community and annual surveys of energy leaders. The three scenarios are perceived by these experts to be more relevant than ever. Discussion of member input has added interesting nuances to each scenario archetype. In this round, the Council has adopted a medium-term time horizon of 2040 and focused on the implications of broader and disruptive innovation for the energy industry.

The 2019 scenarios are summarised as follows:

Modern Jazz. A market-led, digitally disrupted world with faster-paced and more uneven economic growth. Recent signals suggest that this entrepreneurial future might accelerate clean energy access on both global and local scales, whilst presenting new systems integration, cyber security and data privacy challenges.

Unfinished Symphony. A strong, coordinated, policy-led world, with long-term planning and united global action to address connected challenges, including inequitable access and affordable decarbonisation. Recent signals suggest increased activism and commitment to addressing climate change at the sub-national level, and an expansion of the focus from climate change mitigation to a broader, socially inclusive and economically affordable sustainable development agenda.

Hard Rock. A fragmented world with inward-looking policies, lower growth and less global cooperation. Recent signals, such as the rise of populist leaders and uncertainty about the outlook for international cooperation, imply that this scenario is also evolving into a story of regionally firmer security foundations rather than total fragmentation and "harder rocks."

The focused refresh of the scenarios provides new insights into the broader and fast-shifting landscape of innovation, which is emerging from within and beyond the energy system and includes not only new energy technologies but also non-energy technological innovations and a new spirit of entrepreneurialism in energy. The scenarios redirect energy leaders' attention to other non-technological innovations such as new consumer behaviours and innovative business models that disrupt existing value chains and can reshape the whole energy system.

ENERGY SYSTEM IMPLICATIONS

1 ALL THREE WORLD ENERGY SCENARIOS HAVE BEEN VALIDATED BY SIGNALS IN ALL REGIONS AND ARE PERCEIVED AS MORE RELEVANT THAN EVER.

This 2019 update confirms the general direction of the three scenario pathways of the 2016 report. Signals of each scenario have been detected in all regions of the world through the use of a variety of leadership surveys and systematic horizon-scanning methods. There has been a marked shift in perception about the scenario **Hard Rock**, which is no longer seen as an extreme scenario. Perspectives are also more divided about the outlook for effective global cooperation, which is assumed in the scenario **Unfinished Symphony**. The entrepreneurial scenario **Modern Jazz** has generated a lot of questions about new societal dynamics relating to increasing inequality, active consumers and effective market design.

2 GLOBAL PRIMARY ENERGY DEMAND MOMENTUM REMAINS IN LINE WITH THE 2016 SCENARIO MODELLING, WITH PER CAPITA ENERGY DEMAND PROJECTED TO PEAK IN THE 2020S

The rate of growth of primary energy demand per capita is highly dependent on the scenario. The strong global policy effects of **Unfinished Symphony** can achieve a near-flat primary energy demand through to 2040, while **Modern Jazz's** technology-driven efficiency gains are overwhelmed by strong GDP growth with primary energy demand increasing by 13% over the period. **Hard Rock's** fragmented and nationalistic approaches lead to a 21% growth, which is still less than half of the growth of the past twenty years.

Fossil fuels will continue to provide over two-thirds of global primary energy in 2040. Coal's contribution falls, whereas gas grows its share in all scenarios. Oil demand peaks between 2025 and 2030 in **Modern Jazz** and **Unfinished Symphony**, with the former scenario seeing a slow decline afterwards and the latter experiencing a rapid drop by 2040 to demand levels last experienced in 2000. **Hard Rock** oil demand rises till 2040 with a long plateau beyond. Compared with 2016 projections, the first two scenarios experience a notably lower oil demand by 2040, which is offset by an equally higher gas demand.

At a regional level, Central Asia (including India) is the largest driver of primary energy demand growth, while East Asia (including China) succeeds in curbing growth in all scenarios but **Hard Rock** by 2040. Europe and North America are set to experience peak primary energy demand in the twenties and thirties respectively under all scenarios.

3 ELECTRIFICATION EXTENDS TO MORE USES AND USERS, DRIVING DECARBONISATION RATES; HOWEVER, THE QUESTION OF HARD-TO-ABATE SECTORS AND NON-ELECTRIFIED USES REMAINS OPEN.

Demand for electricity grows at its fastest rate in **Modern Jazz** and **Unfinished Symphony** from 2020 to 2040 – at 45% and 60% respectively – as heating, manufacturing and mobility pivot to electrons. By 2040, 20-31% of the energy system will be electrified, the higher figure being achieved in **Unfinished Symphony**. This marks an acceleration of electrification compared to our 2016 report. While the majority of growing demand will continue to be met by fossil fuel generation, the electricity mix increasingly shifts towards renewable sources.

We note that the electrification pathways differ between the scenarios, with renewable power rising from 26% of total power generation in 2020 to 43% in **Unfinished Symphony** and 33% in **Hard Rock,** which is only slightly lower than **Modern Jazz** at 36% in 2040.

4 A NEW MOBILITY REVOLUTION, WHICH IS DEPENDENT ON INFRASTRUCTURE, IS GATHERING MOMENTUM, WITH THE POTENTIAL TO DISRUPT THE ENTIRE ENERGY LANDSCAPE IN THE LONGER TERM.

Transport demand for energy is highly dependent on the scenario, but in all cases there is a dynamic tension between population and GDP growth that is offset by improvements in efficiency. The co-development of EVs, ICE efficiency, ride sharing, autonomous vehicles and new modes of transport is already fundamentally reshaping personal transport demand. The pace of change is a function of the scenario and, in particular, depends on wider infrastructure developments, including storage. The combined impact of these new developments on commercial transport energy demand is assumed to be proportionally lower, however, given the capital intensity of assets and the reduced scope for new efficiency gains. As such, despite the increasing momentum of a new mobility revolution in meeting new passenger mobility demands, overall energy demand in transport continues to grow in all three scenarios.

New developments in technology, policies and consumer behaviour have the greatest impact on energy consumption in the transport sector in **Unfinished Symphony** and **Modern Jazz**. Modelling of both scenarios indicates limited growth to 2040, based on rapid price reduction of EVs, which achieve parity in sales prices with ICEs by 2030.This price parity accelerates the penetration of EVs, and their share of mileage for private cars crosses over with ICE vehicles by 2040. The ensuing efficiency gains offset the increased total population of vehicles. Commercial transportation (other land transportation, shipping and aviation) experiences decreasing energy intensity thanks to lighter materials, more efficient engines, more stringent efficiency standards and a rise in the use of alternative fuels such as biofuels and hydrogen.

With these changes, by 2040 electricity and hydrogen capture 10-16% of total energy consumed by transport in **Unfinished Symphony** and **Modern Jazz**.

Hard Rock differs notably in that the weaker global policy coordination of fuel and efficiency standards and limited technology transfer result in a much slower uptake of EVs and alternative fuels. As a result, the transport sector experiences energy demand growth of 28%, and oil remains the dominate fuel.

5 ENERGY EFFICIENCY GAINS ARE CRITICAL TO MANAGE ENERGY DEMAND FROM INDUSTRIAL, RESIDENTIAL AND COMMERCIAL SECTORS AND TO AVOID REDUCING CLIMATE CHANGE MOMENTUM.

In both **Modern Jazz** and **Unfinished Symphony**, the industrial, residential and commercial sectors generate the majority of the primary energy demand growth from 2020 to 2040. This would be significantly higher if not for the expected acceleration of new energy efficiency solutions.

In **Modern Jazz**, the use of advanced digital solutions helps optimise industrial processes and end-product designs, thus minimising energy consumption while reducing waste. In **Unfinished Symphony**, connected devices and distributed power generation behind the meter combine with new high thermal efficiency construction materials to significantly reduce energy intensity of buildings; additional gains are achieved through effective policies and efficiency standards.

In contrast, the primary energy demand growth in **Hard Rock** is nearly double that of **Unfinished Symphony**, despite a lower GDP growth as improvements in energy efficiency progress much more slowly within this time frame.

6 NEW OPPORTUNITIES ARE EMERGING TO PROVIDE ENERGY-PLUS SERVICES IN AN INCREASINGLY CONSUMER-CENTRIC ENERGY SYSTEM.

Consumer-centricity of the energy system increases in all scenarios. This increase is most prominent in **Modern Jazz**, where demand-side pressure for transparency and value-adding services emerge and deliver co-benefits in terms of cost, health and the environment. A positive feedback loop develops in which greater engagement of consumers leads to better awareness of consumers' energy needs and, in turn, more relevant services and a growth of trust in energy providers.

In **Unfinished Symphony** governments and their citizens align in support of socially just, affordable and deep decarbonisation pathways, and public-private investment in a broad range of clean energy technologies decouples CO_2 emissions from economic growth. Consumers' socially responsible energy behaviours result in economic growth detaching from energy demand. By 2040, the energy intensity of the economy is nearly half of today's level.

7 INFRASTRUCTURE INNOVATION AND INVESTMENT AND PROACTIVE POLICIES ARE NECESSARY TO SECURE AFFORDABLE DECARBONISATION AND SOCIALLY JUST ENERGY TRANSITIONS.

Across all scenarios, energy infrastructure planning and development is a key differentiating factor in determining the depth (that is, the reach and scale) and affordability of decarbonisation and the balance between new winners and new losers (that is, social justice outcomes) as energy transition progresses.

New investments are needed in seasonal storage, clean liquids pipelines and new port infrastructure. Investments will need to cover new build, decommissioning, repurposing and management of stranded assets. Other investments at the ultra-local level will have to occur with new business models to enable distributed generation and energy access on-demand anywhere, anytime and for anyone.

Supplying the future electricity demand alone will require an increase in power generation capacity of 26-90%, that is, 2 to 6 TW cumulative installations. Wind and solar will capture the bulk of this growth, and gas will account for about a third, while up to 33% of coal capacity will be retired. In all, investments of roughly USD 670-890 billion per year will be needed just for power generation. To enable such massive investments, supporting policies will need to be developed and implemented, sometimes against the grain of established market structures. Given the size of the challenge, infrastructure is rapidly emerging as the new frontier of innovation.

8 NEW NET-ZERO CARBON TECHNOLOGIES PATHWAYS (INCLUDING HYDROGEN) AND CARBON ABATEMENT MECHANISMS (INCLUDING CARBON PRICING AND CCUS) EMERGE AND START TO SCALE BY 2040.

Hydrogen production for use in mobility and buildings grows at a faster rate in **Unfinished Symphony**, reflecting the fact that government cooperation and policy support is critical in enabling and scaling power-to-X pathways for trading excess renewables. The rate of growth is nearly double the level in **Modern Jazz** and over ten times the level in **Hard Rock**. In reaching 10.5EJ annual production – which equates to around 2.3% of hydrogen share of final energy – the new hydrogen economy passes an important tipping point in **Unfinished Symphony** by 2040.[1]

Research, development and demonstration continue in carbon abatement mechanisms (implicit and explicit carbon-pricing schemes) and a diversity of direct carbon removal and carbon capture technologies in power generations. The best-case assumption is made of 158 GW of installed capacity by 2040 in **Unfinished Symphony**. Under current technology and carbon pricing assumptions, CCUS only exceeds 10% of installed power generation capacity in the 2050s. As for the role of CCUS in industrial processes, it has potential but will at best take off in the 2030s. Significant improvements on both accounts of technology progress and policy support will therefore be required for CCUS to fulfil its role as a major lever in global decarbonisation.

9 ACHIEVING PARIS AGREEMENT TARGETS REMAINS ELUSIVE, WITH NONE OF THE 2019 SCENARIOS MEETING THE 2°C TARGET AGREED TO IN THE UNFCCC PARIS AGREEMENT.

Unfinished Symphony, which can be seen as the most plausible "high decarbonization" pathway of our three scenarios, is on an emissions reduction trajectory that would achieve a global temperature increase (to 2100) of just above 2 degrees, missing the Paris Agreement target date by around ten years. **Modern Jazz** limits the global temperature increase to 2.5 degrees, while **Hard Rock** sits higher still at 3 degrees. With some recent trends away from a globally coordinated approach to tackling climate change, it is urgent that energy leaders reverse these trends if the well-below 2 degrees target is to be met.

[1]Please note that these numbers are for hydrogen use in buildings and mobility, which is on top of production of hydrogen for use in refineries, for fertilizer and in other industries, which comes predominantly from on-site production.

RECOMMENDATIONS

The emerging trends and new insights highlighted in this report make it clear that disruptive innovation is opening up significant new business opportunities for those energy leaders and organisations that are prepared to seek and create them. Scenarios provide a stage for exercising better strategic judgement and equip energy leaders with a tool for clarifying strategic choices, informing better decisions and enabling new action. Paralysis-in-analysis of complexity is not a real option; instead, we have identified new imperatives for more effective leadership action.

Energy business leaders should:

- Actively prepare for the migration of value from peak resources (commodity volume) to unlimited energy-plus services and for new competition beyond the energy value chain;
- Identify new customer-centric growth opportunities in electrification, storage, power-to-X and the new hydrogen economy;
- Understand and position for disruption in the shift to consumer-centric energy systems in order to maintain the social license to operate.

Policy makers should:

- Identify integrated policy innovation opportunities and implement sector-coupling policies to enable faster, socially affordable and deeper decarbonisation of the whole economy;
- Establish a "new economics" of whole energy system transition that looks beyond zero marginal cost pricing and enables a level playing field in comparing new and better options;
- Encourage demand side participation through policymaking that enables energy system integration, better connectivity among actors (consumers, prosumers and suppliers) and improved consumer access;
- Implement proactive energy infrastructure action plans and enhance systems resilience.

The international community should:

- Renew efforts to facilitate technology transfer, secure new investment and progress regional integration in order to accelerate efficiency and cost gains through common standards;
- Recognise and enhance adaptability and resilience of interdependent food-energy-water systems by preparing energy systems for inevitable global environmental shocks and cyber security threats;
- Reduce the risk of fragmentation by encouraging cross-border, cross-sector and cross-vector strategic partnerships to accelerate progress along net-zero carbon pathways and to secure new opportunities for global trade in clean electrons and clean molecules (gas and liquids), including hydrogen.

The Council promotes and uses plausibility-based, technology-neutral scenarios to support well-informed, globally inclusive and better-quality strategic dialogue and decision-making in relation to emerging and common energy challenges. It invests in ways of using these scenarios, recognising the multiple barriers – including cognitive, cultural and capability constraints – that business leaders and government officials face when working with plausibility-based energy scenarios.

ABOUT THE FULL REPORT

The main section of the full report presents the three global storylines to 2040, with supporting systems thinking maps. It includes a discussion of seven new insights, reflecting deeper shifts in the energy system innovation landscape. There is also a section on "how to use" the scenarios, describing how business leader and policy makers can effectively use these scenarios to: (1) engage in leadership dialogues; (2) enable integrating policy pathfinding; (3) stress test and translate new energy visions into action; and, (4) redesign energy businesses.

The supplementary sections include: detailed comparative analysis of energy sector implications; illustrative, model-based quantification; and regional scenario outlines that provide starting points for discussion of particular regional issues that are not fully and adequately reflected in any global-level analysis.

Introduction

INTRODUCTION

In April 2018, following a global horizon scan for new signals of change and an initial workshop, the World Energy Council (the "Council") validated the continued relevance of its 2016 World Energy Scenarios framework. Members also noted increasing interest by energy leaders in one of the four critical uncertainties and agreed to deepen scenario thinking by exploring new insights about the broad and fast-shifting landscape of innovation. After a research phase, which included interviews with a diverse selection of regional energy leaders and regional workshops in Paris, Abu Dhabi, Berlin and Tallinn, a group of Council Members then convened to see in what ways the 2016 Council's "Grand Transition" scenarios should be updated to reflect how new emerging trends might play out by 2040.

In addition to presenting a new set of narratives, this report includes a comparative quantitative analysis, a set of regional stories outlines, supporting systems maps and a new approach for using the scenarios. We hope this work may serve as a starting point for a deeper dialogue among energy leaders and stakeholders about the opportunities of energy for prosperity, people and the planet that are emerging in the new era of disruptive innovation.

THE 2016 "GRAND TRANSITION" SCENARIOS

Since 2010, the Council has been developing World Energy Scenarios to help our members better understand energy transitions and engage constructively with the world's inherent complexity and uncertainties. The latest report on the World Energy Scenarios was published by the Council in 2016 and launched at its 23rd World Energy Congress in Istanbul. It recognised that the energy system was undergoing fundamental changes, shaped by wider shifts in the global environment, most notably, the rise of the post-industrial society and the emergence of digital productivity. The journey to the new global future was called the "Grand Transition." The scenarios clarified the four key global drivers of change – demography, digitalisation, decarbonisation and geopolitics – that are combining in unpredictable ways to shape the energy transition from hydrocarbon molecules to renewable energy sources and net-zero carbon electrification.

Numerous energy transition pathways are emerging in response to the challenges of the Grand Transition, which reflect regional diversity in energy systems, national security interests and societal preferences. In 2016, the Council focused on three plausible pathways that were relevant to navigating the challenge of global climate change. While all of them reflect the same set of predetermined factors, each individual pathway places a different emphasis on how critical uncertainties might play out. All three were quantified using a global, multi-regional energy system model.

Modern Jazz represents a digitally disrupted, innovative and globally market-driven world. **Unfinished Symphony** is a world shaped by government policies, in which more coordinated and sustainable economic growth models emerge as regions collaborate to address broad environmental concerns and, in particular, climate change. **Hard Rock** explores the consequences of weaker and unsustainable global economic growth with inward-looking national policies.

After the Council undertook global horizon scanning of new signals of change across all world regions in 2018, all three scenarios were affirmed by the Council as still relevant.

Council's World Energy Scenarios Framework

Pre-determined factors

Slow growth rate of global population

Rise of new technologies

Appreciation of planetary boundaries

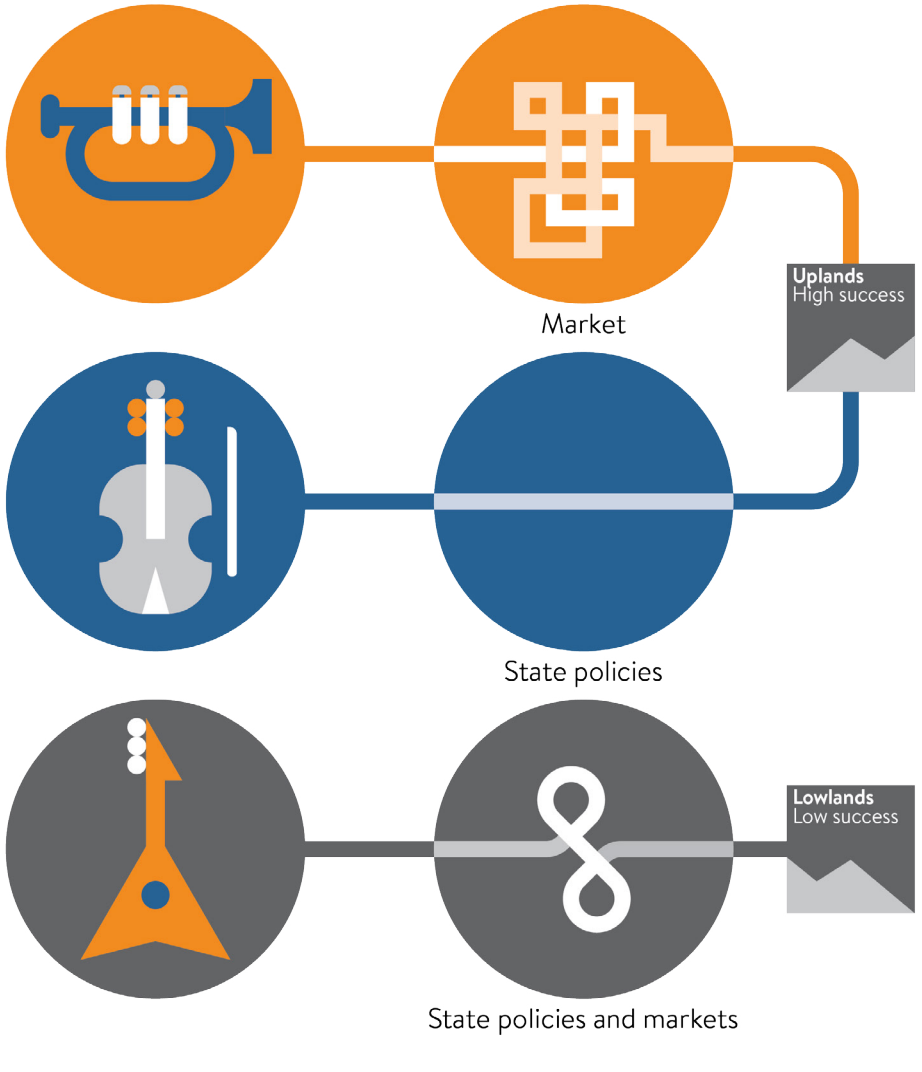
Shift in economic power to Asia

Scenarios

Modern Jazz
Highly digitally disruptive, innovative and agile world. Dominant market mechanisms. Energy-plus services. Data dominance.

Unfinished Symphony
Strong policy, long-term planning, united action for climate and broadening agendas. Co-benefits and synergies.

Hard Rock
Fragmented world and low global cooperation. National and energy security focus. Globally connected challenges.



Critical Uncertainties

Pace of innovation and productivity gains

International governance and geopolitical changes

Priority given to climate change and connected issues

Policy tools in action

HOW DIFFERENT DOES THE WORLD LOOK IN 2019?

What is changing most dramatically is the speed and disruptive nature of change itself – which is the key reason we have focused these scenarios on the nearer future to 2040 rather than on 2060. In 2016, we explored the climate change challenge in broad terms. Less than three years later, we are looking more closely at the growing diversity of clean energy visions and rethinking the role of innovation in the energy transition.

The new tailwinds that are accelerating the pace of global energy transition include rapid shifts in societal norms – for example, a decline in ownership and the rise of a sharing economy; increasing awareness of climate change; an acceleration of decentralised electrification; and the convergence of new technologies and exponential data accumulation. Digitalisation is impacting the whole energy value chain and enabling huge improvements in energy efficiency within existing production and delivery, as well as for wider and new energy uses.

Energy demand is increasingly being driven by end-use innovation in energy-intensive industries such as petrochemicals and manufacturing and by other sectors such as transport and buildings. For example, a new pattern of "combinatorial" technological innovation – the integration of digital and physical – is blurring sector boundaries and accelerating a shift to shared and electrified mobility, smart and circular cities, additive manufacturing (such as 3D printing) and sustainable food systems. New and non-traditional energy transition leaders are emerging within and beyond the energy sector and include hundreds of energy start-ups as well as digital giants.

New visions of consumer-centric and more democratic (that is, community owned) energy systems are emerging, in parallel with wider concerns for a human-centric future, decent jobs and livelihood opportunities. These concerns arise from the ambiguous implications of the accelerating pace of development of smart materials, self-managed systems and self-learning machines, enabled by the convergence of novel technologies such as nanotechnology, synthetic biology, AI, computing and robotics.

The rate of diffusion of novel, converging technologies in energy systems is being accelerated by institutional innovation and social changes, which is leading to unexpected disruptions in global value chains and national energy systems and is challenging business models, government policies and international institutions to keep up. For example, the dramatic decline in the costs of solar energy coupled with a new abundance of natural gas and liquified natural gas (LNG) is challenging the economics of coal in many countries and the role of oil in energy security. In turn, the speed of decarbonisation is challenging the careful pace of economic and social reforms in major resource-holding countries.

The rising demand for heat and cooling and the rapid penetration of intermittent renewable energy supply are also raising questions about grid reliability. Storage has become a new gamechanger, and alternative pathways for zero carbon ("green") and net-zero carbon ("blue") energy – heat, electrical, chemical – are emerging, with multiple technology options.

Despite the nationally determined commitments pledged by over 184 countries to the UN Paris Agreement in 2016, some national governments appear to be slowing their drive to decarbonise their national economies and energy systems. Meanwhile, the bottom-up demand for action is seeding a new global social movement on climate action involving cities, youths and moon-shot philanthropy. A spirit of entrepreneurial energy is starting to flow in different parts of the energy sector, attracting the interest of venture capitalism and fintech entrepreneurs.

New headwinds of the energy transition have also emerged. Global primary energy consumption grew rapidly in 2018, almost double its ten-year average, despite only moderate global GDP growth and strengthening oil prices. Global investment in renewables has stalled, and demand for coal has

increased. The US experienced its fastest rate of growth for 30 years. Despite global growth in demand being met largely by gas and renewables, carbon emissions grew 2%– a more rapid growth than the world has seen in seven years.

Unusually high numbers of hot and cold days and the increasing frequency and impact of extreme weather events such as droughts, floods, wildfires and forest fires, have exposed the vulnerability of all energy systems to global environmental risks and climate change impacts. Renewable systems are especially vulnerable since they often rely on the weather for energy production.

Despite the continued fall in the price of renewables and the promise of zero-marginal-cost clean energy, public acceptability of renewables is not a given. And concerns about the affordability, social justice and technical limits of faster and deeper decarbonisation of whole economies through all electrification pathways – whether based on centralised, decentralised or hybrid grids – are more widely appreciated and rising up political agendas.

In stark contrast to the new excitement ("hype"?) about the rise of "energy prosumers," there are fears about whether the steady jobs lost by reducing hydrocarbons will be replaced by new opportunities for work associated with new ways of producing, transporting, using and trading renewable energy.

Questions about who really benefits from and pays for whole energy systems transitions are moving up the political agenda in many OECD countries. In France, new energy taxes have become the lightning rod of social disaffection, despite the growing recognition that all existing technologies as well as innovation are needed to reach net-zero emissions.

New geostrategic competitions reflect the intensifying competition for digital hegemony and the new risks of non-energy resource shortages, especially for meeting the demand growth associated with the rapid scale-up of the renewable energy revolution, as well as the battery bottlenecks caused by lack of access to lithium and cobalt.

EXPLORING AND NAVIGATING EMERGING NEW ENERGY DYNAMICS

The quickly shifting winds of innovation raise new leadership questions:

- How might digitally empowered energy consumers transform energy use and, in turn, reshape supply choices?
- How can policymakers use all existing technologies and innovation to accelerate whole energy systems transitions along pathways that deliver lowest overall cost and best societal fit?
- How can global energy companies respond to the rise of local energy communities and support new market designs?

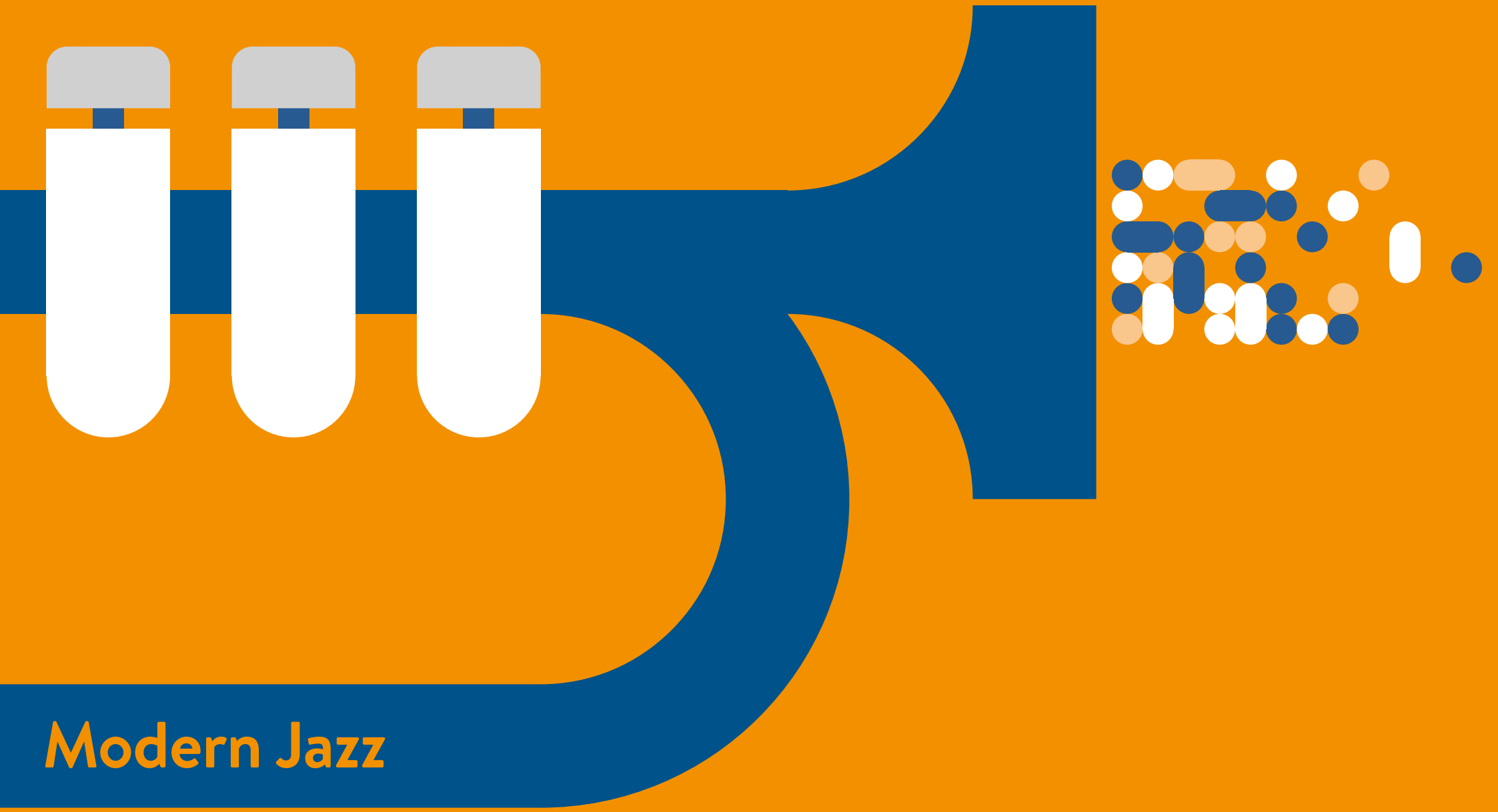
HOW TO EFFECTIVELY USE THESE SCENARIOS

The main value of scenarios is derived in use. As a set, these scenarios provide a clear, pre-decision thinking framework aimed at helping energy leaders explore and navigate the broad and fast-shifting landscape of innovation that is impacting energy transition from within and beyond the energy sectors. Section 3 provides four specific options for effective use, including for: (1) engaging in leadership dialogues; (2) integrating policy pathfinding; (3) translating new energy visions into action; and, (4) redesigning energy businesses.

PART ONE |

World Energy Scenarios to 2040

CHAPTER CONTENTS


Modern Jazz

"WE'VE REACHED THE END OF INCREMENTALISM. ONLY THOSE COMPANIES THAT ARE CAPABLE OF CREATING INDUSTRY REVOLUTIONS WILL PROSPER IN THE NEW ECONOMY"

– GARY HAMEL

MODERN JAZZ

Modern Jazz is a world of increasing speed of innovation, uneven but high productivity growth, and an ever-present potential for new shocks. In this world clean energy abundance increases rapidly, and there is a faster-than-expected acceleration of end-use electrification in mobility and manufacturing. It is a story of exponential growth opportunities brought about by data-empowered consumers, falling energy prices and increasing speed to global market. This is a consumer-driven, digitally transparent and flexible world of much greater energy efficiency in which new investments in innovation are monetized quickly.

DIGITAL INNOVATION AS A COMPETITIVE ADVANTAGE

The enabling factor throughout the highly volatile, innovative world of **Modern Jazz** is digital technology, which impacts the energy value chain in all energy sectors and gives agile first movers an enormous advantage. Energy incumbents become more resolute in the drive to reduce costs and improve profitability and work to secure digitally enabled productivity and efficiency gains. Non-traditional providers flex their digital capabilities to enter energy services. Fintech innovation enables new clean energy start-ups to scale rapidly.

In upstream oil and gas, predictive system optimisation allows capacity margins to be a fraction of what they had been during the 2010s. The impact of digitalisation in energy also opens up new and diverse value-growth opportunities by the mid-2020s, including offshore wind farming and new oil reserves. All forms of energy compete to extend their licenses to operate by leveraging digital technology. Energy blockchain platforms enable renewable energy registries. The oil and gas sector leverages digital technology to reduce its environmental footprint, and some major resource holders promote "conflict-free" barrels. In nuclear, digitalisation transforms project management performance.

NEW ENERGY SOLUTIONS IN A DIGITALISED WORLD

The costs of renewable electricity generation continue to fall significantly in the 2020s, in part because of innovation in China. Moving to get rid of its annual winter smog, China ramps up renewable energy and electric vehicle developments via smart charging, battery recycling and development of an open power market. The rapid build-up of integrated digital and renewable energy expertise allows China to further extend its reach as a global market shaper, exporting its technologies and know-how world-wide.

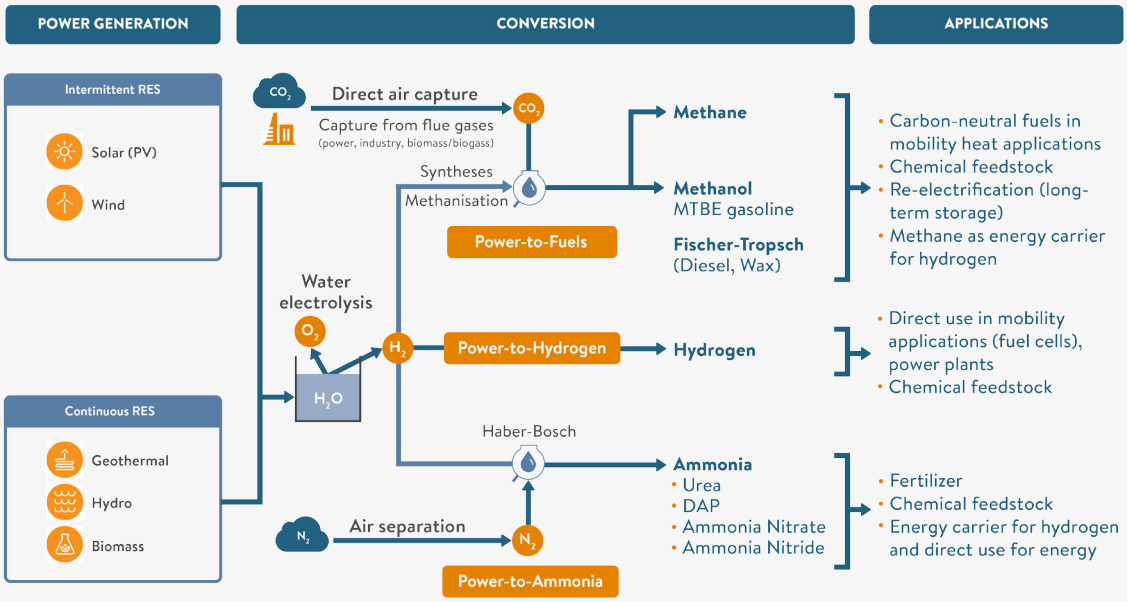
But China is not alone in its energy innovations. Clean energy innovation hubs emerge in most countries, particularly across North America, Europe and India. The resulting global excess in renewable power generation combines with improvements in utility-scale electrolysis to pave the way for domestic and fledgling self-organised regional power-to-X markets.

POWER-TO-X

The concept of power-to-X (P2X) refers to the production of synthetic fuels using renewables power capacities and gas and liquid reconversion pathways. In an integrated energy system based on renewable energies, P2X can provide much needed flexibility. P2X allows the decoupling of the direct use of power from the electricity sector for use in other sectors (such as transport or chemicals) and provides the opportunity to replace conventional fossil fuels with low-emission synthetic fuels, such as hydrogen, methane, ammonia or methanol.

The main drawbacks of this route are low renewables penetration, the high cost of current electrolysers and low efficiency. Continued deployment of lower-cost renewable generation and continued reduction in electrolyser costs as well as efficiency are key for the success of P2X. Today, over 70 projects are operational globally, with scales ranging from 250kW to 6,300kW of electrolyser capacity. The size of P2X installations is growing, with electrolyser units reaching capacities of 50+MW under deployment.

Conversion of Renewable Power into Various Forms of Chemical Energy Carriers



Source: Hydrogen an Enabler of the Grand Transition, 2018 Future Energy Leaders of the World Energy Council (Hydrogen Taskforce); World Energy Council, Innovations Insights Brief, New Hydrogen Economy – Hype or Hope?

The falling cost of electricity generation leads to a new source of costs: the integration of an increasingly diverse supply mix into the grid. Suburbs and rural areas in most developing economies turn to decentralised electrification to provide affordable, zero- and low-carbon energy supply and to digital asset inventories to help coordinate the management of the growing number of privately owned, decentralised supply and storage infrastructures.

But the sector most affected by the combinatorial impacts of digitalisation and low-price clean electricity is transport. Electrified urban transport, battery innovation and grid storage solutions accelerate

the global uptake of electric vehicles (EVs). Private passenger car fleets in many cities contract because of congestion fatigue and the development of on-demand mobility services, both of which drive smarter integration of public transport systems, working from home and ride sharing.

Electrified (BEV) and digitised transport services outperform ownership models on a total cost-of-ownership basis by the end of the 2020s, while providing environmental benefits in terms of lower total carbon emissions, cleaner air and grid flexibility support. By the mid-2030s, internal combustion engine vehicles (ICE), battery electric vehicles (BEVs) and fuel-cell electric vehicles (FCEVs) have reached price parity, giving the market many alternative sustainable mobility pathways for passenger and light duty commercial transport, and spurring urban areas to join the global "smart cities" movement. But even though the EV share of the global car fleet is growing rapidly, in 2040, ICE technology retains a 47% share of the global market.

Large-scale, affordable alternatives for aviation also start to emerge from biofuels, in part driven by the rapid growth in demand for leisure travel as the global middle class continues to expand. Lighter materials, improved engines, digitally optimised flight patterns and big data analytics that optimise route planning and help pilots make in-flight decisions enable significant savings in energy consumption – one of many examples of the impact on energy systems of innovation in adjacent sectors.

Digitalisation impacts all other sectors of transportation: land freight, for example, through higher efficiency trucks, alternative fuels, and convoy and autonomous driving, and marine through alternative fuels, which create huge efficiency gains. Additional sensors on ships help crews optimise routes, while advances in satellite communications enable greater connectivity for optimising ship speed to coordinate port arrival timing. These faster speeds yield significant fuel savings.

As the digital revolution continues to accelerate the growth of services, new energy consumer behaviors emerge. Economic rebound – increasing energy efficiency leading to lower prices leading to greater demand – is less evident. Energy demand growth in electricity for cooling, data storage and processing, heat, industrial energy and petrochemicals is offset by digital productivity gains within and between different sectors. However, as energy-cyber interfaces proliferate, cyber security costs increase. The strong decoupling of energy consumption from economic growth is also enabled by new social norms of the caring economy – reuse, recycling, sharing and dematerialisation – all of which are emerging in rapidly ageing societies.

FOSSIL FUELS IN TRANSITION

Despite geostrategic competitions in technology and data between the US, EU and China the geopolitics of energy no longer pivots on oil and gas. Bottlenecks in access to the non-energy resources needed to sustain the renewables revolution are avoided through market-based innovation. Even so, in this world of zero-marginal-cost renewable energy supply, new concerns about social affordability are triggered by the additional costs of integration, transport and storage of zero-marginal-cost renewable power. Oil and gas prove resilient thanks to cost cuts in production, demand growth in petrochemicals, and rising demand in not-yet-electrified and non-electrified markets – in particular, aviation, freight and energy-intensive construction materials.

An abundance of global gas keeps prices low, securing LNG exports to Europe and Asia in the global, commoditised LNG market. Renewable electrical power purchase agreements continue to develop as a

more diverse array of industries takes up sustainable sourcing, which includes their energy consumption.

During the 2020s, India, South Africa, Indonesia and other large coal users turn to an increasing diversity of low-cost fossil fuel, nuclear and clean energy exporters to meet their urban energy demand growth and to enable their industrial development. In this context, gas acts as a cheap, lower-carbon, transition-fuel alternative to oil and coal. With the growing global demand for energy, gas demand stays steady beyond 2040.

DEMAND-SIDE INNOVATION

In the world of **Modern Jazz**, innovation takes place more rapidly on the demand side. By the late twenties, energy blockchain technology and AI-enhanced metering as well other innovations in the realm of consumer-price automation allow consumers to shift in real time to the cheapest energy source as deregulation encourages aggregators and integrators.

In mature markets many consumers also become producers ("prosumers"), exporting electricity produced from their solar panels back to the grid. The emerging integration of BEVs into the grid also allows personal vehicles to support the transmission and distribution of electrical power.

In less mature markets, increasing flows of investment from venture capitalists to start-up energy entrepreneurs lead to a flourishing ecosystem of small- to medium-sized energy businesses. These enterprises build on the success of new utility business models, such as pay-as-you-go-solar, and expand rapidly to provide other vital utility services, such as cooking, internet access and water, including to previously unreachable populations.

Many consumers prefer individually tailored packages of sustainable services for heat, cooling, power and mobility. The growth in services allied to energy use stimulates further innovation in smart demand response and smart-charging technologies for electric vehicles, saving billions of dollars of investment in new electricity infrastructures while increasing the flexibility of the grid and reducing costs to consumers.

Electrified heating, BEVs, smart metering and beyond-the-meter storage at both residential and commercial sites proliferate. This growth, as well as a number of remarkable improvements in data analytics, leads many non-energy consumer data powerhouses to begin providing energy-linked services. As they do, choices proliferate in grid storage, alternative batteries and combinations of technologies that are marketed to consumers as bundled services.

Developments in energy blockchain registries and certification enable sophisticated comparisons of social and environmental externalities. Transparency in other parts of the energy system also supports informed choices. Accurate and up-to-date energy lifecycle analysis is also common, and the results are easily available. While not all governments require externalities such as job creation and CO_2 to be included in energy prices, consumers find it relatively easy to compare service offerings and make "better" decisions if they wish. The market offers a great variety of energy choices, and for some, the economic, socially responsible, and greener choice is not renewable electricity but nuclear energy or synthetic and bio-fuels.

CUSTOMER-CENTRICITY - AN IMPERATIVE FOR GROWTH

Dynamic, customer-centric energy companies are 85% more likely to outperform their peers with respect to rate of profitability growth, yet only 14% of energy providers are in this category, according to Accenture Strategy research. The study highlights the importance of customer-centricity, reporting that 90% of upper quartile energy providers agree that "Customer expectations are increasingly shaped by the most relevant, real-time, and dynamic experiences."

But what is driving this increasing need for customer-centricity?
Fjord Trends 2019, a rolling survey of consumer-facing industries, echoes the suggestion that customer-centricity drives high performance.

Fjord Trends, 2019 – Inclusivity Paradox
People expect organisations to see and engage with them as individuals. But there is a risk that by trying to be more inclusive, organisations inadvertently exclude others. And by trying to speak to the individual, organisations risk saying something not quite right. Eventually, artificial intelligence (AI) will help overcome this paradox of inclusivity. Until then, organisations must evolve their approach beyond stale segmentation to meaningful mindsets if they're to meet developing expectations.

Fjord Trends, 2019 – Last Straw
Our climate is changing, and so is the way we're thinking about it. Our concerns about global warming, pollution, and sustainability have experienced a cultural shift. Where once it was "too big to do anything about," now it's personal. In 2019, it won't be enough for companies to simply acknowledge environmental concerns. Consumers will expect commitment to be proven through action. Organisations will need to redesign their systems and business models to fit the "circular economy," where users are active participants and sustainability is built into their products and services.

Source: Accenture conducted interviews with 120 senior executives in Utilities; Living Business: Growth Through Hyper-Relevance; Accenture; Fjord Trends 2019

In **Modern Jazz**, in an attempt to avoid new demand-side shocks, the market delivers ad-hoc solutions to problems of intermittency, interoperability, seasonal storage and systems integration. Demand volatility prompts some energy players to seize new opportunities for arbitrage, while others come up with financing innovations that promise short-term returns. Self-organised and ad hoc resilience in response to new energy shocks stimulates new insurance services.

Meanwhile, the pace of electrification of previously non-electrified sectors and geographies increases. And sectors that had previously remained dependent on fossil fuels begin to shift, too. The rapid growth of electrification in Sub-Saharan Africa surpasses expectations, and everywhere, electrification continues to expand into heat and other end-use sectors, including buildings and industry. By the late twenties, the greater flexibility of global and African private sector companies leads them to outcompete the Chinese government for the growing African investment flows to digital electricity infrastructure and software.

Modern Jazz is largely a world of broad-based energy innovation. In leading-edge countries, stability is so utterly reliant on demand-side flexibility and supply-side optimisation that "old-world" capacity reserves in the electric generation system no longer seem necessary. In others, particularly those developing countries with mega-cities, more traditional dispatch logics are still in place, but they are better managed – relegating "blackouts" to history.

MARKET DISRUPTION BY NON-TRADITIONAL PLAYERS

By the 2030s, the falling costs of oil and gas and the rapid expansion of large-scale PV solar in several regions trigger intense competition for new energy export markets. But energy incumbents aren't the only competitors. Digital giants, with their expertise in AI and their capacity to know and interact directly with individual customers, rapidly expand their capabilities in energy systems integration and grid management to capture an increasing share of electrified mobility and other energy-plus services. Leveraging their power through cross-industry collaboration in a broad swathe of markets, they manage to meld expertise in energy supply and aggregation, consumer engagement and experience, and data-derived insight coupled with innovative strategy formulation. Value shifts from commodities to consumers and those serving them.

The relative lack of regulation of innovative digital businesses means that successful innovators move along a growth path towards monopoly. At the same time, the rapid development of low-cost renewables and behind-the-meter solutions slows progress towards big interconnector projects and encourages distributed electrical energy production. Meanwhile, in increasingly decentralised electric power markets, electricity companies re-position themselves as platform players.

By 2040, the speed of business innovation in services – especially those enabled by digital technology, data analytics and AI – outpaces national governments' abilities to shape societies. Policymakers seem mired in arguments about the best way forward, although most agree that businesses should be encouraged to experiment and innovate, especially if growth brings tax revenue to the area.

THE MOVE OF NON-TRADITIONAL PLAYERS INTO ENERGY AND RELATED SECTORS

Incumbent energy players are flexing their capital muscles and moving across value chains, while non-traditional energy players are entering from big tech, the demand side and new start-ups. This diversification of players impacting investment flows challenges traditional business models.

Source: IEA World Energy Investment; CB Insights – deals data on venture includes seed to series E and other venture capital; IEA Global EV Outlook; BNEF; Reimagining Big Oils, Goldman Sachs

Regulators also hesitate to interfere with anything that has provided so many benefits although they recognize that perhaps more controls on data collection and use might be beneficial and that cybersecurity precautions might be called for. But so far, damaging incidents that threaten system security or collective trust in digitised energy systems have failed to materialise in any significant way. This consensus leads to local, self-organising behavior with an outward-looking emphasis. Nevertheless, investors recognise that a balance will have to be sought between the freedom for aggregators and privacy and security matters.

In **Modern Jazz**, technology benefits are not always evenly spread. By 2040 energy systems are highly digitalised and AI-enabled. More developed countries face the challenge of retro-fitting legacy

systems, whereas less-developed nations benefit from a cleaner slate and less behavioral inertia. Human workers can set boundaries of control, but heavily automated systems directed by AI are increasingly common. Environmental and public goods, such as reduced air pollution, increased water use efficiency and quality energy access, are pursued wherever they are cost-effective. But overall, fossil fuels play the major role in primary energy supply, increasingly challenged across markets by cheap, clean electricity.

UNFINISHED BUSINESS – THE CLIMATE CHANGE CHALLENGE

In most countries, there is no concerted effort to contain greenhouse gases or fulfill Paris agreements except where consumers express their values by buying green. But usually, coal and other fossil fuels are replaced not because people are concerned about global CO_2 but because they want to get rid of local air pollution.

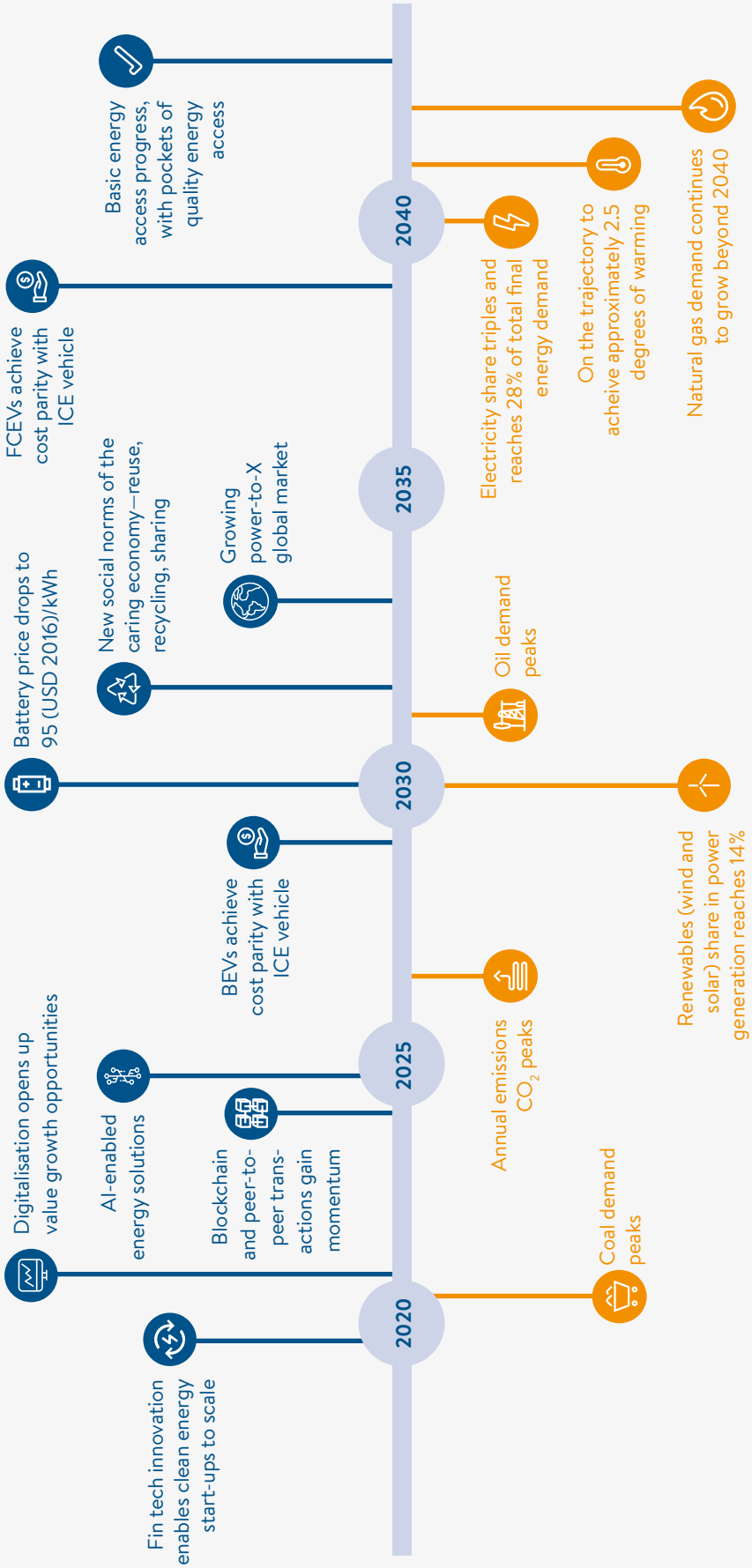
Rather than being mandated through government policies, well-living and sustainability are encouraged through increased demand-side pressure for transparency and value-adding services that deliver co-benefits in terms of cost, health and the environment. A price on carbon is one of many "ethical externalities" priced into services in some places, with the market left to decide which pathway to pursue for best results. The attributes of electrical power (low carbon, local job and wealth creation, no pollution emissions, etc.) rather than the power itself become a major influencer of consumer demand and therefore of pricing. Meanwhile, markets leverage sunk investment in infrastructure.

While the world of **Modern Jazz** enjoys a more vibrant, although volatile, digital energy sector, the lack of state-led, joined-up action results in significant unevenness in relative levels of progress against climate change, both globally and at national levels.

By 2040 with the higher occurrence of extreme weather events, consumers increasingly value solutions that offer reliability and mitigation services. The power of communities sensitive to such issues drives the development of new solutions. The limits of a "market only" approach become apparent, and a new impetus for a more coordinated global approach gathers momentum. Perhaps **Modern Jazz** needs a conductor.

HOW FAR DOES INNOVATION GO IN MODERN JAZZ?

INNOVATION LANDSCAPE



ENERGY IMPLICATIONS

MODERN JAZZ: ENERGY SYSTEM BY 2040

In **Modern Jazz**, accelerated deployment of renewable technologies and aggressive uptake of best available technologies decouple CO_2 emissions from economic growth. Facilitated by digital productivity, the historical relationship between economic growth and primary energy demand weakens.

The **primary energy consumption per capita** peaks around 2025 and by 2030 reverts to the levels seen in 2015. Fossil fuels continue to dominate the primary energy supply, even in a world of inexpensive renewables, due to the falling production costs of oil and gas. Growth in fossil fuel demand can be observed for oil and gas, and gas offsets coal in the energy mix. Nuclear and hydro retain their share, while wind and solar combined quadruple their contribution between 2015 and 2040.

In the **final energy demand,** oil remains the dominant source until 2040 because of the rising demand for transport, while in the heating sectors it is replaced by gas. Electricity shows the largest relative increase in 2040 from today's level, representing a doubling of absolute consumption as heating, manufacturing and mobility begin to shift from fossil fuels. The buildings sector accounts for most than half of the increase in electricity demand, reflecting growth in income levels and per capita consumption in developing economies. In relative terms, electricity in transport increases most, tripling by 2040. Energy efficiency is at the forefront of decoupling the end-use demand for economic output, supported by better systems integration, smart grids and improved load management.

The **electricity generation** sector undergoes a profound transformation towards low-carbon sources. Coal-based generation peaks in the mid-2020s and reverts in 2040 below the level of 2010. However, fossil-based generation remains the dominant source of electricity, albeit at a lower share compared to today, since gas penetration accelerates in the power sector. Wind and solar are deployed at unprecedented rates thanks to the falling costs of renewable electricity generation. Their combined share in total electricity supply triples from today's levels by 2040. The global excess in renewable power generation paves the way for global power-to-X developments, and hydrogen emerges as an energy carrier, first in the long-range transport sector and then for electricity and heat supply.

Modern Jazz achieves a 0.06% compound annual reduction in CO_2 emissions from 2020 to 2040. Global CO_2 emissions stabilise by 2030 and decline afterwards. The global temperature increases to 2.5 degrees by 2100 compared with pre-industrial levels.

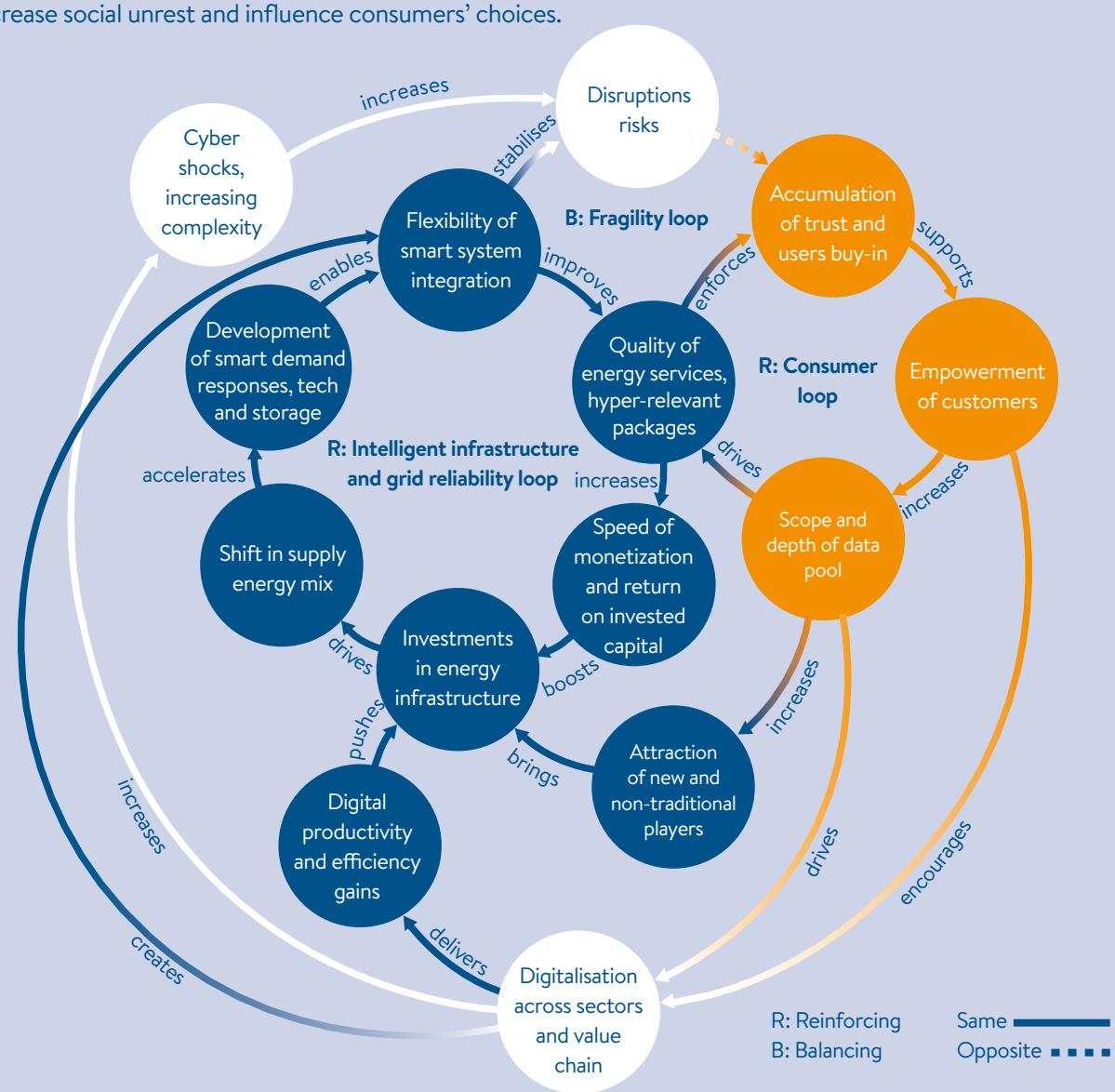
MODERN JAZZ: SYSTEMS MAP

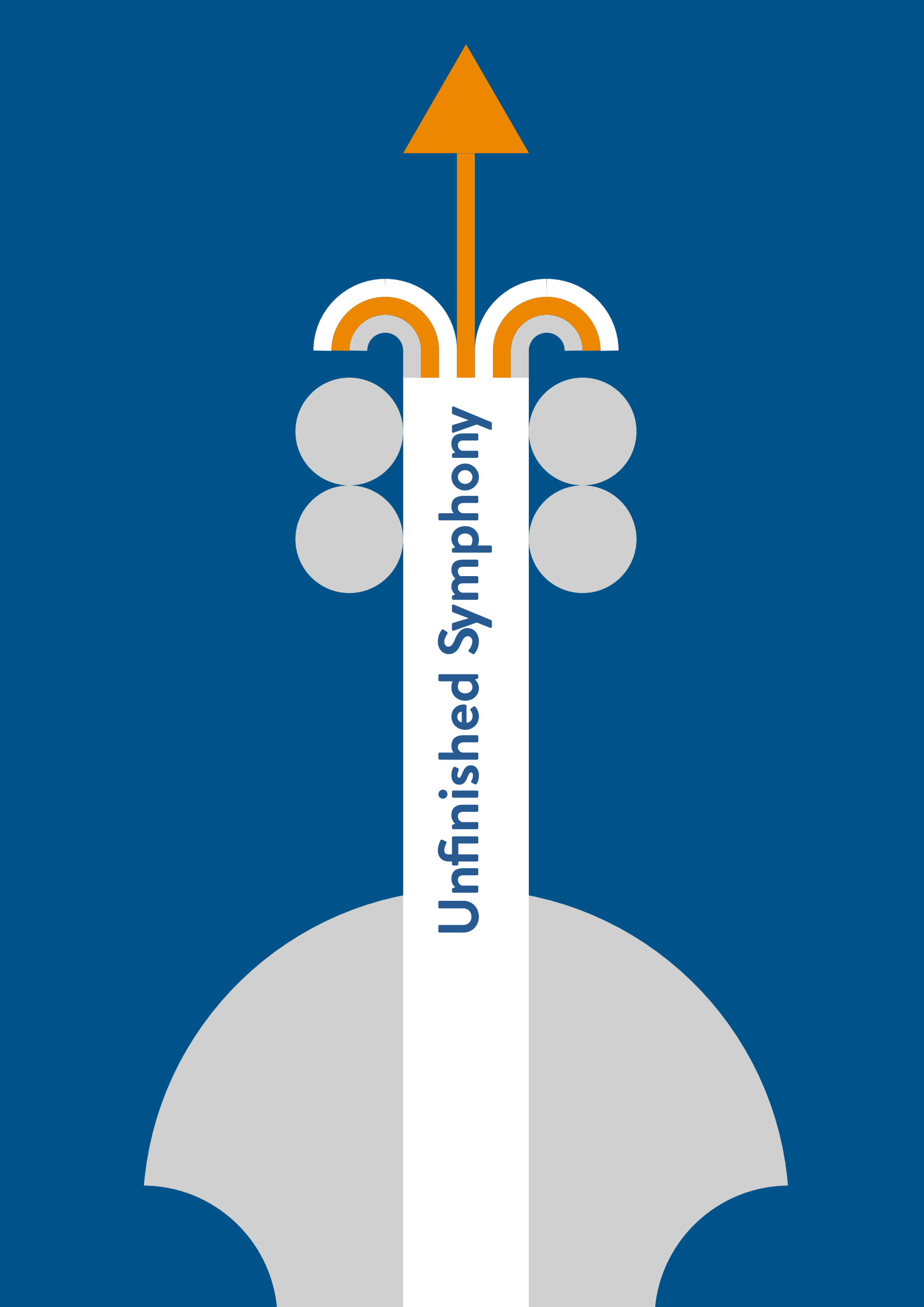
The dynamics of the Modern Jazz world are characterised by the interaction of three feedback loops – 1) an intelligent infrastructure and grid reliability loop; 2) a consumer loop; and 3) a fragility loop, which is stabilised by the first and second loops.

R: Infrastructure and grid reliability loop. Increasing shifts in energy supply from molecules to electrons, coupled with the development of storage solutions and a rise in demand for quality energy services, attract investments in both centralised and decentralised hybrid infrastructure. These investments enable greater grid reliability and system management, with automated alternatives that allow switching between supply and demand.

R: Consumer loop. Experiencing better quality services leads to buy-in, trust and an increase in peer-to-peer and peer-to-market transactions. Many consumers prefer individually tailored packages of sustainable services in heat, cooling, power and mobility. Growth of electrified services, in turn, enables bigger data pools, which lead to further improvements in services. Better service attracts more non-traditional players and brings new investments into the market.

B: Fragility loop. Digital technology delivers high productivity and efficiency gains to market players, but these benefits are not always evenly distributed. In addition, without better system integration and a smarter grid, cyber risks and digital complexity can bring disruption to the system, which, in turn, can increase social unrest and influence consumers' choices.




Unfinished Symphony

“WE MUST ALL
HANG TOGETHER OR
WE SHALL SURELY HANG
SEPARATELY”

– BENJAMIN FRANKLIN

UNFINISHED SYMPHONY

In **Unfinished Symphony**, most governments are keenly aware of four major risks: (1) climate change and its associated environmental and social disruptions including mass migration; (2) systemic vulnerabilities due to digitalisation (such as cyber attacks) and infrastructure development struggling to keep up with new energy sources; (3) the need to balance carbon policies with energy security, availability and cost; and (4) the challenge of allocating the costs of whole energy systems transitions in a socially acceptable way.

To mitigate these risks, national governments are challenged to overcome policy silos and develop innovative policy solutions to address connected challenges of energy security, equity and affordability and environmental sustainability.

EMERGING CONSENSUS

The global consensus embodied in the Paris Agreement continues to grow, even though individual governments often find it difficult to fulfil their national commitments. Governments use a tripod of initiatives: public-private investment in a range of clean energy and storage technologies; bolder leadership in infrastructure innovation and integration; and a collective attempt to develop and commercialise negative-emissions technologies.

Citizens increasingly push states to invest in co-benefit energy solutions, which enable faster decarbonisation and better air quality and help secure opportunities for decent jobs in the increasingly digital economy. As calls for "better lives for all and a healthy planet" increase globally, there is pressure to coordinate multiple global agendas of various UN agencies and other international organisations. In some regions, this pressure includes addressing growing socioeconomic inequality.

Regional transition pathways diverge, in part because many regionally distinct options emerge to access low-carbon energy and to progress net-zero carbon energy for the lowest cost and best fit to local needs.

POLICY COHERENCE AND ALIGNMENT

A new generation of politicians emerges in the G20 countries. These politicians promote holistic national visions to meet the Paris Agreement goal, albeit by different national means (e.g., carbon pricing vs carbon tax). These visions focus on cross-sector synergies and promote policy coherence to overcome the siloed agendas of jobs, health, environment and cyber security.

THE ROLE OF CARBON PRICING

More governments today are using carbon pricing in the form of carbon taxes, emissions trading systems (ETSs) and offset mechanisms as part of broader policy packages to tackle climate change.

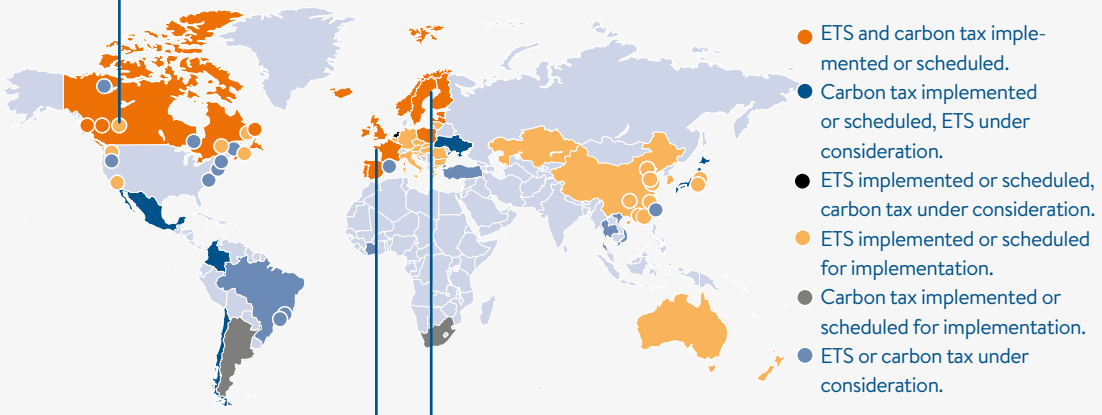
Out of 185 parties that submitted their Nationally Determined Contributions (NDCs), 96 included carbon pricing as a tool to meet their commitments. Fifty-seven carbon-pricing initiatives are being implemented or are scheduled for implementation around the world. These include 28 emissions trading systems in national, subnational and regional jurisdictions, and 29 carbon taxes, primarily applied on a national level.

In total, these price initiatives cover 11 carbon dioxide equivalent ($GtCO_2e$) or about 20% of global GHG emissions in 2018. The prices in existing initiatives range from USD 1 – 127/t CO_2 e. About half of the emissions currently covered by carbon price initiatives are still priced below USD 10/t CO_2.

In 2018, the combined value of ETSs worldwide (not including the Chinese national ETS) is estimated to be more than USD 34 billion, while jurisdictions with an operating ETS now generate more than 50% of global gross domestic product (GDP).

First Carbon-Pricing Initiatives:

The Regional Greenhouse Gas Initiative (RGGI) - 2009
Description: A cap-and-trade system covering CO_2 emissions from power plants in the Northeast and Mid-Atlantic US states. It is the first mandatory ETS in the US and started as a cooperative effort among ten states to reduce GHG emissions.
Co-benefits example: Improved air quality led to USD 10 bn in health savings from avoided illness, hospital visits, lost work days and premature deaths between 2009-2015.



EU - 2015
Description: Oldest and still largest ETS for GHGs operating worldwide; a central pillar of the EU climate change policy. Covers emissions from the power, industrial and aviation sectors.
Co-benefits example: From 1990 to 2016, emissions intensity of the EU economy was reduced by around 50% and decoupling occurred in all member states.

Sweden - 1991
Description: A part of the energy tax (skatt pa energi). The tax placed on carbon-intensive fuels aims to actively reduce dependency of fossil fuels. One of the first countries to apply a carbon price.
Co-benefits example: A carbon tax of USD 150 per tonne of CO_2, has also seen robust GDP growth and a fall in emissions by 25% since it was introduced.

Source: Carbon Pricing Dashboard, World Bank

In **Unfinished Symphony**, a carbon price or tax becomes a pervasive feature of energy policy, building on existing approaches. Policymakers introduce various regulatory schemes toward infrastructure investment requiring large capital and longer paybacks. Where needed, governments also come together to support standards and protocols to improve energy efficiency in power, mobility, industrial and buildings technologies and systems. For example, many regions make investments in electrified mobility solutions and smart infrastructures integrating renewables. Bans on single-use plastics, national targets for recycling and new standards on the use of biodegradable plastics using new feedstocks become ubiquitous. Governments facilitate the emergence of new business ecosystems that cut across energy siloes and other sectors while enabling new growth and prosperity. They also ensure grid reliability through support for baseload power generation from fossil fuels with carbon mitigation, including CCUS, and nuclear to enable affordable and deeper decarbonisation.

Similar incentives are enacted to support growth in clean fuels, including blue hydrogen (produced from natural gas with CCUS) and green hydrogen (produced from renewables), where they make sense; gas and liquid infrastructures are repurposed to transport these fuels.

To encourage affordable and clean energy solutions, governments also introduce new sets of financial incentives such as grants, loan guarantees and tax credits with surprising speed. Energy producers leverage these incentives to ease the financial burden of transforming their businesses and profit from clean liquids, synthetic fuels and other renewables.

Under the combined effects of policies and technologies, demand for fossil fuels peaks around 2030, with coal peaking in the early twenties, oil in the mid-twenties and gas twenty years later (going beyond 2040). With clearer carbon policies, fossil fuel producers move to leverage existing assets and exploit the web of grants, subsidies and other new mechanisms to pivot their businesses towards clean energy, more sustainable industrial feedstocks and new energy-related services.

HYDROGEN

Hydrogen is an energy vector for faster, deeper and more integrated decarbonisation. Its flexibility and versatility can enable switching from electrons to molecules, storing energy for periods of one day up to a season and reaching sectors that electrification cannot. Less carbon-intensive and economically viable processes are emerging in place of steam methane reforming and coal gasification to produce hydrogen, but these new processes still require significant support from governments and industrial actors.

There are more than 90 policies in the European region that explicitly support investment (whether directly or indirectly) in the expansion of the use of hydrogen for energy and climate purposes as well as 11 roadmaps and more than 200 pilot and demonstration projects.

Hydrogen Production Routes and Use

PRODUCTION

Grey hydrogen

Currently, 96% of hydrogen is produced from fossil fuels via carbon-intensive processes.

Main production routes

Steam Methane Reforming (SMR)

Coal gasification

Blue hydrogen

Grey hydrogen, whose CO_2 is emitted during production, is sequestered via carbon capture and storage (CCS).

Main production routes

SMR + CCS

Coal gasification + CCS

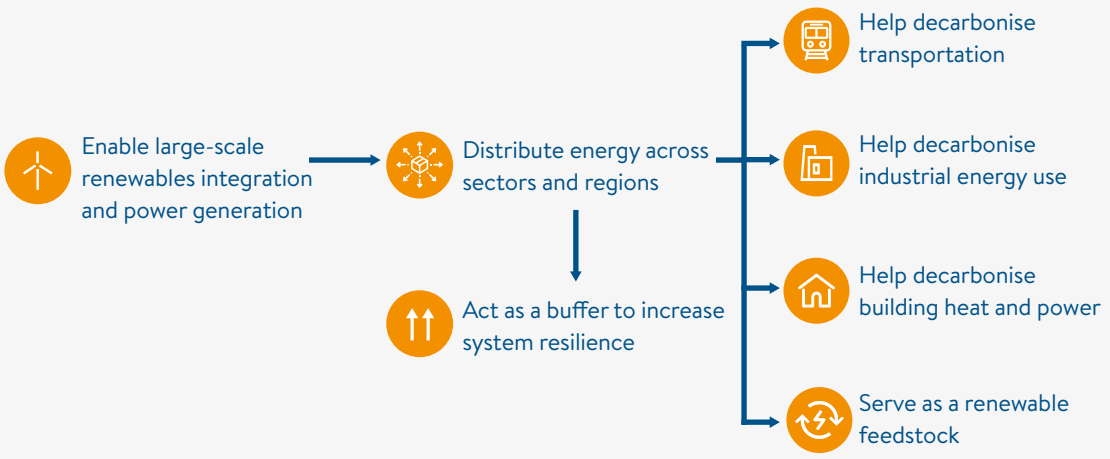
Green hydrogen

Low or zero-emission hydrogen is produced using clean energy sources.

Main production routes

Electrolysis using renewables

ENABLE THE RENEWABLE ENERGY SYSTEM → DECARBONISE END USES



Source: IEA Hydrogen Policy database; Innovations Insights Brief, New Hydrogen Economy – Hype or Hope?, World Energy Council; International Aspects of a Power-to-X Roadmap, World Energy Council, Germany.

REGIONAL PATHWAYS

While there is global agreement about reaching net-zero emissions and going beyond, there are new challenges in aligning urban-national and provincial-federal policy frameworks. As a result, different regions develop their own energy portfolios, which reflect individual affordability and welfare and sustainability needs. These regions succeed in linking energy transition to new industrial investment and development, enabling better jobs and skills policies. Where economical, regions continue to increase the trade in blue- and green-sourced electricity and synthetic fuels in order to provide energy security and to address intermittency and storage challenges.

For example, the EU creates a Clean and Just Energy for All initiative in the 2020s, which follows principles of subsidiarity and accounting based on whole-system transition costs and benefits. This initiative brings higher taxes and service charges to support private investment in large infrastructure projects and to fairly distribute benefits such as job creation across Europe.

Meanwhile, China promotes an "energy citizenship" campaign in its drive towards an ecological civilization. Building on its population's adoption of digital technologies, this campaign leverages citizen data to target energy efficiency and promote socially responsible energy behaviours. With support from central and provincial governments, the result is a personal efficiency culture not so different from personal finance culture.

REGIONAL PATHWAYS

In **Unfinished Symphony**, new tax incentives attract public-private investments to support national portfolios of clean heat, zero-carbon power, storage and net-zero carbon synthetic fuels. These new investments build resilience by enabling switching between supply and storage. Hybrid power systems safely, reliably and flexibly integrate not only all sources of generation and transmission but also distribution and control systems to meet different power needs in an optimised manner.

These hybrid grids along with the repurposed gas infrastructure, including green and blue hydrogen, enable the early development of power-to-X projects. By 2030, an international supply network begins to develop that includes not only blue hydrogen but also other ultra-low-carbon energy carriers and fuels – principally, green hydrogen, power-to-liquid fuels and green ammonia.

Like the emergence of the power-to-X industry, a circular economy begins to develop, supported through new public-private investment into conversion technologies as well as relevant infrastructure. As a result, waste management and industrial-scale molecular recycling make significant gains. New materials, including alternatives to plastics, and new industrial manufacturing processes impact global mining and reduce the demand for trade in metals and plastics.

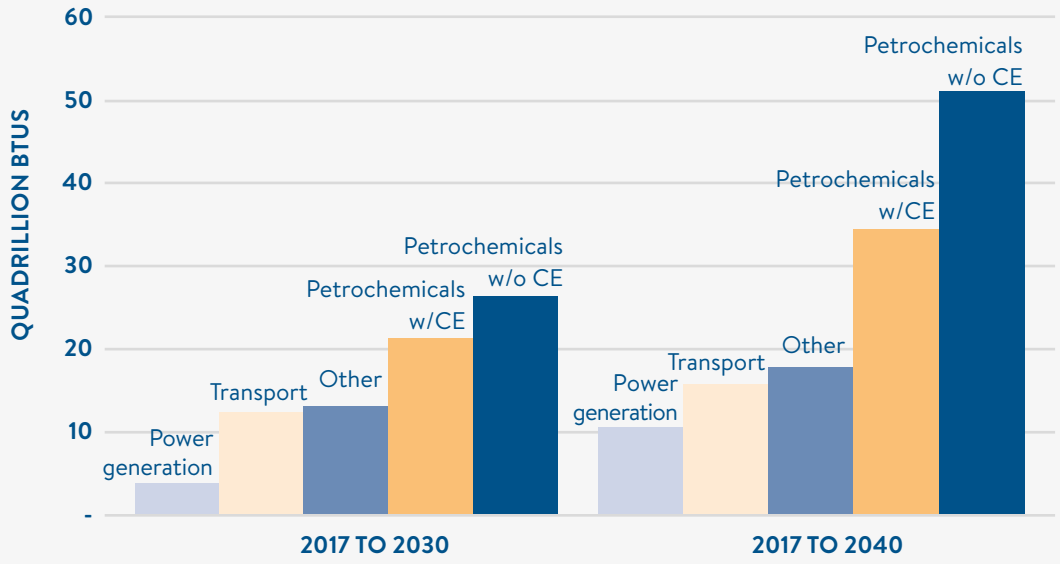
CIRCULAR ECONOMY IN PETROCHEMICALS

Changing consumer preferences and shifting global regulations in relation to plastics and waste management are encouraging the development of a circular economy across the chemicals value chain. There are five key areas for utilising circular economy models in the petrochemicals value chain:

1. Renewable raw materials
2. Energy recovery and carbon utilization
3. Chemical recycling
4. Mechanical recycling
5. End-product re-use

Accenture Research conducted a thought experiment, estimating that circular economy implementation (limited to 3, 4 and 5 of the above) and additive manufacturing could reduce growth in oil and gas by a third by 2040. The analysis focused on the energy content of feedstocks and process energy consumption and was based on an accelerated deployment of the circular economy from 2030 to 2040.

Projected Demand in Oil and Gas Impacted by Circular Economy in Chemicals



Source: Taking the European chemical industry into the circular economy, Accenture Strategy; Accenture Research calculations based on data from ICIS Supply and Demand, The Methanol Institute, USGSIEA World Energy Outlook, 2018.
Note: The forecasts for power generation, transport and other in the above chart represent the IEA's New Policies Scenario. The circular economy assumptions reflect a world in which all key geographies adopt a goal of recycling all disposable or nondurable plastic by 2040, and hence this analysis represents an ambitious case for a circular economy.

To support the infrastructure investment, the finance sector ramps up capabilities to assess public-private investment opportunities such as "green" bonds, helping businesses of all scales invest in capital-intensive and longer-term solutions. Storage technology developments enable regional competition between alternative zero-fossil and net-zero carbon pathways, leading to seamless switching between supply and storage. As a result, investment flows increase to unforeseen levels by 2025.

EMERGING HARMONIES

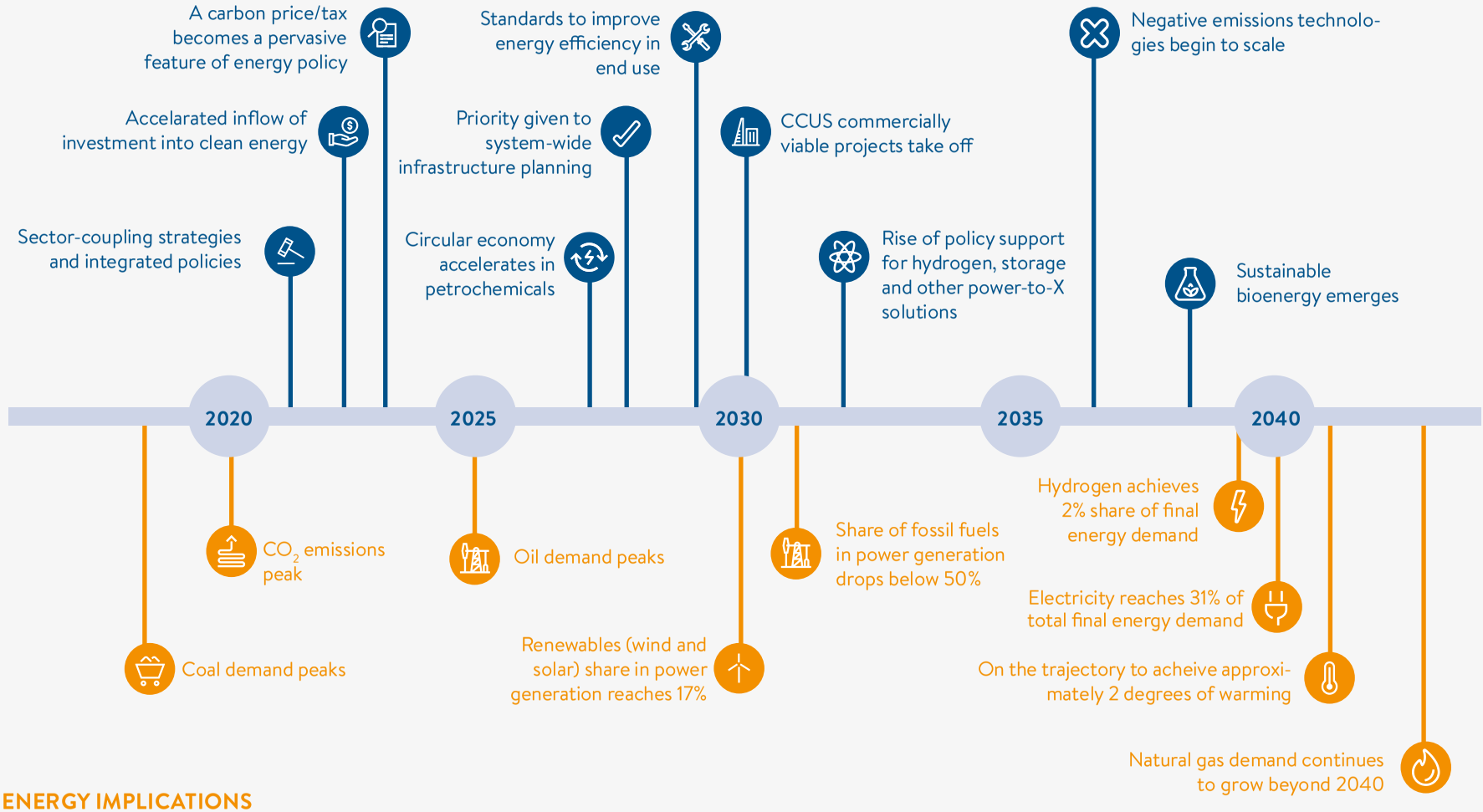
By 2040, the energy system and its adjacent sectors have undergone profound change given the globally supportive policy environment. Energy investments are dominated by no-, low- and net-zero carbon options, including large-scale and distributed renewables, green heat and biofuels. Large-scale nuclear generation is rapidly giving way to small, modular reactors.

In **Unfinished Symphony** the transition is steady and wide-ranging, but also slow and expensive. Despite efforts by many governments to avoid negative net-cost burdens, citizens face rising net costs. Regenerative development models nonetheless emerge from shared learning about what policies best promote technology-neutral carbon mitigation and sector coupling.

By 2040, most regions of the world have learned how to leverage synergies to address climate change-connected challenges and to mitigate the direct and indirect drivers of environmental and societal harm. But in spite of all these strong multilateral policies and cooperation efforts, it seems clear that the world will fail to achieve the 2°C Paris target. More mitigation and adaptation are needed as the effects of climate change are expected to be felt even more strongly over the coming decades. The world has come closer together – but the symphony is unfinished.

HOW FAR DOES INNOVATION GO IN UNFINISHED SYMPHONY?

INNOVATION LANDSCAPE



ENERGY IMPLICATIONS

UNFINISHED SYMPHONY: ENERGY SYSTEM BY 2040

The **Unfinished Symphony** scenario explores an integrated strategy that encompasses climate goals and environmental sustainability. Facilitated by governmental and citizen support of affordable and deep decarbonisation pathways, public-private investment in a broad range of clean energy technologies decouples CO_2 emissions from economic growth. Socially responsible energy behaviours from consumers also detach economic growth from energy demand, with the energy intensity of the economy falling to half of today's level.

The **primary energy demand** increases only by one-tenth from today, but fossil fuels account for more than half of demand in 2040. All the growth in fossil fuel demand is for gas, which has an environmental advantage and replaces largely coal. The need for oil peaks between 2020 and 2030, as clean air becomes a priority and sustainable urban mobility rapidly develops. Nuclear energy sees its share in total primary energy demand doubling from the 2015 level since new investment pours into regions with public support. The availability of sustainable bioenergy starts to emerge as a critical factor since its use increases by one-third in 2040 from today's levels. While hydropower retains its share in the primary energy mix, the contribution from wind and solar sextuples. The final energy consumption experiences limited growth over the time horizon until 2040 due to strong efficiency measures in industry, buildings and mobility. In spite of continuous decline, oil remains the dominant source of energy because of the rising demand for transport, mainly long-distance.

Electricity consumption doubles in 2040 compared to 2015, as clean heat and mobility become a priority in many geographies. Industrial production decouples from CO_2 emissions through increased energy efficiency, deployment of best available technologies and a shift to low-carbon fuels, including electricity. The buildings sector accounts for about half of the increase in electricity demand, reflecting growth in income levels and improved access to clean energy in developing economies. In the transport sector, electricity, biofuels and hydrogen account for one-quarter of the sectoral energy consumption. In **Unfinished Symphony**, electrification and efficiency are at the forefront of this deep decarbonisation pathway, supported by better systems integration, smart grids and improved load management.

The **electricity generation** sector undergoes a profound transformation towards low-carbon sources. The carbon intensity of electricity reduces by more than one-third from today's level, thanks to the massive deployment of renewable energy. Early retirement of coal-fired power plants before the end of their envisioned technical lifetimes is unavoidable in this scenario, and non-fossil-fired generation exceeds fossil-based supply in the 2030s. CCUS plays a growing but still niche role, but by 2040, negative emissions technologies are starting to be scaled up. Significant expansion and upgrading of electricity grids are undertaken to cope with the increased needs for flexibility, together with accelerated deployment of storage and power-to-X options.

Hydrogen emerges as an energy carrier and facilitates sector coupling for providing increased flexibility to the energy system. Since gas steam reforming with CCUS and excess electricity from renewable energy produce most of the hydrogen in 2040, hydrogen also helps in decarbonising the end-use sectors.

Global **CO_2 emissions** peak in the 2020s, and by 2030, the annual global emissions rate falls 1.1% a year between 2020 and 2040. **Unfinished Symphony** is on a trajectory for a global temperature increase of just above 2°C by 2100.

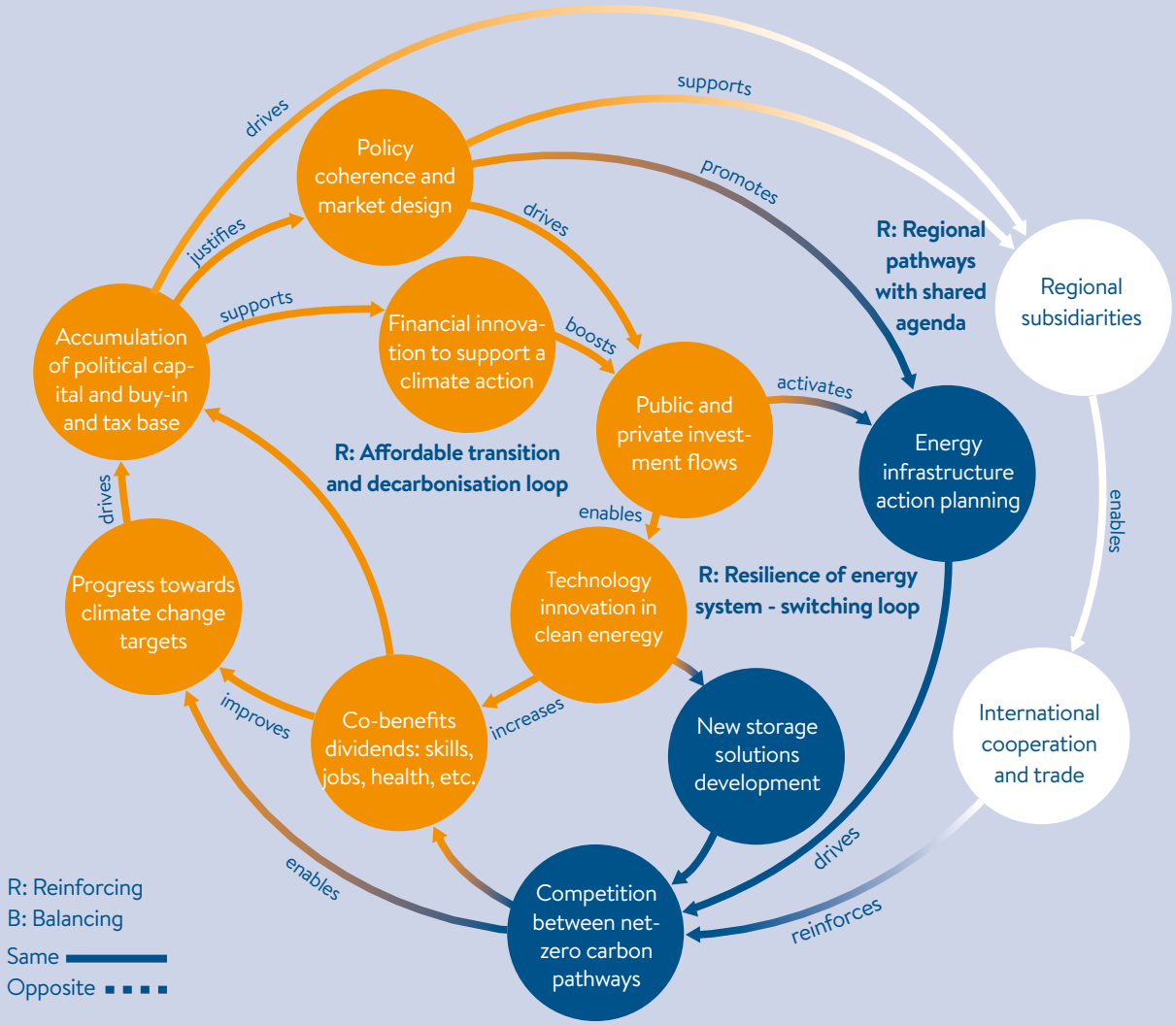
UNFINISHED SYMPHONY: SYSTEMS MAP

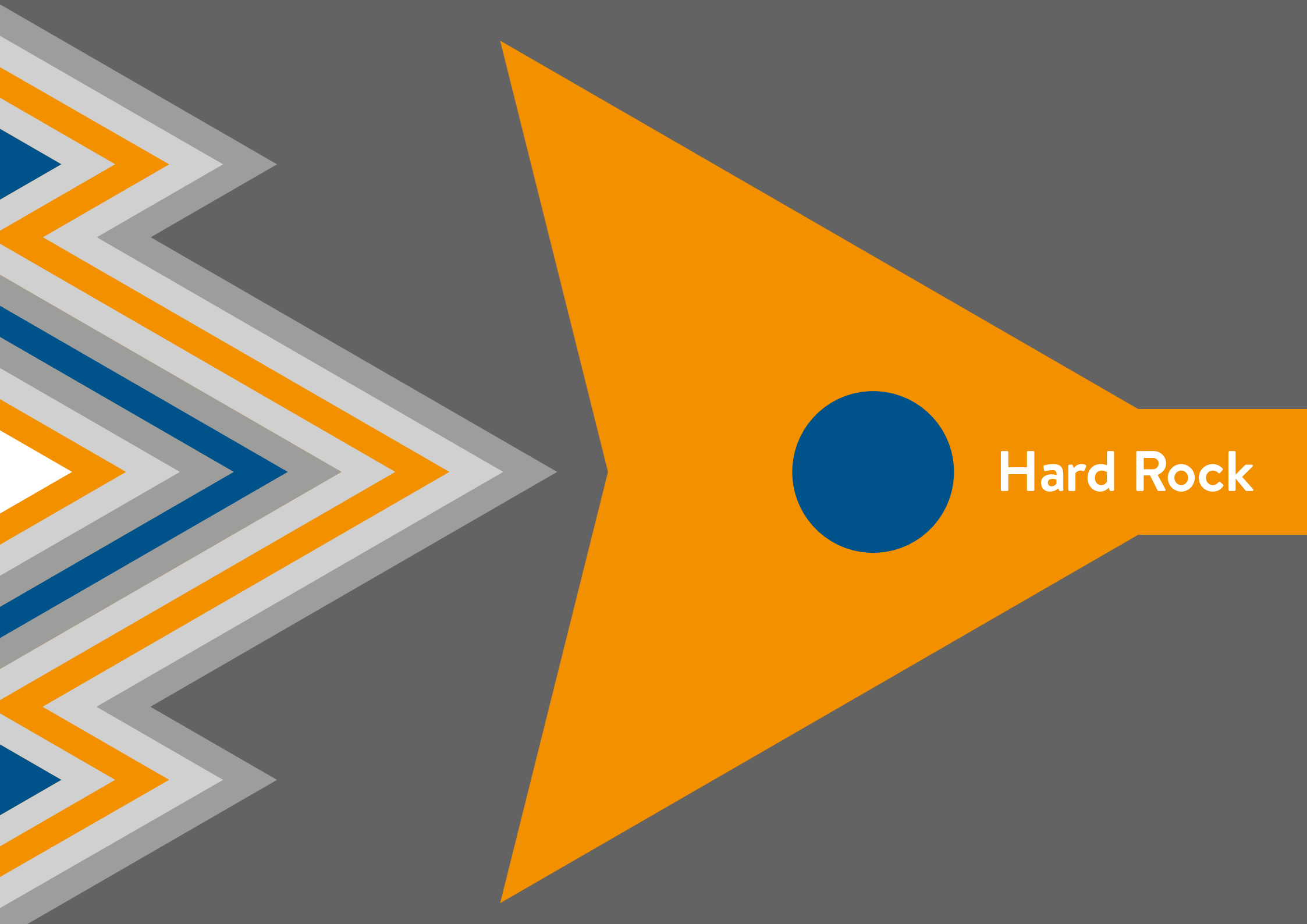
The dynamics of **Unfinished Symphony** are characterised by the interaction of three feedback loops – 1) affordable transition and decarbonisation; 2) resilience of the energy system - switching loop; and (3) regional pathways with shared agenda loop.

R: Affordable transition and decarbonisation loop. Governments emphasise the multi-faceted links between jobs, health, well-living and sustainability. Policy coherence is created to enable Energy Infrastructure Action Planning and steer more investments to technology innovation. Citizens are more willing to pay taxes when they see that the resulting job creation and other co-benefits are fairly applied. Accumulation of trust and an expanding tax base justify new policies and drive financial innovation.

R: Resiliency of the energy system – 'switching' loop. Energy infrastructure action planning, innovation in clean technology development, improved storage solutions and an increase in international cooperation enable development of regional electricity grids and synthetic fuel markets. The competition among net-zero pathways increases resilience by enabling switching between supply and storage.

R: Regional pathways with shared agenda loop. Accumulation of political capital and policy coherence drive regional subsidiaries to align regional pathways that diverge to progress net-zero carbon energy transition for the lowest cost and best fit to local needs. Most countries continue to increase the trade in blue- and green-sourced electricity in order to provide energy security, which, in turn, contributes to co-benefits dividends, linking the energy transition to jobs creation and labour policies.




Hard Rock

“HAPPY FAMILIES ARE ALL ALIKE; EVERY UNHAPPY FAMILY IS UNHAPPY IN ITS OWN WAY”

– LEO TOLSTOY

HARD ROCK

THE AGE OF ANXIETY

In **Hard Rock**, citizens throughout the world become more and more dissatisfied with their traditional political classes and increasing bureaucracy, on the one hand, and with the ravages of global market forces on the other.

Populists and nationalistic candidates win surprising victories in many western countries and insist on going their own way in an increasingly #MeFirst world. Brexit, a fragmenting EU, American inward-looking nationalism, growing pressure from China and the return of authoritarianism strain the multilateral system to a breaking point. These lead to a rebirth of tensions globally with familiar regional arenas emerging such as the South China Sea and the Middle East, where rising tensions continue between both sides of the Arabian Gulf.

The global economy is more volatile, with the two decades marked by several recessions. This volatility leads to a more sluggish average real growth with North America, Latin America and Europe below 2%, while East Asia, Sub-Saharan Africa, MENA and Asia Pacific barely achieve 3%; Central Asia is the only region retaining strong growth at 4%. Global investment flows are reduced in a world of slow growth and high cost of capital. Regional constraints also contribute to the constrictions of finance and data, leading nations to turn to domestic energy security solutions.

While there is sometimes bilateral cooperation and an increase in regional coordination, there is relatively little global cooperation. In this and other areas, it's clear that western institutions, such as the World Bank, the UN and the IMF, are becoming less relevant to local communities, member states and the world at large.

Nations are much more concerned with jobs, health and local environmental stresses than with global issues. The ties that hold the west together begin to fray, and the result is a surprising growth of inequality both among and within countries. Individuals revert to their own identities and cultures, which in many cases are not geographic.

Most countries use whatever capabilities they have at hand – resource endowments, existing assets, automated systems integration and demand-side measures – to achieve local energy security. Technological innovation continues, but slowly in the context of an abundance of cheap coal and unconventional gas and oil and the continued use of oil and gas in heat, transport and industry. In the residential and commercial sectors, construction standards and efficiency gains from more intelligent homes and other buildings advance slowly in the OECD and even more slowly in the sprawling mega-cities of developing countries. The much-touted battery-based electric vehicle revolution fails to occur, and renewable energy subsidies are cut. The commercial mobility and freight transport sectors are largely unchanged, even though trade patterns themselves are shifting. Petrochemicals growth continues, but at a slower pace, with innovation in recyclable and biodegradable plastics.

The world progressively gravitates towards a multi-polar order with very different sets of rules for business and data – the US, a reformed and smaller EU, an expanded Russian Federation, and China. Competition between them is intense. Trade conflicts hinge on import tariffs, IP ownership and resources access and conflict resolution is complicated by a weakened WTO.

There is a shift in energy policy priorities away from addressing environmental concerns towards security. In particular, governments are concerned about the cyber security risks faced by the energy industry, given the difficulty of protecting vulnerable infrastructure and increasingly interconnected objects. Underfunding of basic infrastructure, cyber-attacks and the lack of urban resilience in response to extreme weather events are the major cause of blackouts.

CHINA'S WAY

China aims to forge a different way but is impeded by global developments. In the twenties its Belt and Road Initiative (BRI) increases collaboration on a regional level, but this collaboration becomes more difficult to maintain in the thirties. Some projects endure, especially those developed with Africa and Russia. But China's economy becomes increasingly inward-focused as tensions and anti-Chinese protectionism rises in many parts of the world.

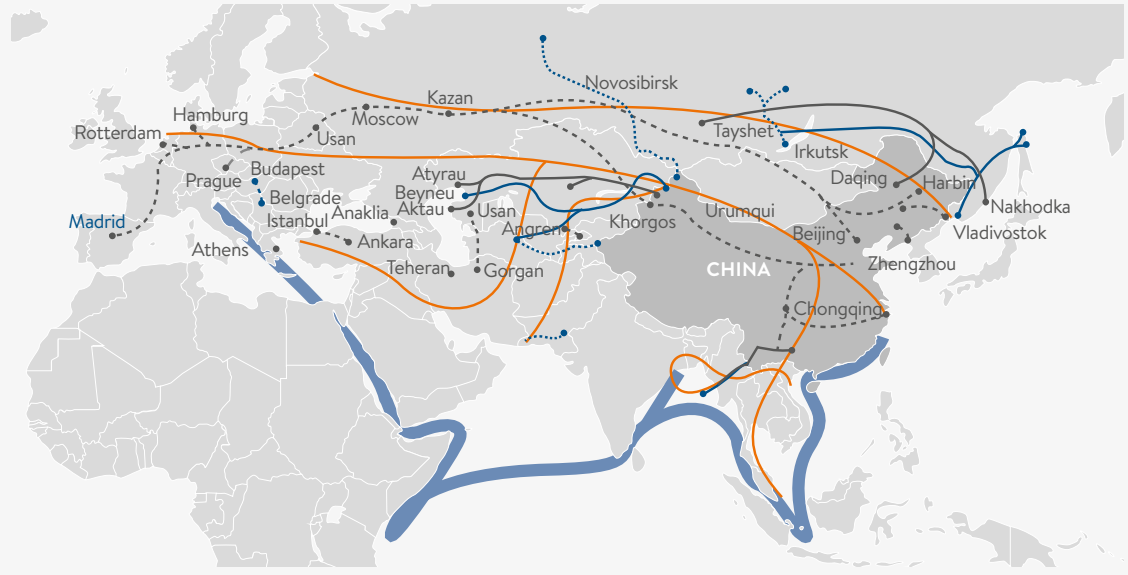
Internally, the state controls all energy and digital networks, reducing its reliance on energy imports as it focuses on security over economic growth, even though growth remains very important. And through regional strategic alliances it has secured the energy and non-energy resources needed to continue its clean air and clean water energy revolution and to extend its export of affordable, smart and integrated solutions. China's focus on domestic "strategic innovation" – its "$500 billion fund" – results in cheap renewable energy and smart grids for many of its cities. China leads in the development of affordable renewables, but most energy supply in China continues to consist of fossil fuels, hydro and nuclear power.

CHINA'S BELT AND ROAD INITIATIVE

The Belt and Road Initiative (BRI) was introduced in Nur-Sultan (Astana) in 2013, when President Xi announced a mega-project to improve connectivity and cooperation on a trans-continental scale, primarily through infrastructure investments. At the second BRI Forum in Beijing in 2019, China declared that the BRI included 125 countries and involved over 1000 projects, worth a total of USD 3-4 trillion. According to the World Bank, the BRI includes 1/3 of world trade and GDP and over 60% of the world's population.

Energy is one of the crucial pillars of the BRI. China's strategic objective, in line with the country's Paris Agreement commitment, is to reduce its dependence on coal. Reducing coal consumption implies a dramatic increase in the use of natural gas and the building of new pipelines.

Belt and Road Initiative Route Map



Source: Chinese Grand Strategy in the Eurasian Heartland, Institute for Emerging Markets Studies, Moscow School of Management SKOLKOVO

FIRMER REGIONAL FOUNDATIONS

Two strands dominate policy making – geopolitically minded energy resource exploitation and domestic energy efficiency improvement. Global powers move fast to reduce reliance on energy imports outside of their spheres of influence, and diverse energy security pathways begin to emerge.

Countries without secure fuel reserves of their own try to avoid oil, coal, gas and even nuclear, if they can, by developing domestic crop-derived bioenergy, energy recovery (such as bio/landfill gas and incineration) and carbon-free sources (such as wind, solar and hydro). These options provide a positive push towards decarbonisation.

Oil- and gas-centric economies remain exposed to oil and LNG price volatility. Other countries find themselves squeezed by geopolitical pressures as powerful energy-producing nations gain leverage over those needing to deal with a growing demand for energy. Global energy companies find that their actions are continuously constrained by regional and national politics. This weakens their global investment programmes with a focus on less risky, more traditional projects.

In response to these new energy supply constraints, geopolitical technology partnerships flourish. But efficiency and cost reductions improve relatively slowly because globalised knowledge-sharing is limited, and blocs seek to bolster only their own regionally domestic industries. Even so, the private sector mobilises to ratchet up efficiency throughout all links of the energy value chain.

QUICK FIXES, LOCAL SOLUTIONS AND PERVASIVE STRAINS

Globally, some countries are less carbon-intense than others. However, on the whole, the decarbonisation agenda is stalled, partly because of a pervasive politics of "quick fixes" with limited availability of investment for energy transformation.

Populist leaders characterise decarbonisation efforts as too expensive and naïve and blame cross-border integration for the lack of local community resilience that has led to the increasing number of disruptions in energy supply. Rather than creating a coordinated response to these blackouts, individual leaders use them to reassert their hold on the energy sector. Every country looks out for its own cost advantage and security of supply. With less cooperation, potential economies of scale and alternative seasonal storage pathways are not exploited, and alternatives to conventional energy systems become less reliable and more expensive. Consumers and governments become exposed to more volatile energy prices.

As local energy security becomes more important, individual countries look to their own sources of strength. India clings to coal, while the US stays dependent on its plentiful supply of fossil fuel. Facing its resource scarcity challenges, the smaller EU accelerates its new model of a circular economy, linking its energy transition to new industrial development plans. While others see this as an attempt to protect the competitiveness of its industries, the EU circular economy also prevents leakage of jobs and provides new impetus for a regional industrial innovation ecosystem. Some countries begin to re-localise energy technology production so that foreign-made systems are prevented from becoming a part of domestic energy infrastructure at any level. Others shift back towards centralised energy generation and a stronger role for the state, including, in a few cases, the re-nationalisation of energy infrastructure and companies.

By the mid-2030s, CO_2 emissions are continuing to rise, and the only hope that environmental and development activists see for avoiding global catastrophe is a stronger push towards end-use efficiency and equity, and local climate adaptation management. But global gains are uneven. Effects of global warming are increasingly felt with growing water scarcity and agricultural hardships in various regions of the world, leading to increasingly erratic economic growth and greater regional tensions.

THE NEED FOR COLLABORATION

The world has long given up on the Paris Agreement. Some climate activists have switched their attention to adaptation – preparing the world for the harsh days ahead. By 2040, annual CO_2 emissions are at their highest level yet, and near-term mitigation is possible only through the use of negative emissions at scale (bioenergy combined with carbon capture), which no country seems willing to pay for. While increased bioenergy is constrained by water and weather, unilateral actions in relation to geo-engineering displace innovation in direct carbon capture and use. CCUS fails to take off because of its poor cost effectiveness and the lack of carbon-related policy incentives.

In spite of significant carbon emission reductions in North America and Europe, global energy-related emissions continue to grow, driven largely by South and East Asia. Cities attempt to pick up the global emissions reduction agenda, but they have neither the scale nor the funds to make much of a difference and are quickly overwhelmed by water and migration challenges.

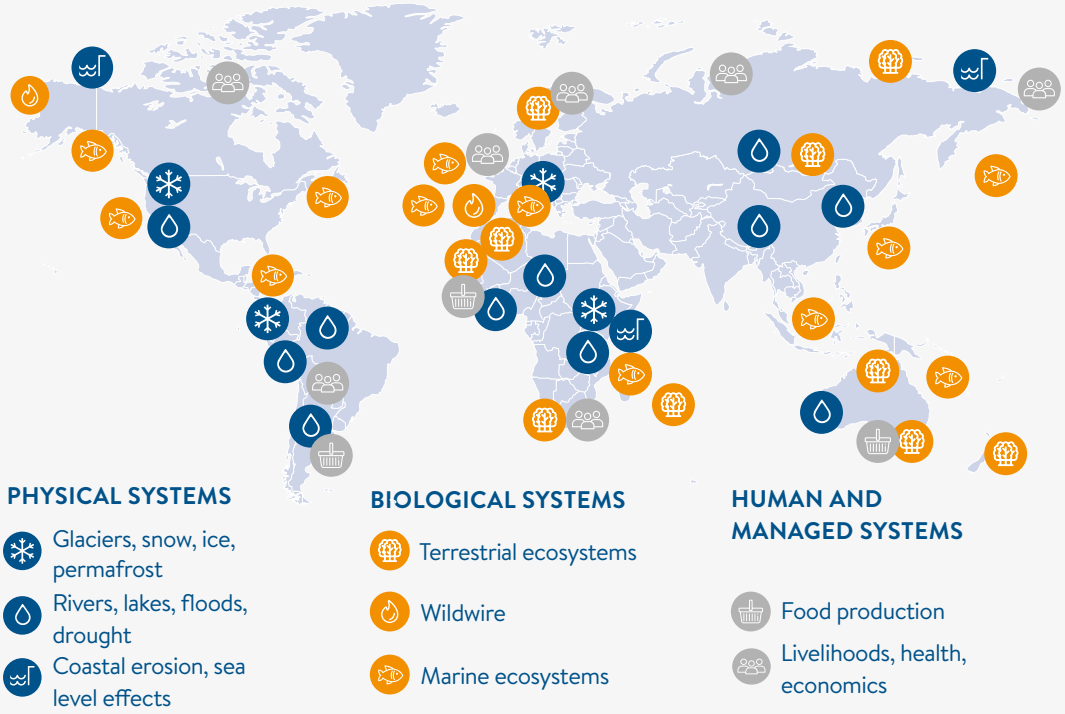
It's clear that the entrenched energy system dynamics throughout the world of **Hard Rock** are difficult to change. Beyond 2040, oil demand plateaus while natural gas demand continues to grow. It looks as if the world is on a pathway towards a rise of slightly above 3°C by 2100.

CLIMATE ADAPTATION COSTS

Climate change has become an urgent issue, and the need to accelerate adaptation to make the world more resilient is critical. Without immediate action, climate impacts could push an additional 100 million people into poverty by 2030. The estimated funding for climate adaptation for developing countries is doubling or tripling every few years.

According to a new United Nations Environment Program (UNEP) report, the cost of adapting to climate change in developing countries could rise to between **USD 140** and **USD 300 billion** per year in **2030**, and between **USD 280** and **USD 500** billion per year in **2050.**

Major Observed Impacts Attributed to Climate Change

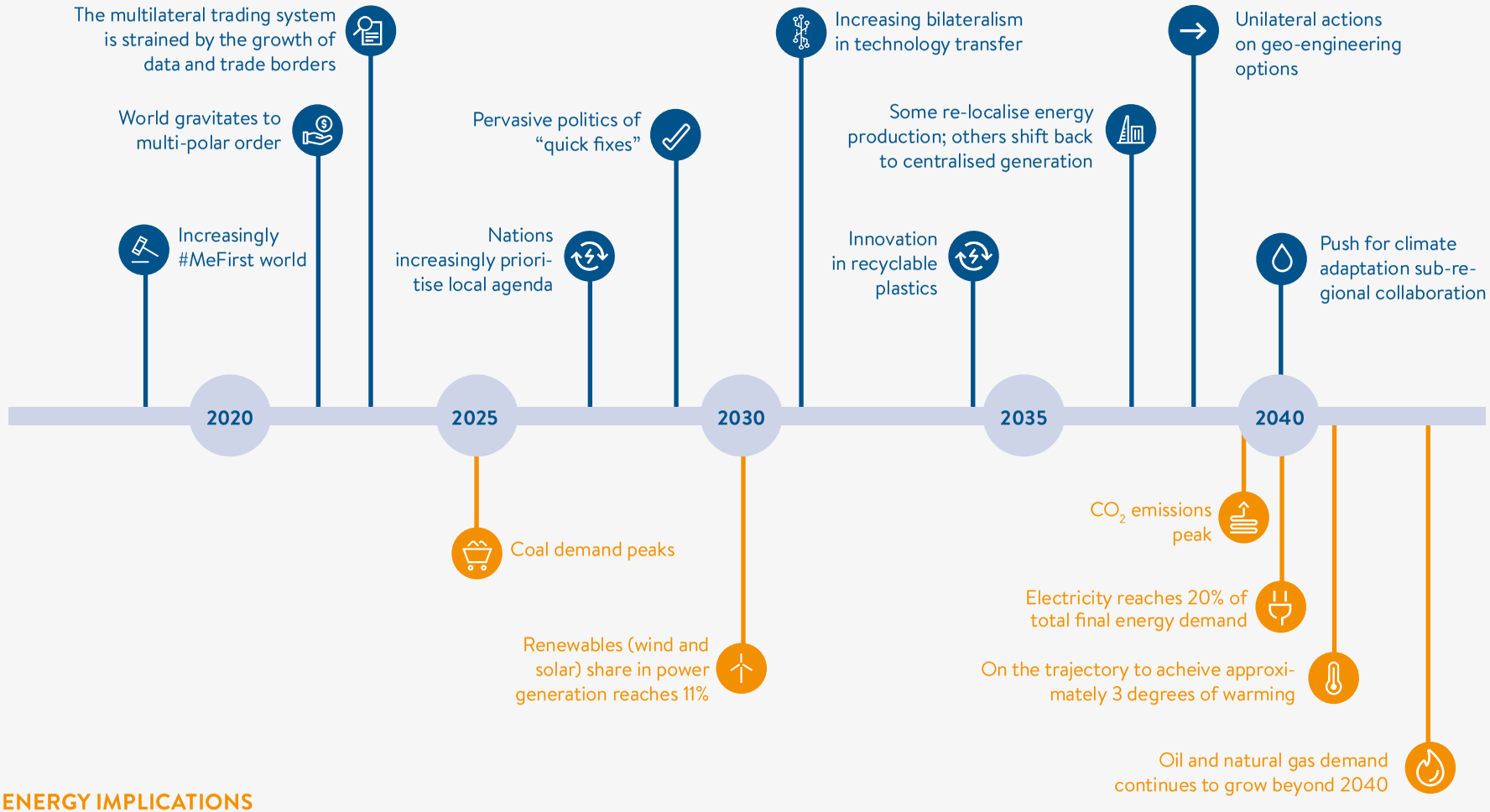


Source: Adapted from IPCC Summary for Policymakers (WGII), 5th Assessment Report (AR5), 2014

By 2040, a consensus is forming within most countries that collaboration is needed to create technological and economic solutions for accelerating climate change adaptation. Reflecting a generational shift in mindsets, the EU, the US and China forge loose agreements among themselves to decarbonise over the long-term, but retain the focus on energy security, water and the resilience of other local natural resources in the short term. The question remains for many: is there enough time to adapt regional flows and ecosystems to the worst effects of climate change?

HOW FAR DOES INNOVATION GO IN HARD ROCK?

INNOVATION LANDSCAPE



ENERGY IMPLICATIONS

HARD ROCK: ENERGY SYSTEM BY 2040

In the **Hard Rock** scenario, energy security drives efficiency, but a fragmented world with trade limits is a barrier for strong technological progress. Clean energy technologies fail to attain the substantial cost reductions seen in **Modern Jazz** and **Unfinished Symphony**, and there is still an active link between economic growth and global energy-related CO_2 emissions. On the other hand, the relationship between economic growth and primary energy demand weakens compared to current trends, and by 2040, the energy intensity of the economy has dropped by one-third from today's level.

While efficiency measures in developed countries secure a continued decline in energy use, the **primary energy consumption per capita** does not show a peak before the 2040s, when it reaches a record high. Fossil fuels dominate the primary energy supply in a context of a globally diversified abundance of cheap coal, unconventional gas and oil. One-quarter of the growth in primary energy demand comes from oil, as alternative fuels in mobility do not extensively materialise. Coal consumption peaks in the 2020s and reverts to today's levels by 2040. The share of gas in primary demand increases to one-quarter in 2040, with gas contributing to efficiency gains and clean air objectives. Nuclear energy almost doubles from today, as nuclear gains increased public support for energy security and environmental sustainability.

Sustainable bioenergy is a concern in this scenario, since the use of biomass increases by at least a quarter in 2040 to mitigate the exposure of oil- and gas-centric economies to price volatility. While hydro attains a limited expansion, the contribution of wind and solar in total primary energy demand quadruples from 2015 to 2040. Oil remains the dominant source of energy as the much-touted electro-mobility revolution does not live up to its promise in **Hard Rock**. Electricity and gas show the largest relative increase in 2040 from today's level, as the heating and manufacturing sectors shift to cleaner and more efficient use of energy. Technologies to support better systems integration, such as smart grids and load management, do not penetrate to a large extent, and the energy system becomes less reliable and more expensive.

The **electricity generation** sector is dominated by fossil fuels, although to a lesser degree than today. Solar, including off-grid applications, and wind emerge as low-cost alternatives for dispersed and rural communities. CCUS options fail to take off because the lack of carbon control policies challenges CCUS' competitiveness. The lower excess supply of renewable electricity, compared to **Modern Jazz** and **Unfinished Symphony**, reduces the needs for seasonal storage, and power-to-X does not become economically attractive even as a decarbonisation option. To a small extent and driven by energy security concern in areas without centralised energy infrastructure, hydrogen emerges as an energy carrier, but only for heating and electricity supply as the transport sector remains dependent on fossil and biogenic liquids.

Global energy-related CO_2 emissions continue to increase, peaking in the 2040s. The commitments of the Paris Agreement are not fulfilled, which implies that drastic abatement of GHG emissions beyond 2040 in line with the stringent Paris long-term target would only be possible through large-scale deployment of negative emission technologies. **Hard Rock** is on an emissions reduction trajectory that would result in a global temperature increase (to 2100) of slightly above 3 degrees.

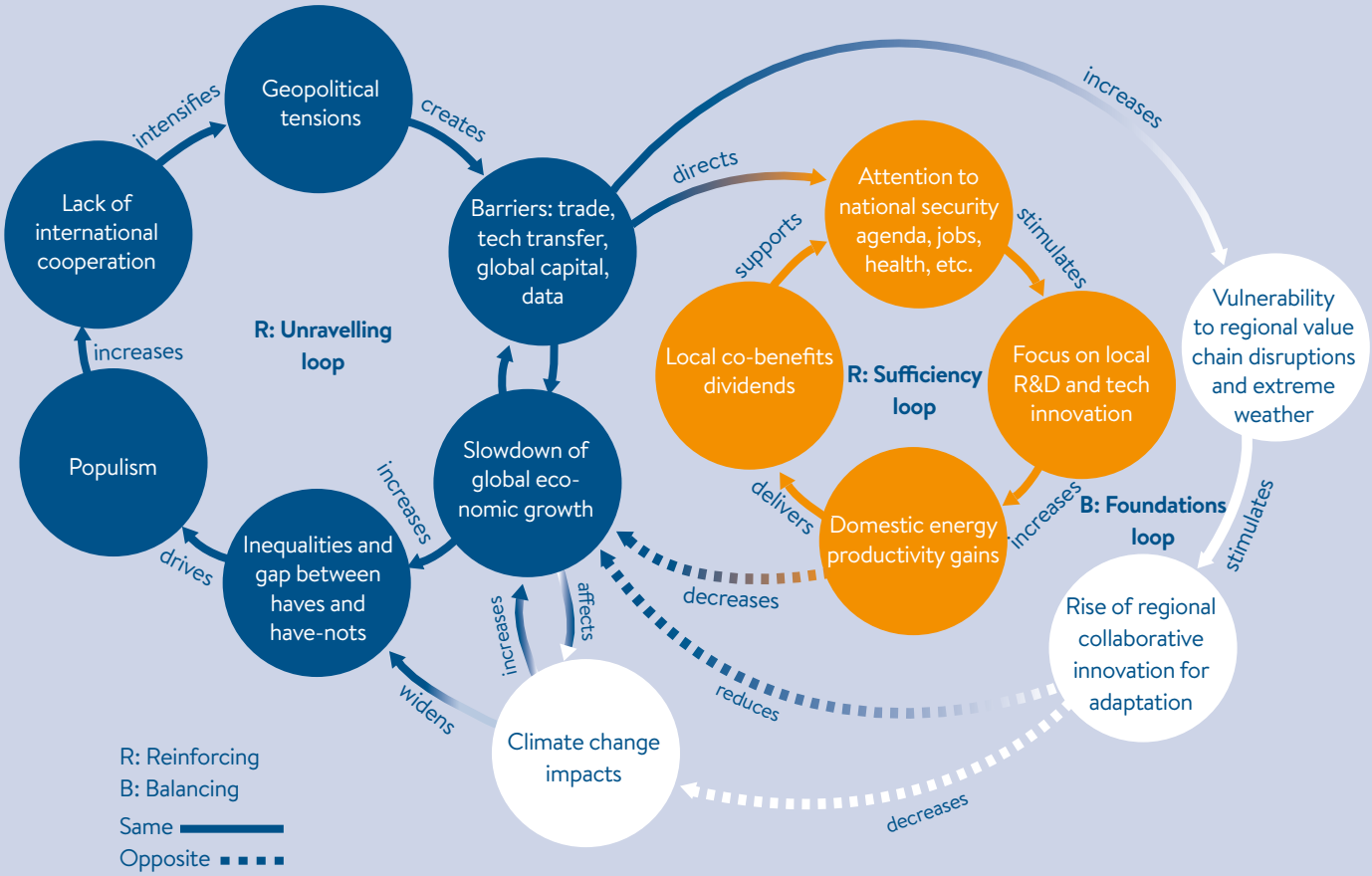
HARD ROCK: SYSTEM MAP

The dynamics of **Hard Rock** are characterised by the interaction of three feedback loops – 1) a global order unravelling loop; 2) a local self-sufficiency loop; and 3) a regional foundations loop.

R. Global order unravelling loop. Slow global economic growth and globalisation create greater inequalities and challenges of "left-behinds". Trade is decreased by the overall slowdown of the global economy, populism and geopolitical tensions. A low-growth world with limits to the availability of investment for energy transformation reduces cooperation in relation to globally connected challenges, which further slows economic growth.

R: Local self-sufficiency loop. As flows of data, tech and capital are constrained, nations are forced to look at their own sources of strength. They are much more concerned with energy security, jobs, health and local environmental stresses than with global issues. This inward focus reinforces innovation at the local level, which brings positive productivity and efficiency gains. However, not all economies manage to build their own resources, and this failure widens the gap between the haves and have-nots even further.

B: Regional foundations loop. As global cooperation fades, the effects of extreme weather, water stress and climate change are increasingly felt on an uneven basis. Vulnerability to regional value chain disruption increases, too, which forces collaboration, but on a sub-regional rather than global basis, in order to create technological and economic solutions for accelerating climate change adaptation.



PART TWO |

Comparative Analysis

INTRODUCTION

This section lays out the expected modelled outcomes for each of the scenarios to better compare and contrast them. It is designed to complement the scenario narratives and provides the linkage to the scenario modelling.

The comparison starts with a high-level summary of results (primary energy, final energy and energy mix) and is followed by the most noteworthy findings within the four demand sectors of transport, residential and commercial, industrial and non-energy uses. The comparison then focuses on four cross-scenario themes of electrification, infrastructure, new technologies and implications for carbon emissions and climate more broadly.

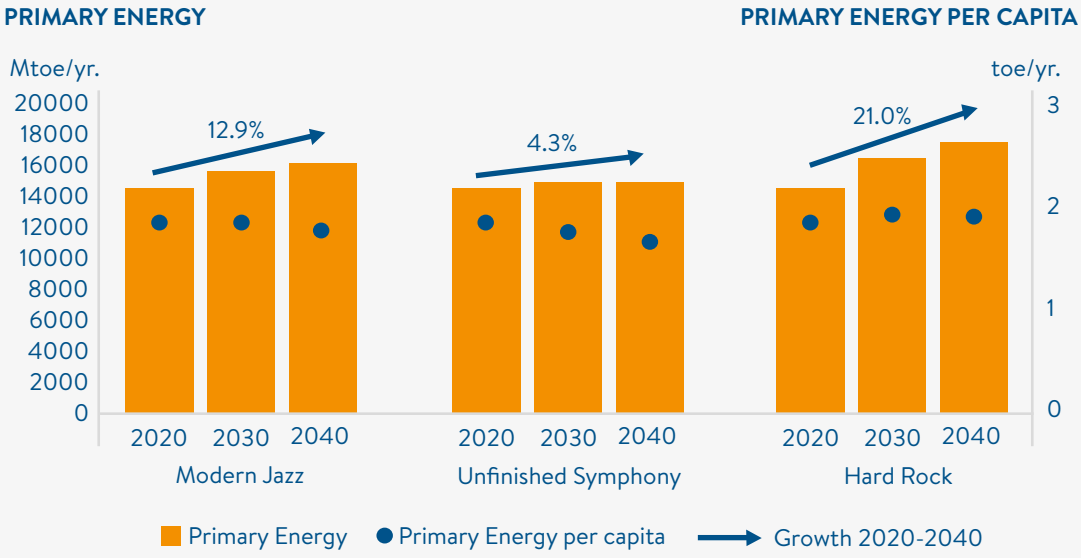
This comparative analysis aims to help scenario explorers identify the scenario signposts and build awareness of each scenario's implications to guide strategic thinking in anticipation of and response to what is happening.

SUMMARY RESULTS

At a global level, primary energy demand grows in all scenarios from 2020 to 2040.

The **Hard Rock** scenario leads to strong primary energy growth of 21%, as neither strongly coordinated policy interventions nor extensive demand-side market-driven innovations exist to offset the increase in primary consumption. The benefits of coordinated regulations and policies of **Unfinished Symphony** result in demand in 2040 being just 4% higher than in 2020, while **Modern Jazz's** market-driven and innovative system experiences 13% growth in demand over the period.

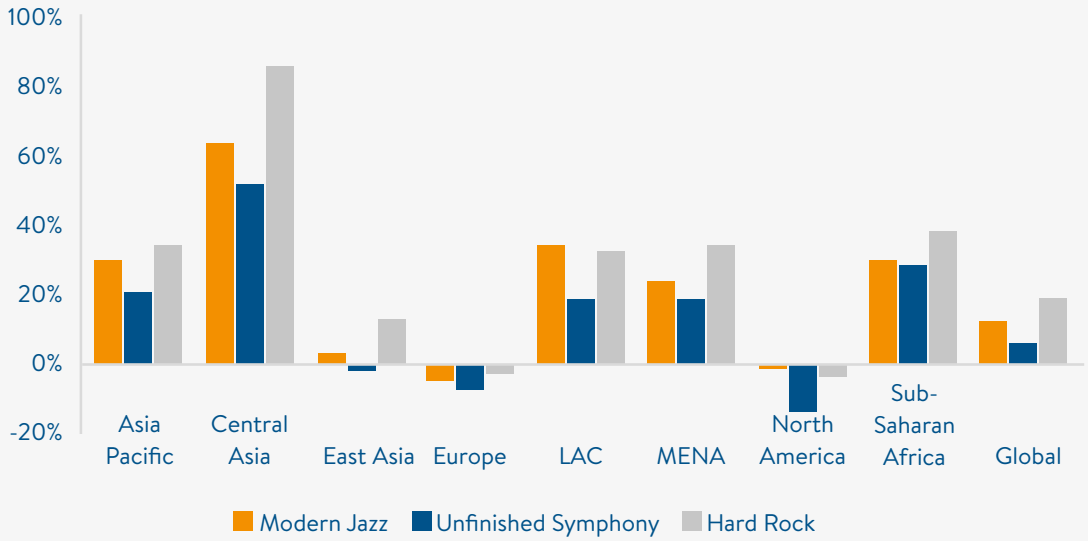
Figure 1. Total Primary Energy (Mtoe/yr.) and Primary Energy Per Capita (toe/yr.)



Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

Central Asia (including India) is the dominant contributor to global primary energy demand growth in all scenarios but with a significant increase under the **Hard Rock** scenario, driven by low efficiency growth in industry and transport. Europe and North America experience declines in primary energy demand in all three scenarios. North America, in particular, experiences a significant drop in **Unfinished Symphony** as efficiency gains offset new demand growth.

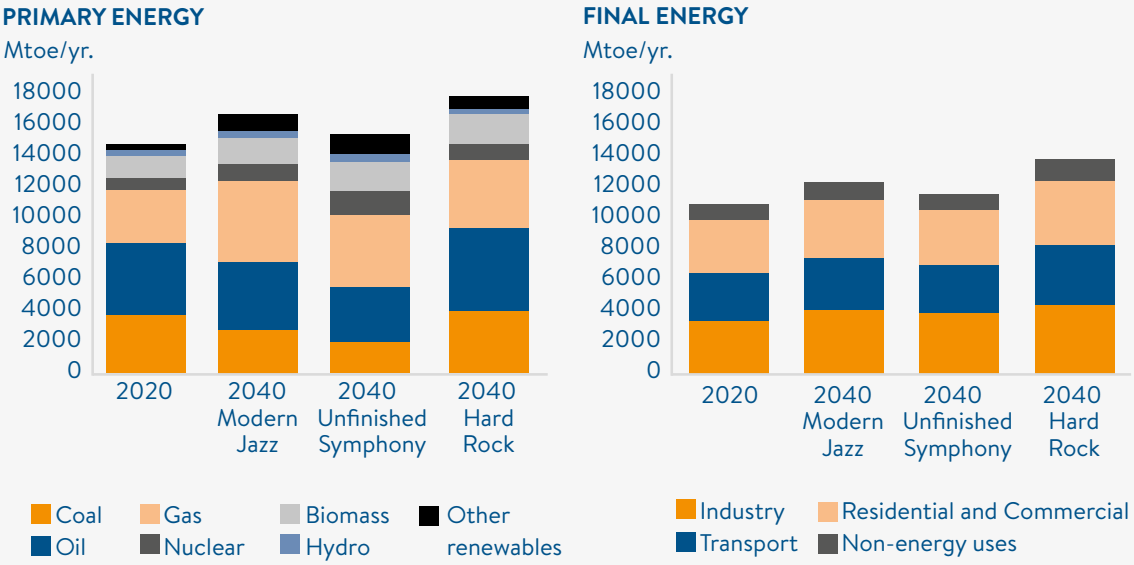
Figure 2. Primary Energy Absolute Growth 2020 to 2040, by Region



Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

Fossil fuels continue to meet more than two-thirds of primary energy demand across all three scenarios. The absolute volume of oil and coal shrinks in **Unfinished Symphony** and **Modern Jazz,** increasing only in **Hard Rock**. Gas, the cleanest of the fossil fuels, increases in volume under all scenarios, with the strongest growth in **Modern Jazz**, where its low cost and high availability is prized.

Figure 3. Primary Energy by Source (Mtoe/yr.) and Final Energy by Demand Sector (Mtoe/yr.)



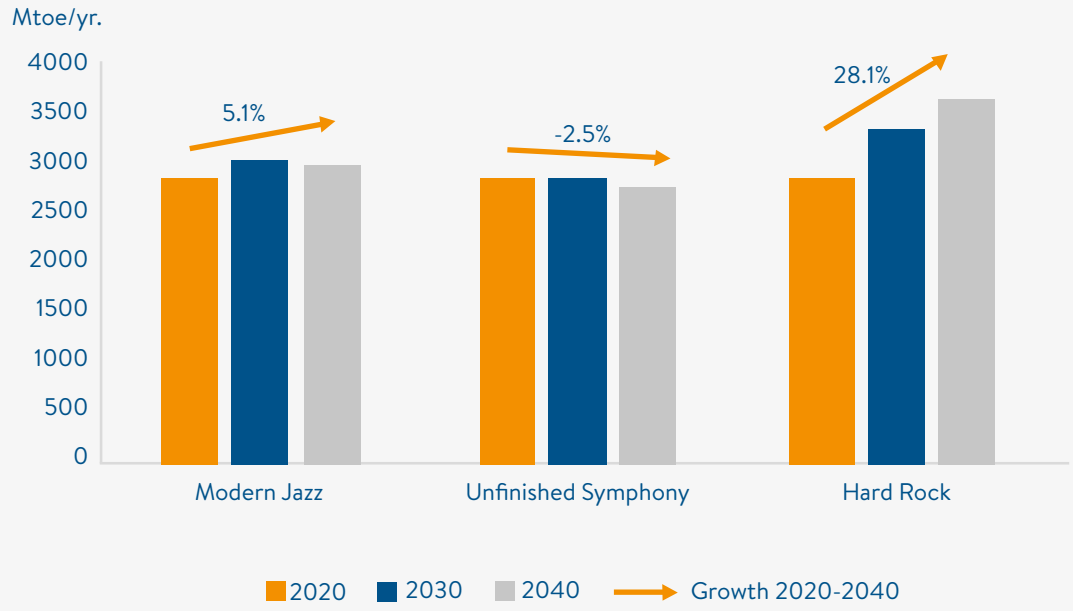
Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy
Note: Other renewables comprise wind, solar PV, solar thermal and geothermal. Non-energy uses are dominated by industrial feedstocks (for petrochemical production, for example). The energy carriers are coal (including hard coal and lignite), gas and oil, including crude oils and oil products such as additives, ethane and naphtha.

Final energy consumption grows from 2020-2040 across all three scenarios. The differences across the scenarios are mostly explained by the transport and industrial sectors. High penetration of EVs, policy-driven efficiency gains and the rise of circular economies lead to flat to low energy consumptions growths under **Unfinished Symphony**, whereas **Hard Rock** sees growths at over twice that pace, and **Modern Jazz** falls in between.

PASSENGER AND COMMERCIAL TRANSPORT ENERGY USAGE

From 2020 to 2040, transport final energy consumption decreases (with a peak around 2025) in **Unfinished Symphony** but experiences 28% growth in **Hard Rock**. In **Unfinished Symphony**, the decrease is driven by enhanced efficiency of ICE and incentivised adoption of EVs supported by an accelerated roll-out of infrastructure for both commercial and consumer transport. In **Hard Rock**, the ICE vehicle pool continues to grow but without a corresponding increase in efficiency.

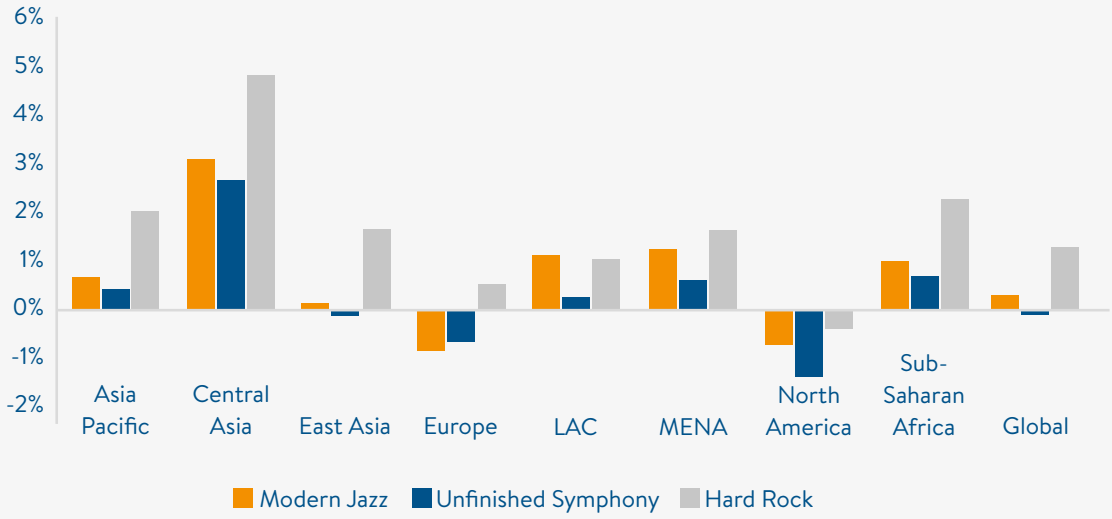
Figure 4. Final Energy Consumption from Transport (Mtoe/yr.)



Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

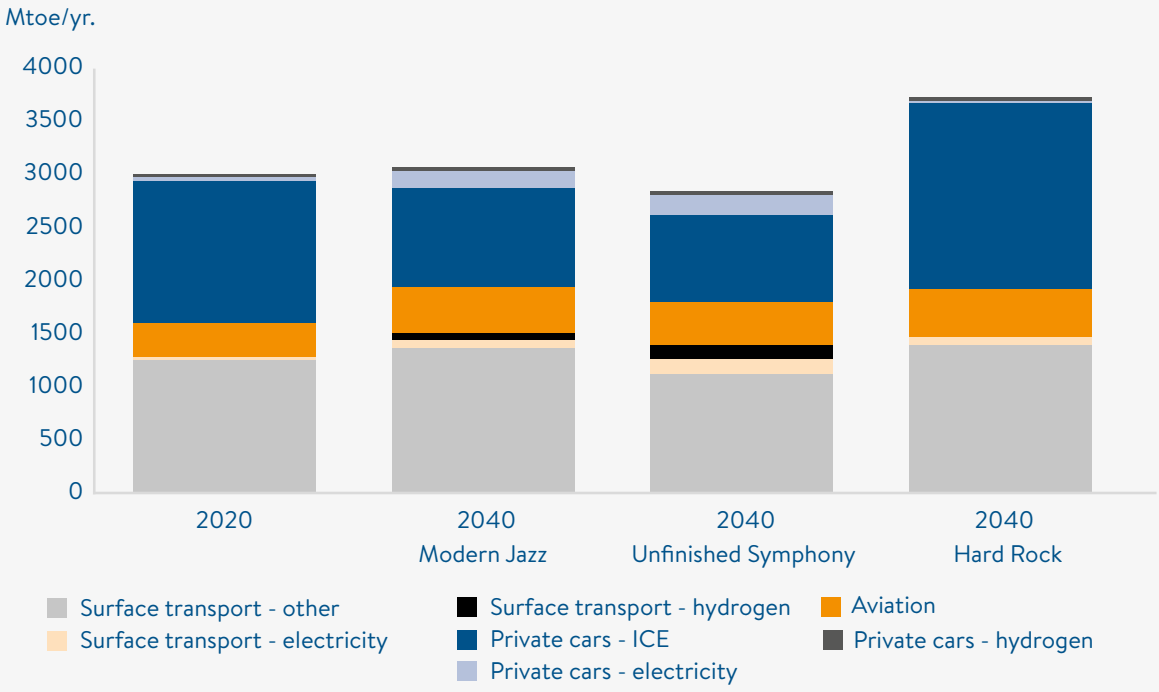
Central Asia sees the highest growth in consumption due to its fast-growing fleet of private and commercial vehicles. Europe and North America mostly see reductions in nearly all cases with lower vehicle growth and continued tightening of regulations and policies such as restrictions on low efficiency vehicles in cities and road taxes related to CO_2 emissions.

Figure 5. Final Energy Consumption from Transport CAGR, 2020 to 2040, by Region



Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

Figure 6. Energy in Transport by Fuel and Transport Segment (Mtoe/yr.)

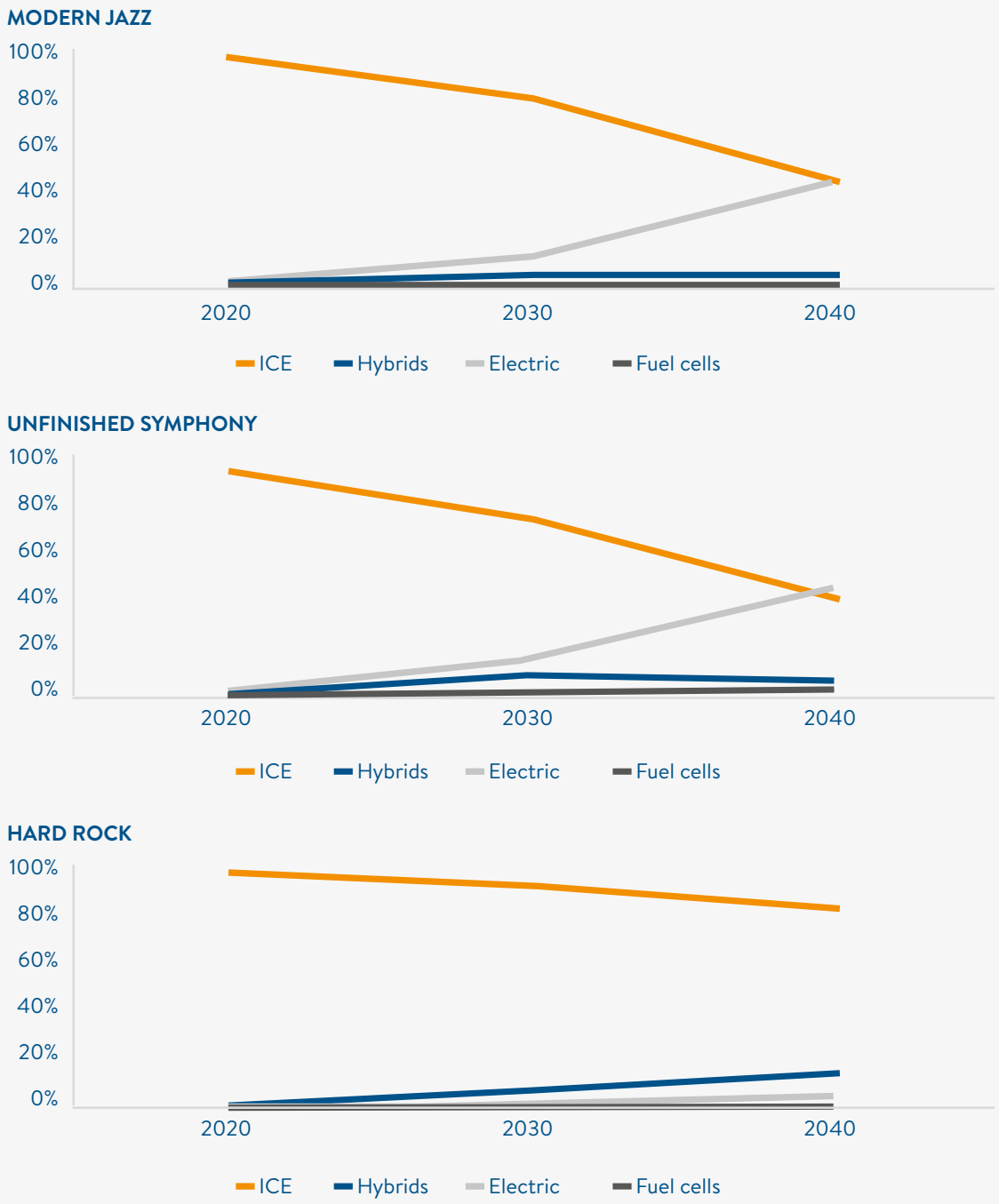


Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

Transport energy consumption of ICE private vehicles is the swing factor across the three scenarios. It drops about 32% in **Modern Jazz** and 39% in **Unfinished Symphony**, whereas it grows 31% in **Hard Rock** from 2020 to 2040. The impact of private transport demand in each of the scenarios will be a critical area to evaluate for the manufacturers of private vehicles and the suppliers of their energy.

ICE vehicles drop dramatically and are substituted by EVs in both **Modern Jazz** and **Unfinished Symphony**, with the crossover point occurring around 2040. This drop is mainly driven by EV costs reaching parity with ICE by 2030. The policy incentives in **Unfinished Symphony** do not hinder innovation in **Modern Jazz**, but they complement it. In this context, they act as an additional driver for cost reductions on top of the innovation that also occurs. **Hard Rock** distinguishes itself with the continued dominance of ICEs and a stronger uptake of hybrid vehicles.

Figure 7. Private Passenger Car Stock, by Technology (% share of total)



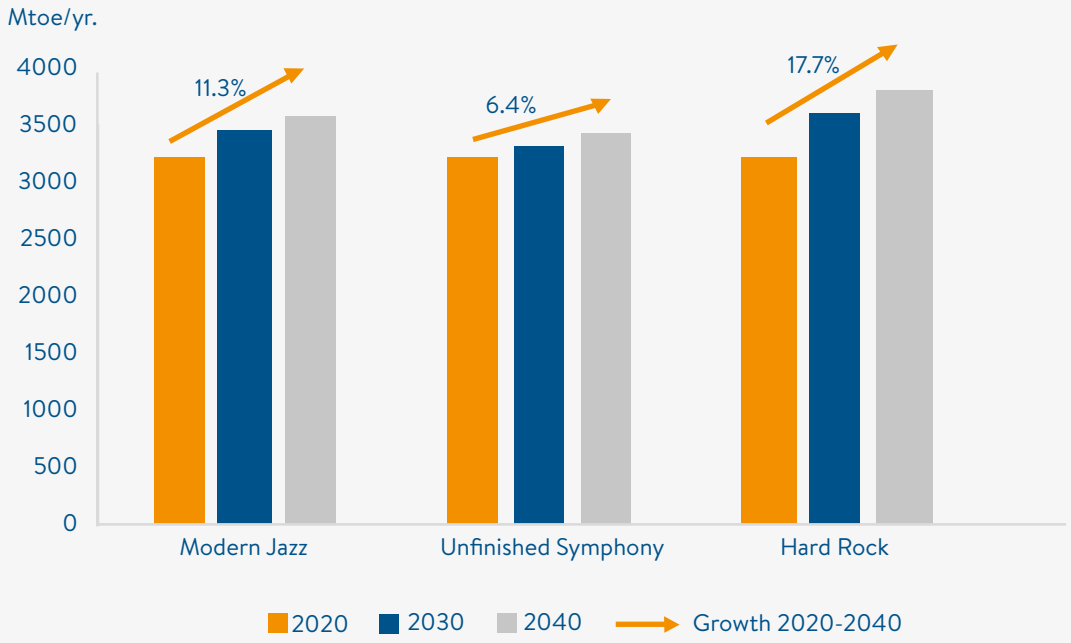
Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

Fossil fuel remains the dominant source of energy for transport across all scenarios till 2040 because of the time needed to renew the stock of vehicles and build infrastructure. The strong energy demand growth in **Hard Rock** contrasts sharply with the rapid demand erosion characteristic of **Modern Jazz** and **Unfinished Symphony**.

RESIDENTIAL AND COMMERCIAL BUILDINGS ENERGY USE

Aggregated energy use in residential and commercial sectors – comprising residential and commercial buildings and commercial process heat – grows in each scenario by between 6 and 18% from 2020 to 2040.

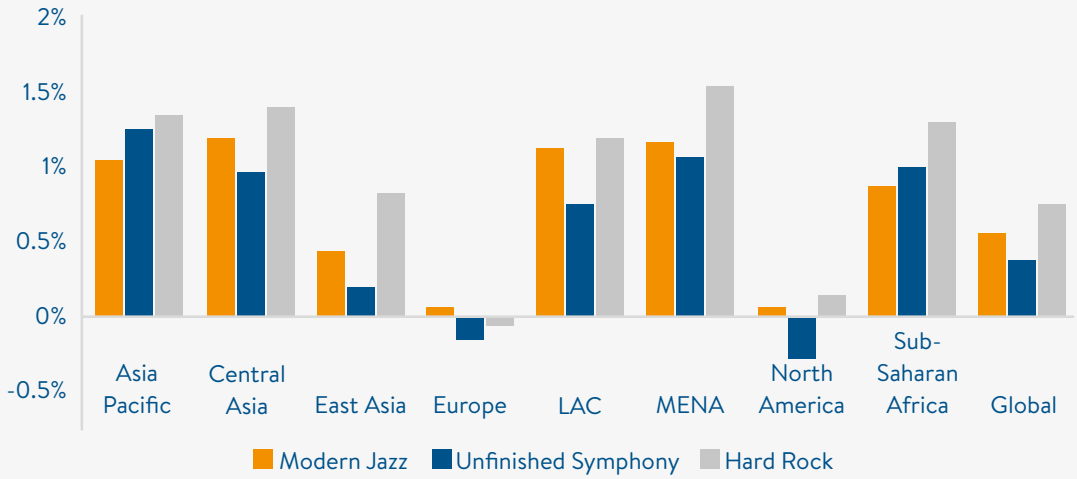
Figure 8. Final Energy Consumption from Residential and Commercial Sectors (Mtoe/yr.)



Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

The relative impact of energy consumption in the three scenarios is similar for most regions, with **Hard Rock** outpacing **Modern Jazz** and **Unfinished Symphony** typically the lowest. All regions exhibit strong energy demand growth except for Europe and North America, where tamer activity growth combines with tighter construction standards and rapid deployment of technologies to lead to further improvements in building energy efficiencies.

Figure 9. Final Energy Consumption from Residential and Commercial Sectors CAGR, 2020 to 2040, by Region

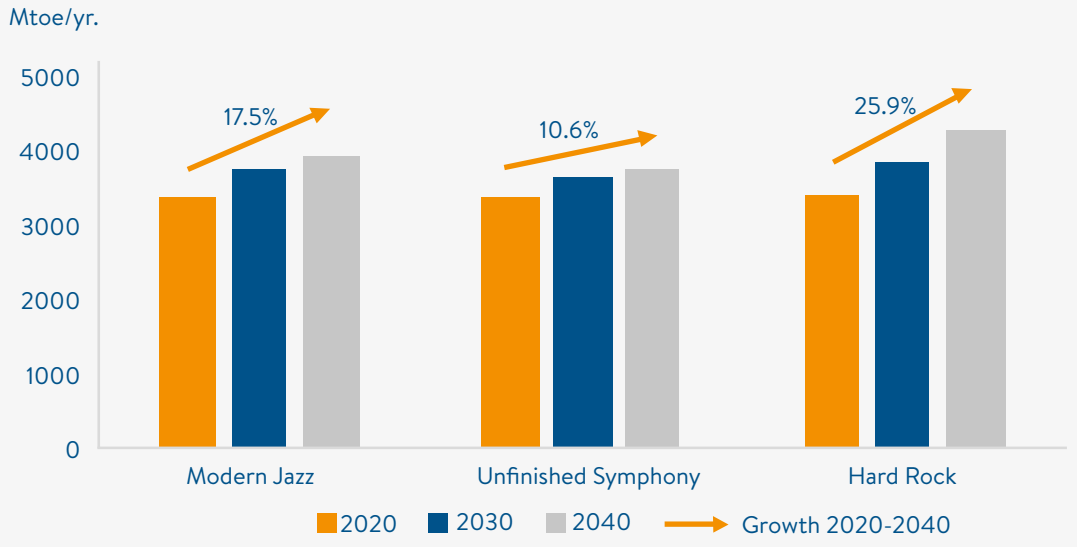


Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

INDUSTRIAL ENERGY USE

Industrial energy demand increases across all three scenarios, but the rate of growth has a significant spread across the scenarios, from 11% in **Unfinished Symphony** to 26% in **Hard Rock.**

Figure 10. Final Energy Consumption from Industry (Mtoe/yr.)

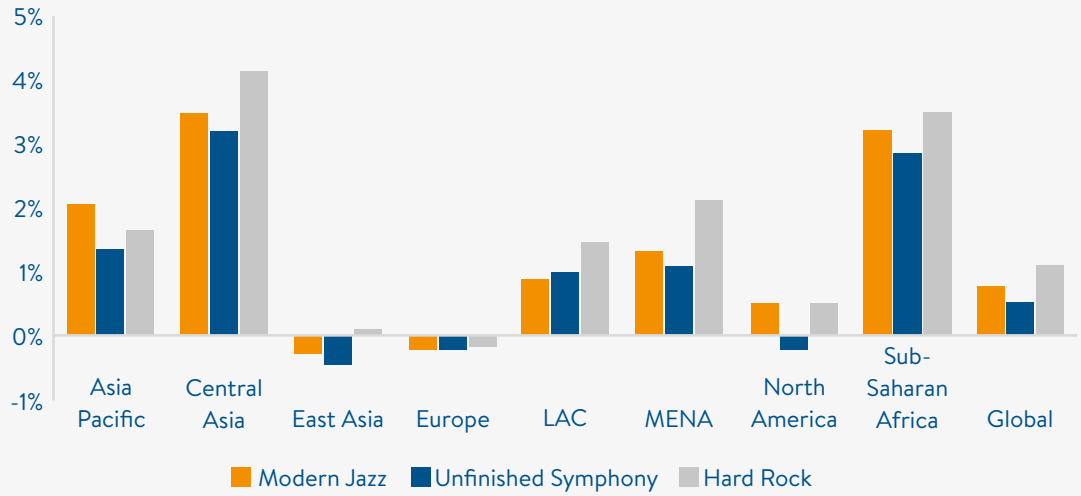


Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

The drivers of the difference are that **Unfinished Symphony** promotes emissions standards and energy efficiency. The emissions standards encourage greener alternative fuels in the sector, while the efficiency measures temper demand growth. **Modern Jazz** falls between the two, with strong economic growth driving industrial demand but offset by innovation in energy efficiency improvements. The **Hard Rock** world leaves efficiency gains on the table, only prioritising energy efficiency when energy security is challenged. Growth in energy demand is highest in this scenario, despite the lowest rate of GDP growth, which indicates a strong de-coupling between industrial activity and energy consumption in this scenario.

At a regional level, the highest rate of growth comes from Central Asia and Sub-Saharan Africa as they accelerate up their industrialisation curve. Industrialised regions such as East Asia, Europe and North America continue to shift toward services-centric economies which, combined with efficiency gains, drives negative or low industrial energy demand growth.

Figure 11. Final Energy Consumption from Industry CAGR, 2020-2040, by Region

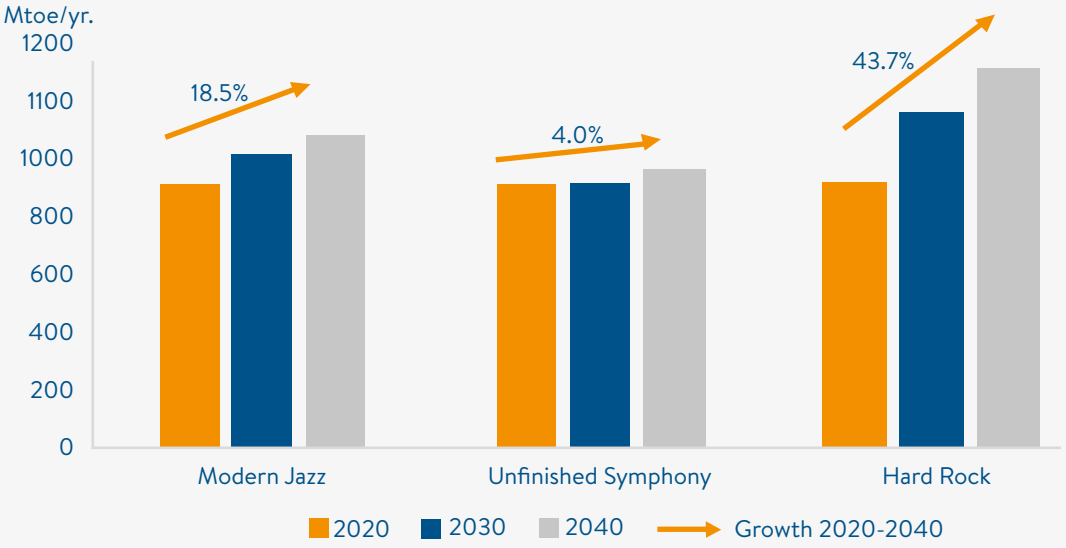


Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

NON-ENERGY USES[2]

Global energy demand from non-energy use sectors (mainly industrial feedstocks) increases in each scenario, though the rate of growth differs significantly between scenarios, with **Unfinished Symphony** the most moderate at 8% and **Hard Rock** the most rapid at 43%.

Figure 12. Final Energy Consumption from Non-Energy Uses (Mtoe/yr.)



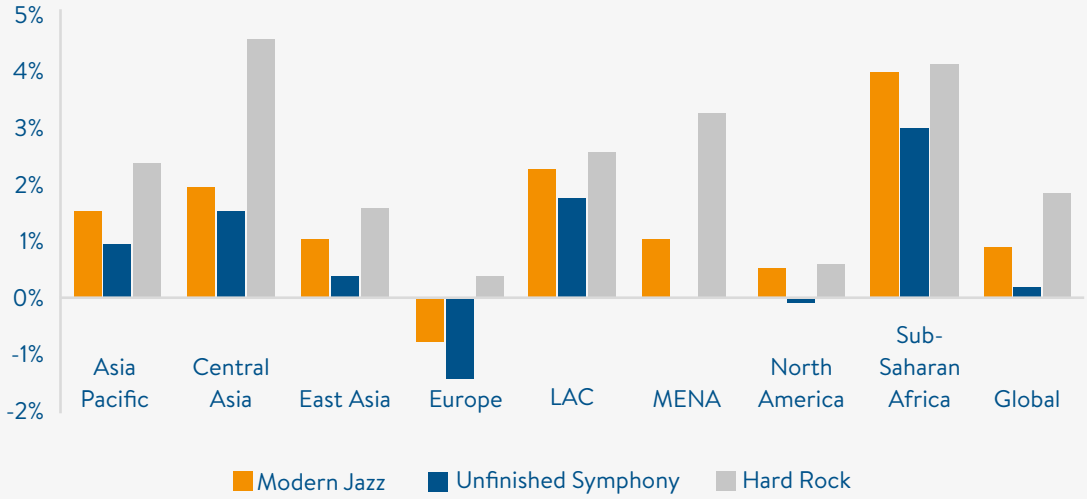
Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

[2]These non-energy uses are dominated by industrial feedstocks (e.g., for petrochemical production). The energy carriers are oil (crude oils and oil products, such as additives, ethane and naphtha), gas and coal.

Circular economy principles and regulations, seeking to restrain the consumption of plastics, curbs growth in demand from non-energy uses to varying extents, particularly in Europe and North America, and most prominently in **Unfinished Symphony.**

Europe is the only region that achieves reductions in final energy consumption from non-energy uses in two of the three scenarios (the exception being **Hard Rock**). Indeed, its chemicals industry leads the way in decarbonisation and adoption of circular economy principles to decrease the need for new hydrocarbon-based feedstocks. In other regions, although there are substantial increases in circular economy uses and direct interventions to curb plastics consumption, economic growth yields sharp increases in plastics consumption, thereby driving overall energy demand growth from non-energy uses.

Figure 13. Final Energy Consumption from Non-Energy Uses CAGR, 2020-2040, by Region

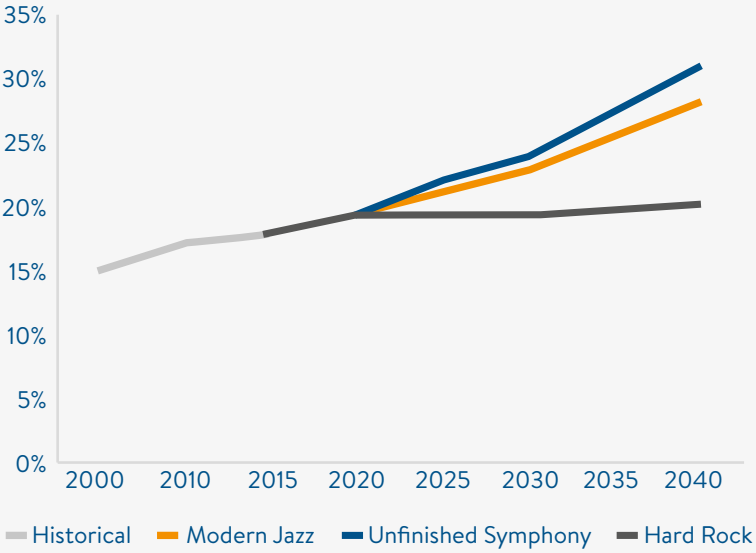


Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

ELECTRIFICATION

Demand for electricity continues at pace until 2040 as heating, manufacturing and mobility move to electron-based power. **Unfinished Symphony** sees the strongest growth, with an increase of 60% (2.4% CAGR) over the period 2020 to 2040 and achieves the highest level of electrification at 31% of total final energy consumption in 2040. Efficiency is at the forefront of a deep decarbonisation pathway, supported by better systems integration, smart grids and improved load management. In contrast, demand for electricity in **Hard Rock** grows by only 4% (at 0.2% CAGR) with electrification progressing to slightly over 20% in 2040 as the global energy mix remains heavily fossil fuel dependent. In between, **Modern Jazz** achieves an electrification of 28% by 2040.

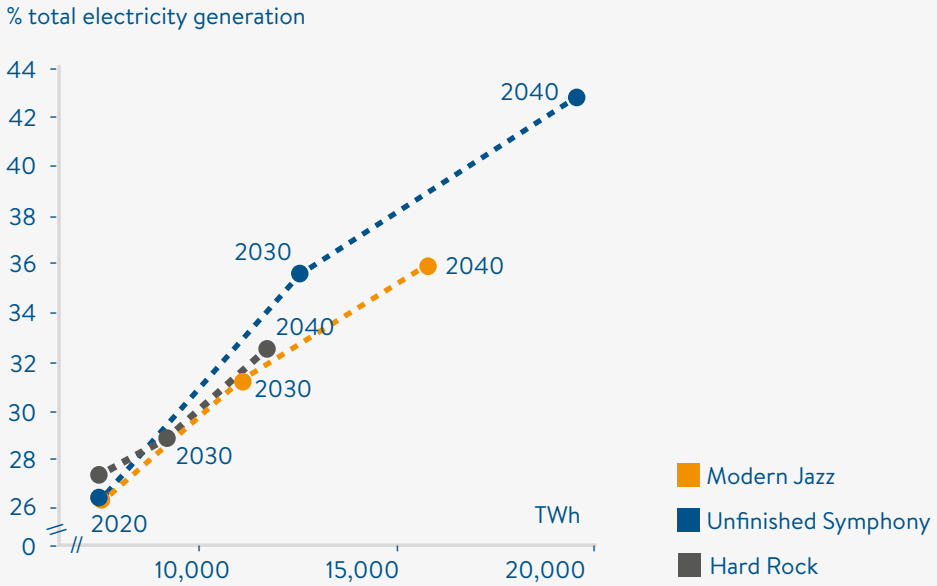
Figure 14. Electrification Rate of Final Energy Consumption (Electricity as % Final Energy)



Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

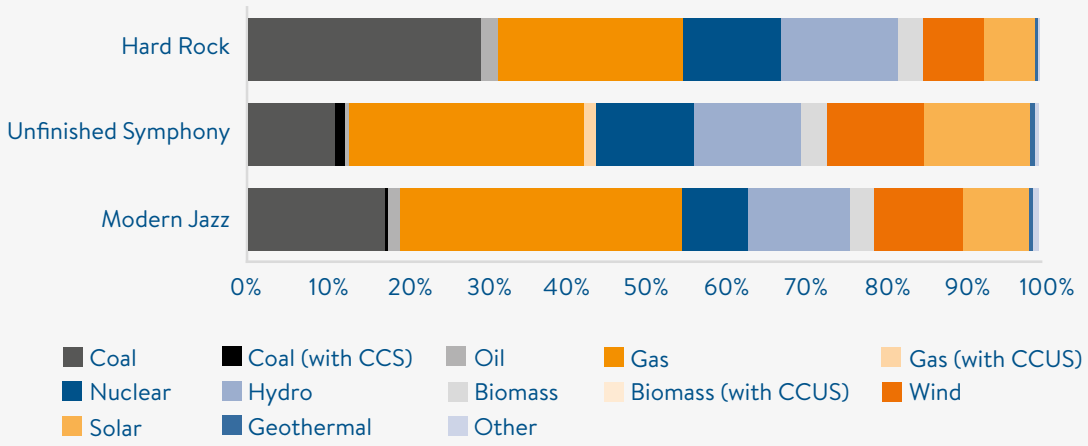
The electricity generation sector undergoes a profound transformation towards low-carbon sources. The change is starkest in **Unfinished Symphony** as the share of fossil fuels drops below 50% in the early 2030s. Coal-fired power generation peaks in the mid-2020s, while gas scales up to become the primary source of power generation in **Modern Jazz** and **Unfinished Symphony** in 2040. CCUS emerges in this latter scenario by 2040.

Figure 15. Renewable Electricity Generation (%, TWh)



Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy
Note: Renewables include hydro, biomass, wind, solar and geothermal

Figure 16. Sources of Electricity Generation, 2040 (% Total)



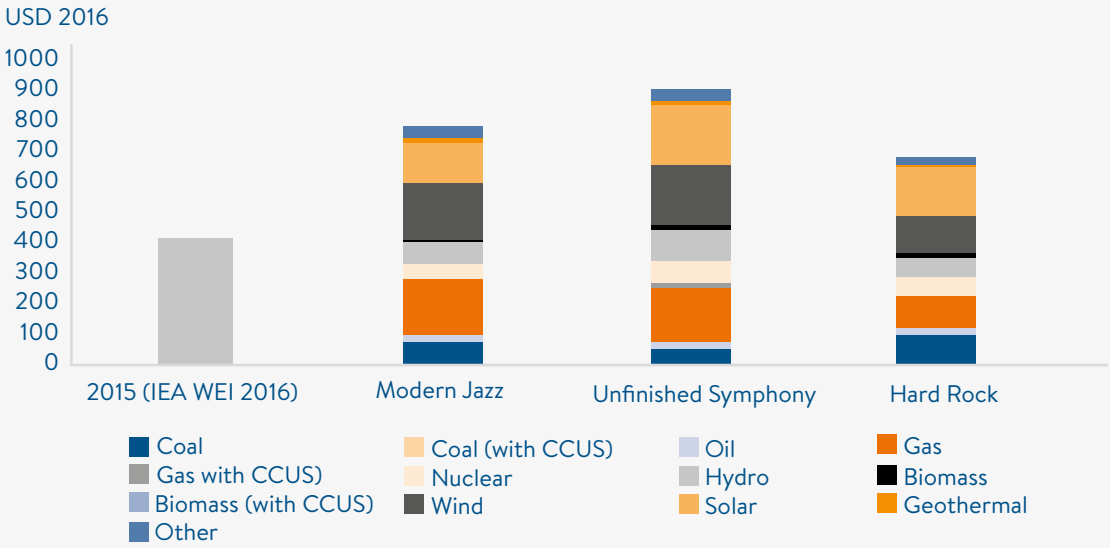
Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy
Note: Renewables include hydro, biomass, wind, solar and geothermal

INFRASTRUCTURE

Across each of the three scenarios, infrastructure is a critical enabler of electrification, not only to bring and integrate new sources of decarbonised electricity and to enable the shift in end-use through storage, but also to deal with legacy power generation.

To fund the electricity demand growth from 2020 to 2040, a substantial average annual investment in new power generation capacity of between USD 670-890 billion is required – double the investment of just over USD 400 billion in 2015. In addition, investments will be required for new and existing electricity grids, storage and sector-coupling systems to enable the safe and reliable integration of new and changing energy supplies.

Figure 17. Average Annual Investments in Power Generation 2020 - 2040, Undiscounted (USD 2016)



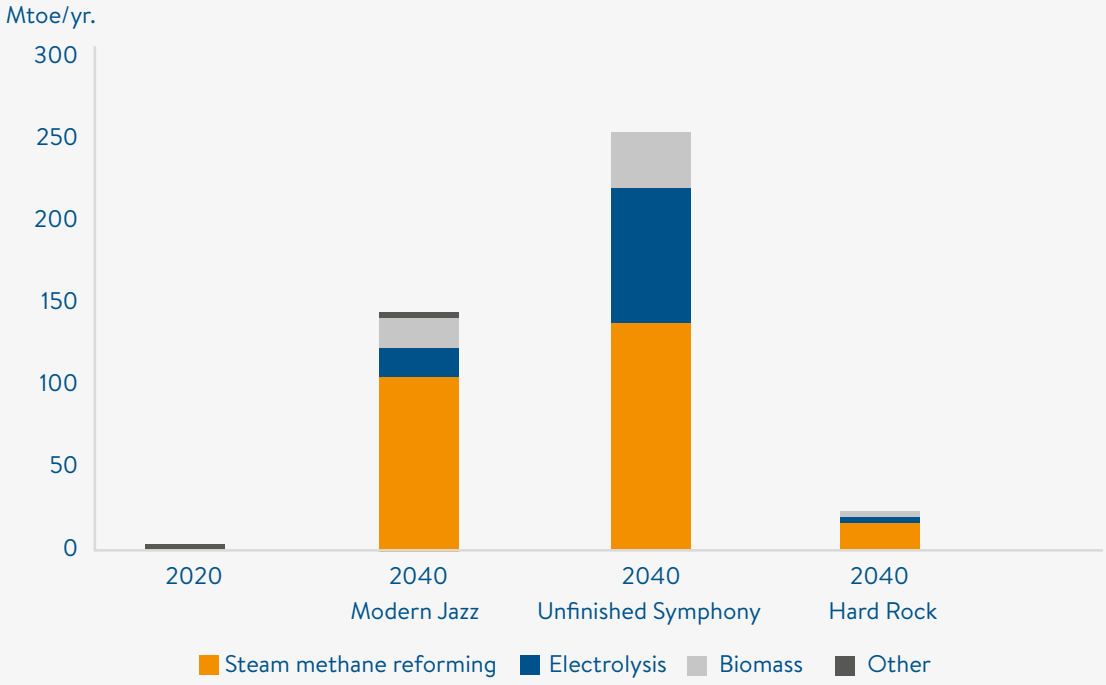
Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy, IEA WEI 2016

From 2020 to 2040, installed power generation capacity increases by 2 TW in **Hard Rock,** 4 TW in **Modern Jazz** and over 6 TW in **Unfinished Symphony.** Thanks to falling costs of new installations and of storage, wind and solar capture the lion's share of this growth in all scenarios. Gas comes a distant second, particularly in **Hard Rock**, while nuclear grows marginally.

EMERGENCE OF NEW TECHNOLOGIES: HYDROGEN AND CCUS

By 2040, hydrogen makes a notable albeit minor entry into the energy mix. **Modern Jazz** creates a global excess in renewable power generation that paves the way for global power-to-X developments and the emergence of hydrogen as an energy carrier, first in the long-range transport sector and then for electricity and heat supply. The biggest strides for hydrogen are made in **Unfinished Symphony**, where hydrogen production for use in buildings and mobility hit around 2% of total final energy, largely in the transport sector in parts of highly industrialised Asia (Korea and Japan). In this scenario, around 2040, there is a tipping point after which the use of hydrogen in buildings and mobility begins to accelerate. Energy security concerns in **Hard Rock** lead to hydrogen as an energy carrier, but only for heating and electricity supply as the transport sector remains dependent on fossil and biogenic liquids.

Figure 18. Global Hydrogen Production for Use in Buildings and Mobility, by Production Technology (Mtoe/yr.)



Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

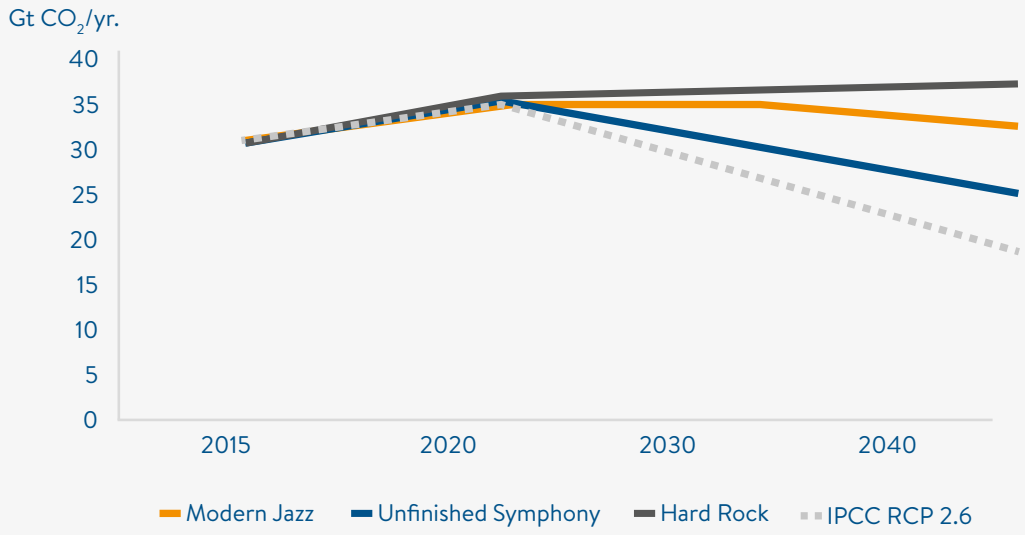
Innovation in carbon abatement technologies progresses in **Modern Jazz**, while CCUS flourishes in **Unfinished Symphony**, thanks to the essential support of carbon-pricing mechanisms, but fails to take off in **Hard Rock**. In **Unfinished Symphony**, CCUS hits a tipping point around 2040, after which there is exponential growth in generation with CCUS. In power generation it remains marginal, with a maximum of only 1.2% of global power generation capacity. In industrial processes CCUS begins to take off in 2030 with several full-scale commercial projects deployed in **Modern Jazz** and significantly more in **Unfinished Symphony**. Overall, CCUS deployment in Modern Jazz is delayed by more than a decade compared to deployment in **Unfinished Symphony**.

IMPLICATIONS FOR CARBON AND CLIMATE

The analyses above demonstrate the wide variations in outcomes for energy demand and supply mix across the three global energy scenarios. The respective implications for climate change are that none of these scenarios meet the "well below 2°C target" in the Paris Agreement. **Unfinished Symphony** is on an emissions reduction trajectory that would achieve a global temperature increase (to 2100) of just above 2 degrees, missing the UNFCCC Paris agreement target date by around 10 years. **Modern Jazz** limits the global temperature increase to 2.5 degrees, while Hard Rock sits higher still at slightly above 3 degrees.

With respect to CO_2 emissions, **Unfinished Symphony** achieves a compound annual reduction of 1.1% from 2020 to 2040. **Modern Jazz** achieves a 0.06% compound annual reduction to 2040, while **Hard Rock** experiences a compound annual increase of 0.6% to 2040

Figure 19. Global Carbon Emissions (Gt CO_2/yr.)



Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy
Note: The Council's scenario emissions forecasts do not include emissions from non-energy industrial uses and from land-use. The IPCC RCP 2.6 scenario presented represents the median of the IPCC AR5 data from within the 2.6 CO_2 equivalent band (430-480ppm).

Economic growth is strongest in **Modern Jazz**, while the progression of action on climate is most developed in **Unfinished Symphony**. However, society and stakeholders appear fated to navigate between two sets of priorities with, for the time being, notably different outcomes. **Hard Rock,** on the other hand, falls very short on both accounts.

PART THREE |

Using Scenarios

“THE FISH IS THE LAST TO KNOW IT SWIMS IN WATER”

–CHINESE PROVERB

Using the World Energy Scenarios as a starting point, members have developed regional scenarios and national scenarios following the same archetype story logic and enriching the narratives with regional and national drivers of change.

There are different ways to make effective use of world, regional and national energy scenarios, depending on purposes and users. This section describes four approaches that have been co-developed by members of the Council to use scenarios in a drive to impact and thereby realise their return on investment in developing a set of common-ground scenarios.

1 IMPACTFUL STRATEGIC CONVERSATIONS – USING SCENARIOS TO CLARIFY STRATEGIC CHOICES AND IDENTIFY NEW AND BETTER OPTIONS FOR ACTION

Plausibility-based scenarios provide a platform to open up a safe space for disagreement that facilitates strategic knowledge exchange improve the understanding of systemic interdependencies and enables new shared learnings in leadership dialogue. As opposed to simply discussing a report, energy leaders can use a set of scenarios to engage in dialogue with each other. A scenario-based conversation enables different perspectives of the future to be considered and contrasted and, in turn, can help improve the quality of strategic judgement. A set of scenarios can also be used as a decision-support tool to stress test an existing strategy and/or design new options for action.

The World Energy Scenarios 2019 can be effectively combined with the Council's World Energy Issues Monitor to provide a more objective starting point for opening up the leadership dialogue. The Issues Monitor is an annual global energy leaders survey that identifies leadership perspectives on key action priorities and critical uncertainties.

EXAMPLE OF PROCESS STEPS FOR USING SCENARIOS FOR IMPACTFUL STRATEGIC CONVERSATION

Step 1. Set the scene – key challenges

- Discuss as icebreaker activity: What is the energy transition challenge that keeps you awake at night?
- Present and briefly discuss findings from the World Energy Issues Monitor.

Step 2. Introduce the World Energy Scenarios

- Present the scenarios video.
- Vote: Which scenario are we least prepared for and why?
- Discuss the outcome of the vote.

Step 3. Explore new threats and opportunities

- Explore the new threats and opportunities emerging in each scenario.
- Discuss strengths and weaknesses of the energy system in each scenario.

Step 4. Design new options

- Identify actions that help combine strengths and opportunities and avoid weaknesses and threats. Prioritise options.

Step 5. Close with a question

- What have we learned?

2 INTEGRATED POLICY PATHFINDING

One way plausibility-based scenarios differ from model-based forecasting and conditional projections is that they focus on the wider context in which the energy system is evolving. The scenarios describe what might happen, rather than what policy makers expect or think should happen. These scenarios can be used to stress test the "baseline scenario" that is often used in policy analysis.

The World Energy Trilemma Index is another tool developed and used by members of the Council. It provides an objective assessment of national policy performance across three key dimensions of successful energy transition management – energy security, energy equity and affordability, and environmental sustainability. In addition to a comparative ranking of overall scores, the Trilemma Index shows trends in national policy performance on each of the three dimensions over the last two decades.

A forward extrapolation of national policy performance allows the development of a business-as-usual baseline that can be used to identify new alternative policy options for achieving the underlying goals featured in each scenario.

EXAMPLE OF EVENT-BASED POLICY GAMING DESIGN

Step 1. Analyse the situation

- Present the World Energy Policy Trilemma Report 2019 – national assessment.
- Discuss the real index and projected trajectory.

Step 2. Identify the gap

- Discuss and clarify the gap between the expected projection and the strategic direction or national vision.

Step 3. Develop new policy options to close the gap

- Present the World Energy Scenarios.
- Discuss new policy options that help could close the gap between the projected and desired future in each of the three scenarios. Identify which other policy domains need to be engaged in progressing new options.

Step 4. Create new cross-sectoral strategies

- Design a team-based competition to create cross-sectoral winning strategies – that is, the combination and sequencing of options that would deliver greatest value for lowest overall costs and best fit to society.

Step 5. Build a new strategy

- Using the new cross-sectoral strategies, test and enhance the national vision.

3 TRANSLATING VISION INTO ACTION

A vision is a normative description of an imagined future (preferred or to be avoided) that reflects shared values and motivates a change in action. To avoid unrealistic dreaming, it is necessary to tether a vision to reality. Translating a vision into actionable policies can be achieved through a process of back-casting from future to present to identify strategic priorities, goals and indicators that are relevant to designing a robust policy pathway and tracking and measuring progress.

Exploring how the goals are linked and interact with each other can lead to the discovery of new cross-cutting solution spaces that can used to enhance policy cohesion and to design new sector-coupling policies. The implementation of innovative, integrated policy options can be complemented by agile approaches that encourage continuous learning and adaptation in the journey to achieve the vision.

4 RE-DESIGNING ENERGY BUSINESSES

Energy companies, facing competition from beyond the energy sector, are developing new business models and using rapid, design-led, action-learning cycles to bring new products and services to the market that are designed to meet a specific consumer need or aspiration. The designers test and refine their initial ideas through simulated experiences and real-world use, making improvements and learning through failure, as well as what works.

For many decades, energy has been treated as an essential service rather than a consumer product or service and has been heavily protected through regulation. But the emergence of the energy prosumer and the emergence of a consumer-centric energy system emphasises the need to rethink the role of innovation in energy transition – and the new business opportunities the energy transition offers.

By combining design futures and scenario thinking approaches, companies can better anticipate fast-emerging new business ecosystems and explore the implications for business model innovation. They can, in effect, “design for disruption.”

PART FOUR |

Designing for Disruptions

“THE FUTURE CANNOT BE PREDICTED, BUT FUTURES CAN BE INVENTED”

– DENNIS GABOR

Managing a successful global energy transition – one that secures the benefits of reliable, affordable and sustainable energy for all – is challenging. If not handled well, this transition can pose an existential threat to industry participants and society.

Today's energy systems are being disrupted by rapid advances in the cost and capability of technology, new business models, policy changes and shifts in societal behaviours. Sectors are converging, new ones are emerging, and value is shifting across and out of industries. Incumbent players are looking to re-invent themselves, and non-traditional players are entering the fray.

A stark example of such disruption is the coal industry, where although demand over the last ten years has remained broadly flat, major policy and societal changes have resulted in significant value leaving the industry. The power sector is also undergoing disruption as value shifts into new ways of generation and to consumer-centred energy services (including "smart everything"). In such a world, traditional sector capabilities may have limited application, and new platforms by technology start-ups can rapidly enter the industry.

The energy industry is not immune to such disruption and must pivot in response. This is a complex undertaking with non-linear implications. For example, reduction in energy consumption and emissions per capita through efficiency improvement or cleaner fuels is offset by higher miles travelled per capita due to lower cost and accessibility of autonomous and shared mobility services. Traditional forecast models are not equipped to incorporate such combinatory developments in technology, policy, business and society.

So how can energy leaders better prepare and equip their businesses for disruption-as-usual?
The answer lies in: (1) moving to a mindset of "disruption-as-usual;" (2) staying on top of emerging and future technology, policy and societal trends; (3) expanding know-how of and access to business ecosystems; (4) designing and understanding potential "Constellations of Disruptions" ("CoDs").

MOVING TO A MINDSET OF "DISRUPTION-AS-USUAL"

Disruption is not a new experience in the business world. Yet there are many examples of companies and industries that have not responded quickly enough to change and no longer exist.

Embracing disruption requires innovation at the centre of the new energy system – and innovators will reap disproportionate rewards. Leading players need to adopt a mindset and culture of "disruption-as-usual" to take advantage of these new opportunities.

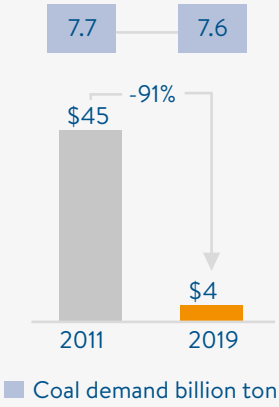
DISRUPTION IN COAL AND OIL AND GAS (OFES) INDUSTRIES

The coal and, recently, the upstream oil and gas sector are undergoing profound disruption as a result of technology-led and often policy-supported innovation, with incumbent players struggling to find a long-term and viable pathway.

For example, in the oilfield services segment, while the market size has still grown, the over-supply of resources has additionally reduced the premium of new technology, lowering the entry barriers for independents who have commoditised technology and compressed margins.

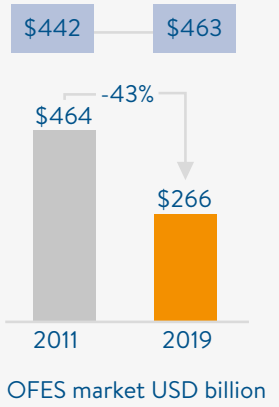
COAL INDUSTRY

Top 4 US coal producers market cap
USD billion



OIL AND GAS INDUSTRY

OFES global companies market cap
USD billion



STAYING ON TOP OF EMERGING AND FUTURE TECHNOLOGY AND SOCIETAL TRENDS

We live in an era of rapid technological innovation, changing market conditions, increasing regulatory intervention and, at times, immense geopolitical volatility. Every industry participant must have a pulse on what is happening in a wide range of technologies and in relation to societal trends based on how consumers intend to live, work and spend. Following these trends provides building blocks for identifying and pre-empting game-changing shifts in the energy markets.

Take, for instance, the shale revolution in North America. Many of the energy majors missed the combinatorial impact of emerging trends in hydraulic fracturing, horizontal drilling and water management. As a result, the majors fell behind and are having to pay (and in most cases overpay) billions to catch up with the industry. Winners were the small and niche independents who spotted the technological advantage of combining these technologies early and were able to work with an ecosystem of different partners to drive the shale revolution that has reshaped the industry.

EXPANDING KNOWLEDGE OF AND ACCESS TO DIVERSE BUSINESS ECOSYSTEMS

Ultimately, the pace and breadth of innovations means no one entity can access, develop, utilise or invest in the range of opportunities that are available or that can collectively shape a targeted outcome.

By bringing together multiple players - in effect forming an ecosystem of participants with common objectives, existing value chains can be disrupted and new sources of value scaled rapidly. This is a new kind

of horizontal and collaborative innovation that has the potential to reshape competitiveness by reducing cost by 40%. Leaders pursuing disruptive growth through an ecosystem initiative must make the right plays, find the right partners and think outside of traditional boundaries.

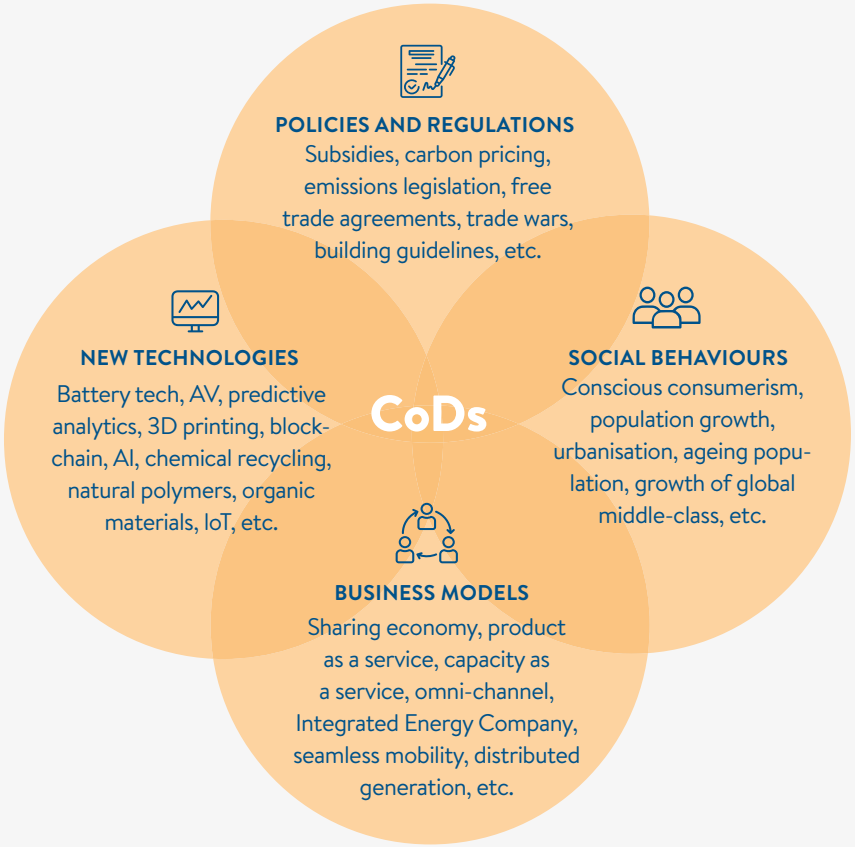
DESIGNING CONSTELLATION OF DISRUPTIONS

The CoDs refers to groupings of trends that when combined provide new ways of understanding the combinatorial effect of technology, social, business and policy trends. CoDs can enable new ecosystem leaders to identify how best to capture emerging and shifting value pools by pushing the boundaries beyond those of the traditional energy sector.

CONSTELLATION OF DISRUPTIONS DEFINED

CONSTELLATION OF DISRUPTIONS

A collection of disruptions that, at their intersection, yield game-changing shifts in the way energy markets operate.



The CoDs approach can be used not only to understand the disruptions characterised in the scenarios, but also to identify combinations of elements that could de-rail them. These combinations are often missed, and the exponential impact across the technology, policy, consumer behaviour and business model vectors are often grossly underestimated.

ADVANCING CONSTELLATION OF DISRUPTIONS

At its heart, the CoDs approach seeks to realise fast-emerging value growth opportunities by helping leaders navigate an uncertain world in a structured way. Traditional global energy modelling systematically fails to incorporate the combinatorial effects of innovations. with CoDs tool, the user in effect, removes this shortcoming somewhat top-down and makes a measured judgement on which disruptions could yield material combinatorial effects on the sector at hand. Once the disruptions of interest and their relationships have been explored, this judgement can then be taken forward into a formal modelling exercise.

Through an immersion in the scenario content and an application of the CoDs tool leaders can begin to identify where disruption-driven opportunities may arise and what with what implications they might have for the energy sector.

The Council, Accenture Strategy and The Dock (Accenture's Global Centre for Innovation) have co-designed a toolkit for exploring the Constellation of Disruptions concept through an engaging and immersive experience. At the 24th World Energy Congress in Abu-Dhabi in September 2019, the Council, Accenture Strategy and The Dock will be convening 70 to 80 CEOs in a "Design for Disruption" workshop, taking them through a series of exercises to explore the CoDs concept and to use it to uncover pockets of disruptive innovation.

Reflections for Industry Leaders

REFLECTIONS FOR INDUSTRY LEADERS

Updating of the scenarios has confirmed the unpredictable uncertainties facing energy players as they prepare for the coming decades and think through their strategic options. Clarifying complexity using scenario thinking yields seven key takeaways for energy leaders.

1 PEAK VALUE – VALUE CREATION IS SHIFTING FROM BEING COMMODITY-CENTRIC TO CUSTOMER-CENTRIC

In all three scenarios, the energy world is shifting from a supply-side driven system – shaped by the availability and price dynamics of commodities – to one where the end customer has much greater decision power on which sources of energy and which players will win. With peak demand for fossil fuels expected to occur in the coming decades as a result of declining energy consumption per capita and an accelerating supply of renewable energy, oil and gas companies and major resource holders are facing a new phenomenon of "peak value" and the associated challenge of managing stranded assets. For example, coal players have already experienced a peak value effect, with the four largest US companies having lost nearly 90% of their value from 2011 to 2018. Some parts of the oil and gas business ecosystem, such as oilfield services, are already exposed to this dynamic, with valuation reductions exceeding 70% for the largest players.

At the same time power over value capture is rapidly moving closer to end-consumers. Energy solutions and offerings are rapidly diversifying, driven by innovations in technology, service and business models, the entry of new players able to disrupt traditional offerings, and evolving policies and incentives supporting cleaner and more efficient energy consumption. In turn, consumers are becoming more astute and selective in their energy choices. Industry participants will have to become more customer-centric to capture new demand-side value creation opportunities and to optimise decisions that create value by better matching supply with instantaneous demand for specific applications.

2 STRATEGIC CHOICES ARE GROWING AS THE POTENTIAL RAMIFICATIONS OF DISRUPTIONS EXPAND

The scenarios highlight how system-level disruption occurs from the interaction of technology, societal, business model and policy factors. In turn, these disruptions are having multiple ramifications that impact market structure, economics, consumer behaviour and national and international policies and regulations. Material impacts are occurring at many levels, from evolutions in primary energy mix to product designs that embed greater sustainability considerations to changing consumer influence on new product uptake or rejection, often amplified by the power of social media.

Energy leaders, therefore, must contend with expanding strategic choices in a more complex, fast-evolving industry landscape with more fluid pools of value and a more diverse network of players and competitors.

3 DIGITALISATION WILL OFFER OPPORTUNITIES IN ADDITION TO IMPROVING ECONOMICS

Digitalisation is already at the heart of many ongoing transformation programs in different energy sectors, with a potential value upside of more than a trillion dollars. Digitalisation can improve the financial performance of energy companies by enabling movement beyond operational performance improvements, such as cost savings, to enhanced customer management leading to new value creation and capture.

Digitalisation can play a key role in managing climate change priorities and enabling socially affordable energy transitions. For example, it can manage fugitive methane emissions and support

step-change energy efficiency improvements. Digitalisation can also play a pivotal and wider role in measuring and reducing the carbon footprint of other industrial and services activities, enabling greater stability of increasingly interdependent infrastructure systems, enhancing cybersecurity and providing end-consumers with the means to minimise their environmental footprint.

4 INFRASTRUCTURE NEEDS SHOULD NOT BE UNDERESTIMATED

Infrastructure emerges in all three scenarios as a key determinant of the pace, breadth and direction of change. It impacts the extent to which diverse sources and vectors of energy can be integrated into a manageable system, the health of regionally integrated solutions, the reliability and security of the energy system and the ability of new players to enter the market and provide new solutions and offerings. For example, in the mobility transition, the pace of electrification and adoption of alternative fuels such as hydrogen will be significantly influenced by new developments in charging and fuelling infrastructures, not just by improvements in underlying technologies, such as batteries and electrolysis. In a similar way, the rapid drop in costs of wind and solar power has been underpinned by a massive ramp-up in generation infrastructure. Policies, both national and international, will have a major role to play in enabling, incentivising and accelerating the mobilisation of the required investments to maintain, upgrade and build the needed infrastructure across all major sectors, particularly in power and transportation.

5 DRIVE TO THRIVE IS A COLLABORATIVE STRATEGIC IMPERATIVE

Disruptive impacts are happening faster in both the uptake of new solutions and value propositions and the abandonment of old ones. This report has highlighted the urgency for business and policy leaders to shift their strategic mindset from linear improvements and technology bets to the drive to thrive using networked strategies and co-creation of new constellations of disruptions. Energy leaders must therefore invest more effort in creating, assessing and testing systemic ideas. They must also open up space for consideration of new and different possibilities, regularly revisit their assumptions and bridge multiple innovation horizons rather than simply rely on better long-term forecasting.

6 RAISING ONE'S GAME IS VITAL TO ACHIEVE CLIMATE CHANGE AMBITIONS

The stark reality is that none of these plausibility-based scenarios achieves the goal of limiting global warming to a global average temperature rise of less than 2°C. This report stresses the positive network benefits of international cooperation and integrated policies assumed in the Unfinished Symphony type scenario. But even this scenario falls short of reaching the target. Government and business leaders must therefore raise their game to accelerate and amplify the entire range of existing technology improvements and new solutions already in development and encourage wider innovation across the entire economic and societal landscape.

7 ENERGY TRANSITION WILL BE A SOURCE OF VOLUME AND VALUE GROWTH

The transition to reliable, affordable and sustainable energy supply and services creates a new imperative in linking profitability and social license to operate. It is opening the door for participants, incumbent and non-traditional, to pivot between maintaining the core and creating new value. There are business opportunities in how energy is produced (renewables, new fuels, distributed generation), how energy is consumed (smart systems, sustainable products) and how energy is managed (efficiency, storage). In fact, there will be almost USD 100 trillion invested in the energy system through 2040, and substantially more and different players are staking a share of that opportunity. The innovators and agile participants will be best placed to capture a large share of the value and volume in this new landscape.

ANNEX |

CHAPTER CONTENTS

MIDDLE EAST AND NORTH AFRICA

REGIONAL LANDSCAPE – CHALLENGES AND OPPORTUNITIES

The Middle East and North Africa (MENA) region is experiencing **rapid population growth** accompanied by a rise in social expectations and urbanisation. Young people under the age of 24 make up more than half the population in the region today and will be the agents of change as the energy sector is modernised and digitalised.

Energy demand growth in the MENA region is among the highest in the world after China and India. While some countries like the UAE have invested heavily in renewable energy, most of the oil-producing countries in the region rely on **oil and gas** to meet domestic demand and for export revenues, exposing the Middle East's oil and gas producers to price volatility. Efforts to diversify the economy and lessen reliance on fossil fuel imports are uneven across the region.

Grid integration is seen as an important enabler of successful energy transition for the region. Linkages of gas and electricity grids across the MENA are in early stages of development and are hindered by regional tensions and border disputes as well as an uneven price structure across the region resulting from energy subsidies.

The East Mediterranean could become an important **gas hub** as a result of recent large discoveries of natural gas deposits. Disputes over maritime borders among a number of countries in the region need to be resolved before a functional hub can be developed. This would help in de-carbonisation efforts as gas could displace fuel and crude oil in electricity generation.

The MENA region with its arid deserts is very susceptible to climate change. Saudi Arabia recently experienced unexplained power cuts in the north and in the south due to what are believed to be extreme **weather** phenomena. Any further rise in temperature would have an impact on urban life, where the use of air conditioners for cooling would soar to unsustainable levels.

Water resources per capita in the region are scarce, and the expected increase in demand for water as well as rising temperatures all add stress on water supply, making the **water-energy nexus** a critical concern for the region. Desalination is an energy-intensive process and will need to be adapted to the use of more renewable energy technologies such as solar. Natural gas could displace some of the more polluting fuels used in desalination processes, but more innovative solutions are required.

REGIONAL PATHWAYS TO 2040 – KEY HIGHLIGHTS

Modern Jazz

In the digital and innovative **Modern Jazz** world, the MENA region doesn't follow a "universal" regional energy strategy or development model. The focus in some countries is on creating a robust solar-belt industry, for example, while others concentrate on technological developments to accommodate the new hydrogen economy. Gas, solar energy, wind and hydropower make up a significant share of the energy mix in virtually all MENA countries. Surplus electricity and gas are traded at market value across borders, creating effective regional grids and an integrated economic bloc.

Although there is overall progress in diversifying energy systems, many hydrocarbon-based economies are struggling to generate revenues. In Saudi Arabia, some of the goals of the economic reform policies contained in Vision 2030 have been attained, resulting in a more balanced revenue stream and creating new jobs by enhancing the role of the private sector.

The region has introduced enabling policies that allow for greater entrepreneurship along with incentives for regional innovation ecosystems that enable businesses to seize new global opportunities quickly and effectively.

The free flow of people and goods is facilitated by fast-speed trains powered by clean energy and hyperloops connecting urban centres, the first of which is due to be in operation in the UAE by 2020. Hydrogen-powered cars and trucks along with electric vehicles are replacing combustion engines, reducing demand for gasoline. Oil and gas pipelines made redundant by the shift to cleaner energy are retrofitted to carry hydrogen.

Efforts to switch to clean energy for power generation, desalination, transport and energy-intensive manufacturing industries are applied across the region, with some more advanced than others. Blockchain and smart grids help to ensure an even and efficient distribution of electricity.

Regional and cross-regional coordination between countries like the UAE, which has taken a lead in developing solar and nuclear energy in the Gulf region, and Morocco in North Africa, which is also a leader in solar, wind and hydropower, is replicated elsewhere in the region. Iran, Iraq, Syria and Yemen are left behind as they have not recovered fully from decades of underinvestment, sanctions, conflict and social unrest.

In this scenario electrification grows to 23% by 2040, a 50% increase over the electrification rate in 2020. Wind and solar share in electricity generation increases significantly from just 4% to 20%. Gas continues to play an important role and accounts for 56% of electricity generation. Several countries in the region, among them the UAE and Saudi Arabia, turn to nuclear energy to meet electricity demand. The UAE leads the way with the first phase of its nuclear power plant due to come on line imminently, replacing natural gas, which is the dominant fuel used in power generation.

Unfinished Symphony

Unfinished Symphony is the story of the creation of regional coordinated strategy and action in response to fear of economic losses from weaker oil demand growth, which, in turn, results in lower oil exports and revenues. A greater awareness of climate change, the water stress nexus and the concern that several countries in the MENA region might miss their climate goals drive the development of new visions and the emergence of post-carbon strategies.

The economies that rely heavily on fossil fuels are exposed to boom-bust oil-price cycles that curb investment in infrastructure and social projects, leading to a bigger gap between rich and poor. However, a more integrated economic bloc allows for the transfer of technology from the more advanced, low-carbon economies, leading to regional balance.

Pressure on the state sector to provide economic stimulus declines as the private sector expands and takes on some responsibility for job creation in a region where unemployment is extremely high. An increase in private-public partnerships has achieved a more diverse economy and created jobs to absorb a young workforce in which women have a bigger role.

Digitalisation and regional price convergence help to achieve grid integration, resulting in stability and more efficient uses of electricity. Air quality improves as enhanced energy efficiency measures are applied and energy subsidies scrapped.

Trade flows increasingly head east as the decarbonised western economies are energy self-sufficient and less reliant on Middle Eastern oil and gas. China plays a more active role in defending vital trade routes East of Suez. Some technology transfer across the region allows the less advanced economies to decarbonise, but there are exceptions in those countries that did not adopt enabling policies in a timely manner.

Following the move away from fossil fuels, electricity in final energy demand increases to 26% by 2040, with the share of wind and solar generation reaching 30%. A wider use of CCUS has mitigated the environmental impact of oil and gas production by capturing CO_2, and measures have been adopted to reduce methane emissions. In this scenario, electricity generation from nuclear almost doubles in 10 years (2030 - 2040) in the MENA region, almost seven times more than in the **Modern Jazz** scenario and almost three times more than in **Hard Rock.**

Hard Rock

Hard Rock is a world of low trust and a search for community resilience. The economic reform programme has stalled as governments cut spending on capital projects to focus more on social spending to stave off potential unrest as geopolitical tensions persist. Oil and gas remain the mainstays of the economies of the oil-producing regions, making them vulnerable to market forces.

The creation of new regional grids and cross-border trade in electricity and gas provide better access within the region and beyond, with Egypt and Iraq expanding their gas production capacity to serve both the region and the European market.

Cross-border trade in turn provides a buffer against disruption within the MENA region and strengthens regional alliances, which are bound by economic rather than political imperatives. On the western flank of the MENA region, Morocco serves as a conduit for energy access to Africa, where it began to make inroads decades earlier, helping to lift hundreds of millions of Africans from energy poverty and allowing for clean cooking alternatives to replace biomass. It is also well positioned to supply clean energy to Europe.

Rising temperatures and extreme weather phenomena have made some areas in the MENA region uninhabitable while causing higher salinity in seawater, which has reduced the availability of fish and caused degradation of coastal areas. Climate change exacerbates a region-wide drought that has a devastating impact on countries that failed to adopt mitigation measures.

Digitalisation and smart grid solutions are introduced, but not evenly. Cyber threats increase, requiring

large investments in security to protect vulnerable systems. Energy security is threatened as regional tensions persist, and conflicts occur in cyberspace in this digitalised world.

Technologies are developed to remove CO_2 from oil and gas production and to use it for enhanced oil recovery, making fossil fuel attractive again. But subsequent breakthroughs in PV electricity storage mean that in areas with connected grids, there is enough capacity that oil and gas production is no longer needed in the power sector, though it continues to be used as feedstock for an expanded petrochemicals and chemicals industry.

Electricity sees moderate growth in final energy demand to only 16% by 2040. Gas displaces other fossil fuels and accounts for a 63% share in electricity generation.

LATIN AMERICA AND THE CARIBBEAN

REGIONAL LANDSCAPE – CHALLENGES AND OPPORTUNITIES

The Latin America and the Caribbean region (LAC) is going through a significant change in its energy mix by introducing new energy policies, making structural reforms and implementing regional integration initiatives that translate into making progress in meeting the UN's SDGs. Most of the region's inhabitants have **basic access** to electricity; however 3% of LAC's population (19 million people) still remains without electricity access[3], and there is room for improving quality of service and resilience of the power system.

During recent years, the region has experienced **slow economic growth** due to falling energy commodity and raw material prices. Political instability is also a matter of concern, which has resulted in **energy policy** uncertainty and therefore mixed signals to investors

LAC is digitising at a steady pace, with improved broadband infrastructure, a proliferation of e-services and over half of its citizens online. However, further innovation on the energy demand side will be required in order to pick up the pace of electrification of end-use energy services. The lack of digital skills will also need to be addressed.

The impact of **extreme weather events** continues to be a high priority for energy stakeholders. In a region where hydropower provides over 50% of electricity generation, the increase in intensity and frequency of droughts has impacted hydropower generation and caused unprecedented surges in fossil fuel-based generation.

Important progress in **regional energy integration** has been achieved mainly as a result of multilateral and sub-regional initiatives for electricity trade – for example, Central American Electrical Interconnection System (SIEPAC) in Central America, Andean electrical interconnection system (SINEA) and the southern cone interconnected system. However, power trades mostly remain at the bilateral level, and more integrated and dynamic multilateral exchanges are constrained by political, regulatory and ideological differences between countries.

The LAC region has a **diverse endowment of energy resources.** Oil exports are dominated by Brazil and Venezuela, the latter holding the world's largest proven oil reserves. However, the region's oil export potential has been falling during the last 10+ years. Gas production has a more varied set of producers. Argentina, Venezuela and Trinidad and Tobago dominated gas production for a number of decades, but now Bolivia, Brazil, Colombia and Peru have all become significant gas producers.

In the region, **renewables** continue to be a priority to improve energy security. With the exception of

[3] The IEA defines energy access as "a household having reliable and affordable access to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average."

hydropower, some countries are more advanced in terms of renewable energy as a share of installed power capacity: Uruguay (38%), Honduras (27%), Nicaragua (24%), Costa Rica (17%) and Chile (13%), among others.

Untapped **hydropower** potential also remains significant. However, large projects designed to exploit hydropower seem increasingly complicated due to social and environmental concerns about the impact of large reservoirs. Further, the realities of climate change causing shifts in the availability of runoff and the uptake of intermittent variable renewable energy (wind and solar) have led to an increase in demand for LNG as a source of power due to its reliability and flexibility.

REGIONAL PATHWAYS TO 2040 – KEY HIGHLIGHTS

Modern Jazz

In a **Modern Jazz** world, digitalisation and innovation are viewed as the critical elements for energy leaders in the LAC region, as companies need to adapt to an increasingly complex energy supply and demand chain. The use of smart energy technologies, greater digital connectivity and diverse energy storage options in the midstream lead to electrification of end-use sectors and to energy efficiency improvements.

In this market-dominated world, technology choices and developments are driven by competitiveness, cost and reliability. Markets give a stronger voice to consumers, while changing societal values drive behavioural shift to products and services that meet environmental and social compliance.

However, with greater digitalisation, the region struggles to handle unemployment due to the extensive application of automated processes. This leads to social unrest as traditional economic policies appear unable to accommodate fast-paced innovation.

The increased share of intermittent renewable energy sources in the power system creates new grid reliability, but also introduces new demand management challenges, especially making full use of the excess solar and wind production that could foster power-to-heat and power-to-hydrogen technologies. However, better demand-side management and storage and enhanced transmission and distribution infrastructure help to bring the required flexibility to the system.

The falling costs of new technologies and the growing electricity demand resulting from end-use electrification in industry, buildings and the transport sector lead to increased penetration by new market entrants. In addition, innovative financing models encourage the development of distributed energy systems that blur the lines between consumers and producers.

Although share of alternative energy sources, such as wind and solar, doubles to 13% of electricity generation by 2040, hydro still plays the major role, accounting for 47% of electricity production in 2040.

Unfinished Symphony

In **Unfinished Symphony**, the LAC region is shaped by an effective system of broad-ranging regional and international governance, including strong collective climate change policies and the regional integration of energy systems.

A critical mass of new solutions to address energy supply and demand and climate change emerges as cities take the lead and then progressively link up, leading LAC governments to introduce a diversity of

green measures in harmony with each other. In LAC, a large fraction of electricity is already produced by hydropower, so many LAC countries focus attention on decarbonising total final energy demand in the transport sector, especially where transport is the largest consumer of energy.

Regional integration happens at a fast pace, building on common goals. A milestone occurs when the HVDC link between Panama and Colombia is built, connecting the entire region from Mexico in the North to Argentina in the South. This integration is also reflected in regional climate targets involving low-emission energy systems and an integrated effort to comply with, and periodically increase, Nationally Determined Contributions (NDCs).

Swifter transition of power from one political leader or ruling party to the next leads to a more stable investment environment, especially where a consistent long-term energy strategy generates trust. In this world, investments are directed towards infrastructure for risk prevention and recovery systems that build greater system resilience to deal with climate threats to the water-energy-land nexus. A concerted effort to invest in digital skills and to encourage the uptake of business digitalisation in relation to renewable energy systems provides new employment opportunities, that, combined with socio-economic progress and overall job creation, reduce the threat of social unrest.

In **Unfinished Symphony**, energy policy plays a leading role in the rapid development of renewable energy sources. Regional cooperation enables an enhancement of infrastructure that creates dynamic resilience in response to climate change. The region also takes advantage of complementarities of variable renewable energy endowments, especially hydropower in some regions complementing wind and solar in others. The electricity share of final energy demand increases by one-third in two decades and reaches 23% by 2040. Hydro accounts for 53%, while in the same period, the share of wind and solar grows from only 7% to 18% by 2040.

Hard Rock

In **Hard Rock**, the LAC region experiences constant and radical political regime shifts, which impact the consistency of energy policy and overturn plans and processes started in previous regimes. Fragmentation in political and economic systems weakens regional and international governance, resulting in trade relationships driven by national economic and energy security concerns.

Vertically oriented and nationally owned energy companies dominate investments and trade in the energy system. However, limited regulatory reform allows for deployment of alternative energy led by private sector investments. Even though strong and stable energy markets is one of the major concerns in **Hard Rock**, market rules and structures and legal, financial and regulatory institutions fail to establish a competitive wholesale market that could provide the maximum possible benefits to consumers.

One reason for this failure is the lack of investment in energy infrastructure. Without a resilient energy system, the isolated efforts to mitigate the effects of climate change are ineffective. Facing the challenge of extreme weather events and hydropower generation uncertainty, some governments begin to develop gas-fired thermoelectric capacity and nuclear energy.

Governments attempt to deal with the increasing numbers of displaced people in order to avoid economic losses and major labour market shifts. While politicians and government planners try to design ways to reap the benefits the energy transition offers, their major concern is how to mitigate the unemployment that comes along with it.

Investment required for energy infrastructure remains centralised in **Hard Rock**, leading to centralised energy supply systems instead of distributed generation. Lower economic growth and reduced capacity

for electric transport infrastructure mean that fossil fuel vehicles dominate the sector, and the electric vehicle share is marginal.

In this world, electricity growth in final energy is constrained, reaching only 19% by 2040. Hydro continues to account for half of electricity generation (52%), while wind and solar increase moderately to 10% relative to the other two scenarios.

NORTH AMERICA

REGIONAL LANDSCAPE – CHALLENGES AND OPPORTUNITIES

North American countries have the most significant fossil energy resources in the world, both individually and collectively. A significant share of the GDP of each country is based on production, use and export of energy commodities, which help to sustain positive economic growth in the continent.

The region is characterised by **diverse policy directions** in relation to climate change commitments and innovation efforts at national, sub-national and municipal levels. The US decision to leave the Paris Agreement has created uncertainty in the North American energy sector. At the same time, however, states such as California, New York, Arizona and many others, have adopted more aggressive climate goals. In 2019 a few members of the Democratic party introduced an ambitious plan, the Green New Deal, which aimed to decarbonise the US economy while simultaneously creating jobs. However, as the Green New Deal has relatively little Congressional support, its implementation in the near future is uncertain.

In contrast to the US shift, Mexico has indicated that existing contracts stemming from its energy reforms will continue as planned, and if those contracts achieve the forecast oil production capacity, the government may consider pursuing new contracts. Canada, from a national perspective, is often more aligned with individual US states that support clean energy policies.

The North America energy sector is extensively integrated, with billions of dollars traded in oil and natural gas each year. However, the **energy trade relationship** among the three countries is undergoing important changes. While continental energy trade is helping to promote economic growth in all three countries, it also prompts debates on the environmental impacts of energy resource development and the expansion of energy infrastructure.

The US-initiated **renegotiation of the North American Free Trade Agreement** has resulted in a yet-to-be-ratified new agreement that does not currently appear to pose significant challenges to the energy sector. Current and potential future tariffs on materials important to the energy sector, however, such as steel and aluminium, remain a source of concern.

In recent years, the US has become the world's top oil producer, while Canada, with some of the world's largest reserves, has increased its oil output substantially. Technological advancements in **unconventional oil and gas development** are leading to reduced US dependence on energy imports, thus increasing its energy security. Canada has traditionally been a net exporter of all forms of energy, which underscores its own perennial and persistent energy security.

The US has taken significant steps to switch from coal to natural gas in electricity generation. **Solar** and **wind** are increasingly attractive due to technological improvements, reduction in equipment cost and economies of scale. Led by investments in wind farms and solar arrays, clean-energy investment in the US rose 12% to a record high of USD 64.2 billion in 2018. Mexico has also shown important investments

in solar and wind farms, after obtaining very competitive electricity costs from the auctions celebrated in 2016 and 2017. While the investments in solar and wind units are mostly private, the public utilities continue to invest in combined cycle units and less in hydroelectric and geothermal units.

The **shift away from coal** is expected to continue, accompanied by a growing effort to manage the coal industry's decline and to mitigate the impact of retiring coal plants in a way that benefits asset owners, workers and communities. For instance, Canada launched the Coal Transition Initiative in 2018 with one of the objectives aimed at creating cleaner jobs and developing workforce skills and new business opportunities for local communities. Canada's largest province, Ontario, recently completed its government policy-driven shutdown of coal-fired electricity generation and is the largest jurisdiction in the world to have successfully accomplished such an objective to date.

The regional capacity for innovation is a cornerstone for energy transition. With its vibrant innovation culture, entrepreneurial spirit fuelled by many clean-tech incubators and highly skilled workforce, North America offers numerous investment opportunities.

REGIONAL PATHWAYS TO 2040 – KEY HIGHLIGHTS

Modern Jazz

In a world of increasing speed of innovation and digital disruption, North America develops promising new energy technologies. Projects such as the 30-megawatt Block Island Wind Farm in the US are being replicated across the region.

Unconventional non-energy actors, such as technology companies, enter the market, making a significant impact on the energy system. Incumbents are increasingly diversifying their businesses to tap into new opportunities, too. For instance, traditional vertically integrated utilities are restructuring their business models to integrate distributed energy generation and building cross-sector partnerships in transportation and the heating industry, making the existing system more flexible.

Many states and provinces adopt clean energy requirements that not only drive the development of renewable energy, but also encourage oil and gas companies to begin developing renewable projects themselves. This is often supported by long-term, 15-to-20-year power purchase agreements with utilities.

The rise of "prosumerism" is changing the relationship between energy producers and their customers. Public sentiment sets some cities, states, provinces and countries apart in their pursuit of a low-emissions economy. The state government in California supports innovative initiatives to establish a decarbonised energy system. In Canada, Quebec and Manitoba, with nearly 100% non-carbon emitting electricity systems based on their strength in hydropower, are turning their attention to the transportation sector to reduce their emissions even further.

Research and development in natural gas exploration lead to continued rapid growth of unconventional gas supplies, mostly in the US and Canada. The increased adoption of electricity and natural gas in transportation offers opportunities for significant emissions reductions.

With increasing digitalisation, cyber threats are among the top concerns for energy leaders, especially in regions with high infrastructure maturity like North America.

As a result of increasing technology development, electricity reaches 27% in final energy demand by 2040, with solar and wind more than double their total share to 19%. The role of natural gas shifts as the number of coal retirements increases and renewables become a larger part of the energy mix. Gas share in

electricity generation grows from 32% in 2020 to 44% by 2040. Nuclear and hydro account for 13% and 12% respectively of the electricity generation mix.

Unfinished Symphony

In this world, tensions between national and sub-national policies are addressed through greater alignment and harmonisation across environmental and climate change regulations and policies among Canada and the US, and increasingly, Mexico, as well as a movement from a predominantly climate change agenda to a broader affordability focus.

Consumers begin to demand back-up options in the case of climate events, natural catastrophes and cyber security breaches. These demands lead to an increase not just in renewable energy but also in micro-grids for residential, industrial and commercial consumers. Low-emitting, large-scale baseload generation continues to be important, however.

Increasing awareness of the cost of climate change inaction pushes governments to set ambitious greenhouse gas emissions-reduction targets. New York and all six New England states commit to lower CO_2 emissions by 80% below 1990 levels by the year 2050. Efforts to achieve ambitious targets across the region include decarbonising electricity generation, transportation and heating. However, the transition to clean energy poses social and economic challenges, both for fossil fuel producers and for resource-based communities.

Regional integration enables a more resilient response to a changing climate. Larger-scale integrated efforts like the Pan-Canadian Framework on Clean Growth and Climate Change prove useful. Greater integration in Mexico allows hydro projects to play a role as an inexpensive, low-emissions storage solution with dependable capacity to balance the intermittency of wind and solar generation. Canada and the US benefit from this approach individually and in partnership with each other.

Rapid development of the continent's rich endowment of wind, solar and small- and large-scale hydro resources and the replacement of coal and fuel oil for power generation enable the region to expand clean continental-scale electricity generation. As a result, electricity share in final energy demand reaches 31% by 2040, a 50% increase over electrification rate in 2020, with gas accounting for 37% of the total electricity generation by 2040. Nuclear continues to play an important role, accounting for 14%. Solar and wind increase their share by less than three times after 2020, reaching 24% by 2040.

Hard Rock

In **Hard Rock**, fragmentation persists, both in the region and within countries. The constitutionally divided responsibility for energy matters and frequent shifts in policy direction continue to hinder progress of energy and climate policies in North America, and a clear continental consensus remains elusive.

A disconnected, opposing approach towards energy policy often exists between federal, state and local governments. For example, some states in the US have vertically integrated utilities, while other states have restructured to unbundle electricity generation from electricity distribution.

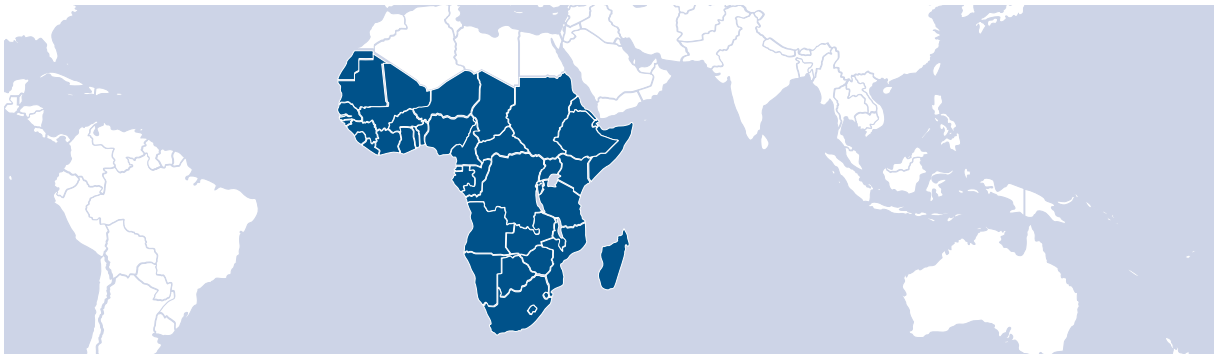
Energy prices become an issue. Remote Canadian communities face higher prices due to the transportation cost for supplying fuel for power generation. In the US, a growing number of American consumers are having difficulty paying their energy bills and are being disconnected despite nearly universal access.

New trade barriers create uncertainty for energy leaders despite the resource abundance that has led to the US becoming the world's largest gas producer and a major exporter of crude oil and liquified natural gas. Mexico continues to focus on reducing its energy imports. Firms like PEMEX increase their expenditure in Exploration and Production to reduce the natural gas import from the US.

Innovation brings positive outcomes on a more local level. Some areas of Canada invest in nuclear technologies such as Small Modular Reactors (SMRs), and both the US and Canada invest in nuclear fusion. Mexico looks at further development of geothermal energy for power generation. By mandate of the national utility Federal Electricity Commission, private investors are building substantial natural gas transportation capacity to take advantage of low natural gas prices in the US and to reduce the cost of electricity for consumers.

In this world the electrification rate doesn't change much, reaching only 22% in 2040, while the share of wind and solar in electricity generation increases doubles to 15%. Gas accounts for 40% in the electricity generation mix, while nuclear and hydro account for 16% and 14% respectively.

SUB-SAHARAN AFRICA



REGIONAL LANDSCAPE – CHALLENGES AND OPPORTUNITIES

Sub-Saharan Africa is represented by 46 countries that differ from each other in many ways. Such diversity results in **different paths of development and transitions.**

With more than 60% of its population under the age of 25, Sub-Saharan Africa is the **world's youngest region.** A common characteristic across the region is low levels of education. 27% of the world's illiterate people live in Sub-Saharan Africa, and 17 countries still have literacy rates of 50% and below, with youth literacy rates being the lowest of any region (75.3%).

Despite a large **endowment of energy resources,** including fossil fuels, hydropower and rich uranium resources in some countries, the energy sector remains poorly developed in terms of access to modern energy services and sustainable energy supply.

Around 600 million people **lack electricity,** and 890 million people cook with traditional fuels. Thirteen countries in Sub-Saharan Africa have less than 25% energy access, compared to only one in Asia.

Regional integration and power interconnection are among the key priorities for the region, as it attempts to enhance equity, affordability and energy sustainability in a fast-shifting context. Integration also helps to address many of the challenges arising from the **rapidly growing, young population.** Many new and better jobs are needed, which, in turn, require improved new skill-sets.

Intra-African trade, promoted by the recent creation of the African Continental Free Trade Area (AfCFTA), could provide a regional market that would absorb a significant portion of locally made products. In addition, increased local industrialisation could result in inclusive beneficiation of local resources, which means increasing domestic use of resources for livelihood and living standards.

The region continues to be **vulnerable to extreme weather events.** The region's high levels of poverty and limited adaptation capabilities affect electricity generation and grid facilities.

The **energy-water-food nexus** plays a significant role in the region. Water is a critical resource for food and energy production, impacting the stability of energy supply and demand.

At the same time, the region is witnessing a vast technology revolution, with more companies ready to innovate. Almost all African countries are promoting renewable energy, particularly solar and wind, supported by improved efficiencies and the falling cost of technologies.

Vast opportunities in the region are attracting more sustainable investments, including FDI, which, in 2018, reached $32 billion, a 13% rise in comparison to the previous year. China and India have increased their presence in the continent.

REGIONAL PATHWAYS TO 2040 – KEY HIGHLIGHTS

Modern Jazz

Modern Jazz is a competitive market landscape that drives higher efficiency, innovation, open access to information and deployment of new technologies.

Investors look at the region as a space for innovation and an opportunity to change people's lives. China plays a unique role in developing African energy infrastructure through the establishment of small and medium-sized enterprises.

Digital technologies allow forward-looking companies to innovate and address the increasing demand for energy services. However, the region's education gap and shortages of digital talent create a barrier to growth for technology firms.

While regional development is mainly driven by the market, governments still play a role in creating an enabling environment and incentives for entrepreneurs who use digitalisation to create innovative and new businesses. Pan African financial institutions serve as a guarantor for entrepreneurs to develop and market new energy technologies.

Regional integration is an important priority for Sub-Saharan Africa, but growth and new development tend to be country-focused. As a result, different countries move forward at different rates, determined by the enabling environment that is created and the extent to which domestic resources are processed and used locally.

Countries in the region promote decentralised grids (including micro-grids for off-grid and grid-connected electricity) and adopt innovative and disruptive digital technologies (pay-as-you-go solar power systems and product bundles) to address an infrastructure gap.

Distributed systems together with development of storage facilities and affordable electricity tariffs boost access to modern energy services by bringing electricity to a greater proportion of the population.

Technology transfer and innovation mean that Sub-Saharan Africa can skip carbon-intensive phases of development. Utilities are forced to adapt to changing demand patterns and adopt new business models.

The regional effort doubles the electrification rate from to 18% by 2040, with a significant shift towards renewables in electricity generation. Solar and wind share increases fivefold from 2020 and reaches 19% in 2040.

Unfinished Symphony

In **Unfinished Symphony** Sub-Saharan Africa increases international collaboration both with developed regions and with emerging countries like China and India. Long-term contracts with these partners help the region deal with volatile commodity prices.

Manufacturing, industrialisation and resource processing are developed on a sub-regional basis rather than on a country level. Given the complex geography and vastness of the region, Pan-African cooperation is challenging – but still develops significantly by 2040.

Established policy and legislative frameworks help to attract both local and foreign investments in regional projects. More inclusive growth is achieved through job creation programs designed especially for the young.

Regional integration is shaped by the presence of strong regional governance bodies and institutions such as African Union Commission (AUC), African Development Bank (AfDB), the New Partnership for Africa's Development (NEPAD) and others, which work together to produce structural policy reforms. These reforms make the energy industry more efficient, and as a result, more affordable and accessible. Strong international partnerships and global-level agreements attract funds for climate change mitigation and adaptation.

Electricity sector reforms and policies supporting refurbished and new infrastructure increase access to renewables. An improved quality of life helps support substantial employment and technology transfer as well.

Electricity interconnection gains momentum through the development and expansion of intra-African trade and substantial progress on Programme for Infrastructure Development in Africa (PIDA) interconnection projects. These two factors positively influence Africa's industrial development and foster the build-out of substantial infrastructure in the region, helping to create resilience in response to extreme weather events.

Greater access to public and private financing facilitates the modernisation of the supply infrastructure and the development of renewable energy. By 2040 electricity in final energy reaches 19%, while solar and wind share increases to 27%.

Hard Rock

As export-oriented growth opportunities for the region decline, there is greater focus on energy security and resources development for domestic consumption, local industries and agriculture, with emphasis on more efficiency and resiliency.

As unequal resource allocation persists, governments struggle to address major development hindrances, such as food shortages and a low level of energy access, especially in rural areas.

In the absence of international cooperation and regional integration, funding for climate adaptation and mitigation becomes difficult. The region is exposed to the challenges of the energy-water-food nexus.

Political instability and an unreliable business environment significantly reduce FDI and external technology transfer. As a result, many rural areas lack reliable electricity access.

This, in turn, means that adequate jobs are not created at the needed rate to absorb the growing young population, and there is little economic growth. As the number of unemployed youths grows, the possibility of social unrest and lack of social cohesion rises.

In response to the increasing desire for self-sufficiency, Sub-Saharan African countries incentivise companies to fund development of the local economy with the hope that such development will expand the tax base through increasing employment and transferring skills. Stricter oversight of certifications and local obligations for multinationals also help to secure the corporate tax base, diversifying and expanding domestic sources of national income.

An absence of adequate financing and technology transfer results in poorly developed grid infrastructure and weak diversification in power generation, leaving oil, gas, hydro and coal to ensure energy security. Electricity grows to only 10% by 2040, with a reliance on coal (38%) and hydro (31%) in electricity generation. Solar and wind share increases to 10%.

EUROPE

REGIONAL LANDSCAPE – CHALLENGES AND OPPORTUNITIES

European countries are wealthier than most countries in other regions, despite suffering recent macroeconomic growth rates that are lower than the rest of the world. Europe is challenged by a **rapidly aging and mostly urban population.**

Stable legal systems and a strong economic base have traditionally been the backbone of European progress. But recently, the region has experienced migration issues, a slowdown of economic growth, **political tensions and social unrest** both within and between countries.

Europe has led the **decarbonisation and deregulation agendas** of energy markets for several years. Introduction of the first international CO_2 emissions trading scheme has largely been considered a success, with important lessons learned in the process. In addition, **integration of networks** has delivered more coherent and active international energy markets.

Investments in **renewable** energy have risen in all countries and have strongly increased the share of renewables in energy balances.

Liberalisation and restructuring of energy markets have delivered positive results in terms of prices in some regions but have been less successful in other regions.

Citizens are more aware of the impacts of climate change and the wider systemic risks of climate inaction and are ready to engage with new technologies. However, digitalisation of the energy sector is often challenged by prevailing data privacy issues that have hindered the introduction of new solutions.

Progress in energy market transition has been uneven among the European countries despite strong political objectives in the European Union. **Differences in regulations and political priorities continue,** even if interconnections between the countries exist or are planned. Scheduled closures of several nuclear and coal power production facilities have also raised concerns about security of supply in several European regions.

REGIONAL PATHWAYS TO 2040 – KEY HIGHLIGHTS

Modern Jazz

In **Modern Jazz,** Europe becomes more business-oriented and open to new technologies, supported by facilitation of decarbonisation and digital solutions to encourage citizen engagement in energy transition.

At the national and European level, most governments agree that businesses need to be freer to experiment and innovate. Increasingly, private companies take on public roles, providing social support.

Technology giants enter the market, driving innovation competitiveness in the region. China's technological breakthroughs in rechargeable battery technologies result in a domination of the market and trigger a race to quickly catch up in order to avoid the marginalisation of European manufacturers and service providers in this sector.

A new era of energy abundance for prosperity unfolds, and economic value migrates from manufacturing volume to value-adding services, driven by a sharing economy and smart digital solutions. Governments facilitate fair competition and support the application of new solutions to poorer citizens.

Energy markets become more liberal and flexible to address energy security concerns. Energy increasingly flows across national borders where empowered citizens are engaged in trading via digital solutions. Traceability technologies like blockchain proliferate, driven by consumer desires for greater transparency and trust.

In cities, building renovations reduce energy needs while new modes of personal and public transport result in new principles of infrastructure planning, such as new roads dedicated to electric vehicles. Digitalisation brings significant productivity gains in offshore wind that help to address summer and winter heating and cooling demand.

The quickening pace of the new digital economy increases the need for cooperation on cyber security and data privacy regulation, which evolve along with new technologies.

Electricity in final energy demand reaches 30% with a diversity of fuels. The share of solar and wind in electricity generation increases to 19% in 2040, a 50% increase in comparison to their share in 2020. This is enabled by investment in storage and the use of natural gas facilities for flexible dispatch and back-up.

Unfinished Symphony

In this world, challenges from within and outside Europe, including the threat of another global financial crisis and recession, draw the European countries closer together.

Europe is driven by strong political commitments and coordinated action to benefit all citizens in the region and beyond. New intelligent subsidiarity, whereby decision-making is realised at a level where it is more efficient, results in different measures and approaches being adopted in pursuit of shared goals. Subsidiarity allows targets to be set for the whole – but different states go their own way to meet them. For example, decarbonisation targets reward lowest carbon emissions rather than mandating a particular renewables pathway.

Europeans feel that the EU project of harmony and fairness to all – a good society – is worth sacrificing for, with greater integration being a major influence on the direction of businesses.

Opportunities for sector coupling and hydrogen development are seized, partly as a route to affordable emissions reductions and as a means to address common challenges, such as the implications of higher cost energy and the repurposing of infrastructure.

The EU develops an International Energy Infrastructure Action Plan that is enacted by the market and that promotes early action, definition of liabilities and standard asset lifecycle extension in synergy with new infrastructure to support the new energy ecosystem.

The development of trade in clean liquids and synthetic fuels is enabled largely through increased cross-border cooperation on energy policy and energy-tech developments such as power-to-X. The single electricity market is supported through reforms, primarily in anticipation of the push for global grid developments by other regions. Interconnection projects such as the one connecting Ireland to France to tap the Atlantic wind frontier or the super grid in the Northern Sea, which connects off-shore wind to Netherlands, UK, Norway, Belgium and Germany, become even more impactful, but require better cooperation among governments.

Governments lead in developing strong innovation strategies in relation to selected technologies, including renewables, nuclear and CCUS. New technologies and infrastructures result in public transport being the main driver in mobility transformation.

In larger countries, governments influence allocations of industries and pay support to guarantee that new factories (and employment and tax revenues) are brought to their country. In general, however, the economy is targeted more towards services than industrial development.

In **Unfinished Symphony**, the rate of electrification increases to 29% by 2040, with 31% electricity generation coming from gas, 17% from nuclear and 20% from wind and solar.

Hard Rock

In **Hard Rock**, Europe is a region with low trust, minimal cooperation, and uneven productivity gains, in part because data sharing among regions is limited to a smaller European heartland. This restriction makes it more difficult to empower consumers and constrains activities of global companies.

The ties that hold the EU together begin to fray, resulting in increased inequality among and within countries. Countries shift away from the EU framework towards individual national energy policy frameworks. Individuals revert to their own identities and cultures, which in many cases are not geographic.

European citizens become dissatisfied with heavy-handed, top-down bureaucracy on the one hand and the ravages of global market forces on the other. Nevertheless, some countries with strong international industrial, digital and service policy ties benefit economically from opportunities to sell their products and services to less advanced countries.

Energy sector cooperation among European nations diminishes, with priority given to national interests. Each country looks for its own cost advantage and security of supply. Cross-vector policy differs from country to country, leading to uneven costs and decarbonisation rates. With less cooperation and therefore no economies of scale, energy becomes more expensive. However, countries where governmental support to industries is present, more jobs are created.

Challenges are exacerbated by a declining and aging European population attempting to deal, in an incoherent way, with a growing and young population to its south. In this and other areas, European institutions are becoming more irrelevant to local communities and to the world at large.

In **Hard Rock**, renewables are limited to richer citizens and dedicated communities. Fossil fuels like coal remain a strong resource in a number of countries, leaving the decarbonisation agenda to those countries where it provides employment and economic growth.

Increase in share of electricity in final energy remains almost around 19% in two decades. However, wind and solar increase by half to 15% in 2040.

EAST ASIA

REGIONAL LANDSCAPE – CHALLENGES AND OPPORTUNITIES

East Asia comprises six countries that are home to 22% of the world's population. It is one of the three major energy markets of the world, together with North America and Europe. Coal supplies 59% of the primary energy of the region followed by oil and gas. It is home to diverse energy markets in terms of development, ranging from China, the world's largest energy consumer, with 100% access to electricity, to North Korea, with only 39% access to electricity. With the exception of China, most of the countries in the region, like Japan, South Korea and Taiwan, meet over 90% of their energy needs through imports, mostly in the form of fossil fuels, primarily oil, followed by natural gas and coal.

With respect to demography, the region is undergoing radical changes with a **rapidly aging population.** More than one in three people in East Asia are above 65 years of age. The highest rate of population aging is found in Japan and South Korea.

Heavy **reliance on energy imports** makes energy security an ongoing concern for the region. To maintain a stable energy supply and keep the economy going, reduction in fossil fuel consumption, diversification of the energy mix and the deployment of renewables top the policy agenda of all the countries in the region with the exception of North Korea. The government of North Korea is looking at using more of the country's indigenous coal for electricity feedstock to provide alternatives to hydropower and oil.

In addition, over 90% of Asia's entire nuclear consumption, including consumption in Central Asia and the Asia Pacific regions, comes from East Asia. While nuclear power currently accounts for 1% of the primary energy supply, it is expected to increase significantly over the coming decades to support industrial development of the region. China, Japan, South Korea and Taiwan have commercial nuclear power reactors. In addition, for some countries natural gas power generation remains a way of addressing energy supply and environmental issues.

One of the East Asia's biggest challenges that puts even the global energy transition at risk is the ongoing trade war between the world's two largest emitters, the US and China. The uncertainty in bilateral trade between the two has impacted the economic growth of China, which has fallen to a multi-decade low. This trade war has also impacted the global and regional decarbonisation agenda. For instance, increased tariffs by the US on imported solar modules and wind turbines and the lowered interest of China in buying US LNG exports is slowing down coal-to-gas switching in China.

REGIONAL PATHWAYS TO 2040 – KEY HIGHLIGHTS

Modern Jazz

In the **Modern Jazz** world, the region increasingly takes advantage of digitalisation and disruptive innovations to secure its energy needs through sustainable alternatives.

China, followed by Japan and South Korea, leads in terms of technological development and energy innovation. China drives renewable energy and use of next-generation vehicles, including hybrid vehicles, electric vehicles and fuel cell vehicles via smart charging, battery recycling and development of an open power market. The rapid exploitation of digital and renewable energy expertise allows China to be a global market shaper, exporting its technologies and know-how world-wide.

Commercialisation of hydrogen as a fuel becomes promising, particularly in Japan, South Korea and China. Japan explores the potential of hydrogen and ammonia as carbon- free fuels and develops ammonia utilisation technologies that draw strong interest from Europe, Australia, the US and Saudi Arabia. Initiatives, including many that use blockchain, gain momentum. Partnerships become increasingly common. For example, TEPCO, Japan's leading utility, partners with blockchain energy start-up Conjoule GmbH to develop peer-to-peer marketplaces for producers and consumers of renewable energy, as well as owners of batteries and other sources of flexibility.

As the world moves towards new levels of interconnectedness, cutting-edge technologies become mainstream in energy grids and smart utilities emerge. Digitalisation advances lead to new business models and start-ups that incorporate intelligent energy management services. Based on AI and big data, these start-ups look at providing energy efficiency optimisation, operation and maintenance monitoring, carbon emission management, electricity sales, micro-grid services and other digitalised technology solutions.

Clean coal technologies such as ultra-supercritical power plants (USC) and CCUS, R&D aimed at cost reduction of renewable energy, hydrogen utilization and electricity storage gain momentum. Initiatives such as advanced energy management systems and energy-saving practices like the green building index are implemented, and more efficient technologies are utilised in the industrial, transport, residential, commercial and even the agricultural sectors. Mongolia begins privatising the state-dominated energy sector to boost innovation and use of advanced technologies. Enormous improvements in energy efficiencies in both supply- and demand-side technologies continue to be developed and implemented across the region in varying degrees.

In **Modern Jazz**, electrification in East Asia rises from 24% in 2020 to 35% by 2040. While the contribution of coal reduces by half to 30% in 2040, the region doubles its reliance on gas in electricity generation to 24% by 2040. Similarly, owing to the resumption of nuclear power generation in Japan and capacity expansion in China, the share of nuclear in power generation increases by half and reaches 11% in 2040.

Unfinished Symphony

In **Unfinished Symphony,** regional integration and global cooperation are key to meeting the challenge of a secure energy supply in East Asian countries.

Projects like the Asian Supergrid between China and Mongolia and other projects to connect pipelines flourish. An increased global emphasis on providing support for technology innovation and technology transfer to developing countries also makes a difference in the region.

On a cross-regional scale, the Trans-ASEAN Gas Pipeline, LNG transportation as a virtual pipeline the ASEAN Power Grid (APG) and other regional networks support region-wide trade in electricity and increase energy security. The increasing interdependence of economies enhances collaborative efforts across the region to meet energy challenges.

Governments recognise that renewables must play a bigger role in their energy mix. Policy incentives encourage research in renewable energy as well as in its industrial application, and governments attempt to align energy demand with environmentally sound energy policies. China's innovations help other economies in the region to adopt best practices for reducing environmental impact.

In Asian mega-cities, rapid mass transportation systems reduce the need for shared mobility. Some Asian cities, such as the Yokohama Smart City in Japan, implement integrated planning in urban settings to boost the standard of living with more efficient and less carbon-intensive energy systems.

Technology transfer and joint development of technologies such as in LNG shipping, CHP and CCGT, among others, helps in coping with increasing energy demand.

In order to manage the growing dependence on Middle Eastern oil, East Asian economies explore opportunities for more Russian crude imports, develop and utilise more natural gas, establish joint emergency oil stockpiles and establish better coordination among importing countries in order to reduce oil price shocks. Developing mutually beneficial cooperation with countries in the region remains a key priority for the government of Mongolia, which strengthens its international ties and works with international companies to develop its renewables potential.

South Korea continues to expand cooperation with resource-rich countries and strengthen the competitiveness of its new energy business models and innovative energy start-ups. Taiwan's markets remain relatively open and are thus attractive to the European and North American players. Moreover, Taiwan's strategic location in East Asia, with close proximity to key markets, including China, means leading technology firms see the country as a potential hub for the Asian market.

As highlighted in Japan's G20 presidency 2019, governments continue to work together to increase cross-border and public-private collaboration using a range of mechanisms, including Technology Collaboration Programmes, Mission Innovation, Innovation Accelerators and Regional Centers.

The share of electricity in final energy climbs from 25% in 2020 to 42% by 2040. The solar and wind share in electricity generation increases almost three times in two decades, reaching 29% by 2040, with most of the increase coming from developments in China. Although coal is currently the dominant energy source in the region, contributing 62% of its electrification needs, the share of coal drops to a low of 21% by 2040. Switching from coal to gas leads to significant improvements in air quality. Nuclear remains significant to regional power companies, growing from 5% to 17% of electricity generation by 2040.

Hard Rock

With growing geo-political tensions in **Hard Rock**, primarily the US-China trade war, governments establish policies and inward measures that aim to enhance security and address environmental concerns within their own countries. While technological cooperation and technology diffusion take

a setback, the straining multilateral trading system creates incentives for more rapid development of viable alternatives, such as electric storage and affordable hydrogen, to meet rising energy demand.

In China, the UHV transmission-based distribution grid brings electricity from the west of China, where renewable power sources are based, to the demand-heavy east, and this and other initiatives continue to meet the energy security challenges at the country level. In addition, China's emissions trading system is set up at a massive scale, promising to shape global trends and spur a faster transition toward clean energy and a low-carbon economy.

Mongolia's hydroelectric plants continue making the largest contribution to the country's renewable energy. In South Korea, inward-looking initiatives that include voluntary agreements, energy audits, appliance labelling and standards, fuel economy and increased use of public transit continue to play important roles in energy savings. The "Basic Energy Plan", established after the Fukushima nuclear accident, promotes renewable energy and contributes to Japan's decarbonisation agenda.

However, foreign businesses with operations in East Asia and foreign investors face uncertainty, which discourages investment. The region, as a whole, continues to rely on cheaper domestic energy resources, such as coal. International power grid connections become politically difficult for ASEAN countries and impossible for Japan, South Korea, North Korea, and China. Eastern Asian power grid interconnection seems unlikely to be realised before 2040.

In **Hard Rock,** because of the increasing concerns over energy security, the competition for securing oil supplies in Northeast Asia and the Asia-Pacific region intensifies. Ongoing tensions between China and Japan continue because of their overlapping claims to petroleum resources in the East China Sea and competing oil pipeline proposals for importing Russian oil and gas.

Although many Asian countries have abundant hydro, wind, solar or biomass, high costs, uneven distribution of resources, intermittency and the lack of either the necessary infrastructure or the necessary investment levels remain barriers to higher levels of integration for renewables. The electrification rate reaches 27% by 2040, with 16% of it derived from solar and wind. Meanwhile, the contribution of coal decreases by two-thirds in two decades and reaches 44% in 2040.

CENTRAL ASIA

REGIONAL LANDSCAPE – CHALLENGES AND OPPORTUNITIES

Central Asia is a **dynamic region** that comprises 13 countries that are home to over a quarter of the world's population. Diverse economies range from the world's third largest energy consumer, India, to smaller nations - some that rely heavily on extraction and export of energy products and others that rely on the import of oil and gas. With a 78% share, fossil fuels dominate the primary energy supply of the region.

Underpinned by strong economic growth and population, India, one of the first countries to ratify the Paris agreement, is the largest energy market in the region and the fifth largest power producer in the world. Demand for energy in the country is driven by **rapid urbanisation and industrialisation**. India's investment in the energy sector grew by 12% in 2018, the highest growth rate of any country across the globe. Although coal continues to be the largest primary energy source, the country is tapping into its vast renewable energy potential and investing more in solar power than coal with an aim to become a world leader in renewable energy. The first half of 2019 witnessed a 58% share of renewables in total capacity installed.

Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan have large volumes of oil and natural gas. Historically, the majority of the Caspian oil and gas was supplied to Russia and Western Europe. However, since the beginning of the century, the picture has altered significantly as access has been opened to new markets in the east with China's investment in the region. The countries around the Caspian Sea now play a vital role in meeting the growing energy needs of China. However, political instability, corruption and lack of infrastructure are challenges for the energy sector. Renewable energy potential remains largely untapped.

Although Central Asian countries have made progress in achieving **universal access to electricity**, the situation remains grim in remote parts of the region, particularly in Bangladesh, Pakistan, Nepal, Sri Lanka and Bhutan. In addition, clean cooking remains a challenge. More than six million people lack access to modern cooking fuels and technologies and continue to rely on burning of fuels such as wood, dung and charcoal for cooking and heating.

Many countries such as Bangladesh are among the most **vulnerable to climate change**. While the countries in the region are adopting forward-thinking and **progressive energy policies** designed to meet the UN's SDGs and their commitments to the 2015 Paris Agreement, progress has been uneven across the region.

REGIONAL PATHWAYS TO 2040 – KEY HIGHLIGHTS

Modern Jazz

In **Modern Jazz**, the region relies on digital and other innovative technologies to meet its increasing energy needs.

India invests heavily in EVs and urban transportation systems to meet the twin goal of curtailing emissions and fulfilling rising urban needs. Digitalisation advances lead to automation in transportation services, and sharing models transform businesses. For example, the country continues to give a huge push to become a global hub of manufacturing and invests heavily in EVs. Car and bike-sharing services like Ola and Bounce become more popular. More partnerships, such as that of Tata Motors with Tata Power, work to set up a public EV charging infrastructure.

Distributed energy systems, smart grids, smart metering and blockchain increase energy efficiency and transparency at all stages of the energy value chain in many Asian countries. Sri Lanka accelerates deployment of smart grids, building onto the first smart grid launched in 2019. India's private utilities continue to be at the forefront of smart meters and smart grid deployment. Nepal, in its early stages of modernising its hydro-powered infrastructure in 2019, embraces the digital technology wave by implementing smart metering.

Island-scale energy developments flourish, including micro-wind in Sri Lanka and micro-hydro power generation in Bhutan.

Despite the significant and rapid progress toward full energy access enabled by markets and entrepreneurs, the challenge of scaling still exists as well as the need to move from basic access to affordable, quality access for all.

In **Modern Jazz**, electrification in Central Asia increases by 50% from that in 2020 and reaches 25% by 2040. The region increases its reliance on gas in electricity generation from 18% in 2020 to 25% by 2040, while contribution of coal and oil reduces by half to 28% in 2040.

Unfinished Symphony

In **Unfinished Symphony**, a series of reforms enables improved collaboration on climate issues between the US, China, Europe and India with an emphasis on providing support for technology innovation and technology transfer to developing nations.

To meet the challenge of a secure energy supply in Central Asian countries, regional integration becomes critical. Governments recognise that renewables must play a bigger role in their energy mix. Policy incentives encourage research in renewable, clean energy as well as in its industrial application, and governments attempt to align energy demand with environmentally sound energy policies. Electricity climbs to 23% by 2040. The solar and wind share in electricity generation reaches 32% by 2040, with the majority of this increase coming from developments in India.

India's regional ambitions through multilateral and bilateral energy cooperation with Nepal, Bhutan, Sri Lanka and Bangladesh continue to flourish. The Bay of Bengal Initiative for MultiSectoral Technical and Economic Cooperation (BIMSTEC) initiative and the Act East Policy are both successful. India accelerates its "green" cross-border energy trade to enhance energy security for its neighbours.

Coal to gas switching leads to significant improvements in air quality. European policy-makers plan to expand their relations with the Central Asian states, and energy security is a key factor driving this expansion. Kazakhstan has the eleventh largest oil reserves in the world and in **Unfinished Symphony** has the greatest capacity for production growth of any non-OPEC member. It begins to provide an alternative to Russian oil for China – catching the attention of other international investors as well.

Broadly, the energy market of Central Asia reorients itself to the East. The pattern of enhanced energy cooperation between Central Asia and China is followed by closer resource sector links with India.

Regional gas share in electricity reaches 34% by 2040 in comparison to around 20% in 2020, while consumption of coal and oil experiences an eightfold decrease, accounting for only 10% of the power generated in 2040. Nuclear in Central Asia, especially in India, remains significant for regional power companies and doubles to 11% by 2040 in comparison to that in 2020.

Hard Rock

With growing geopolitical tensions in **Hard Rock**, governments establish policies that aim to balance security, social welfare and environmental concerns within their own countries, based on the local context and without much consideration for global impacts.

Significant penetration of renewable energies is still realised in India, but not in other countries. Developing Central Asian economies such as Bhutan, Pakistan and Bangladesh struggle to achieve economic growth in the face of fragile infrastructure and challenges to basic energy access.

Import-dependent countries such as Pakistan, which rely heavily on trade with Middle Eastern countries like Saudi Arabia and Iran, experience a knock-on effect of the US-China trade war with slowing productivity and tightening monetary policies. Economic development slows, resulting in poverty and only a marginal improvement in inequality. Central Asia tends to look at developed economies for financial assistance, particularly in addressing energy needs.

Low investment, corruption and mismanagement in Uzbekistan and Turkmenistan and lobbying by oil and gas companies pose a challenge in diversification of energy sources of the countries. Small-scale on- and off-grid sectors continue to remain dormant in Kazakhstan. No specific schemes or rewards are there to financially support their deployment.

In **Hard Rock**, many countries experience little change, with some developing countries remaining "developing." Although many Asian countries have abundant hydro, wind, solar or biomass, high costs, uneven distribution of resources, intermittency and the lack of either the necessary infrastructure or the necessary investment levels are barriers to higher levels of integration for renewables. The electrification rate reaches 18% by 2040. Only 16% of electricity supply is derived from solar and wind, a 50% increase in comparison to their share in 2020, while the contribution of coal and oil decreases to 54% in 2040 in comparison to 59% in 2020.

ASIA PACIFIC

REGIONAL LANDSCAPE – CHALLENGES AND OPPORTUNITIES

Asia Pacific comprises over 15 countries with many small island nations ranging from developed to lower middle-income economies that are home to one-tenth of the world's population. Oil and coal supply 59% of the primary energy of the region, with Indonesia and Australia being among the largest coal suppliers in the region. It is home to diverse energy markets that have different energy resource endowments and consumption patterns. But Asia Pacific countries share a common challenge to meet rising demand in a secure, affordable and sustainable manner.

To meet the rising energy demands, massive investment in new energy generation and transmission is required, and countries have to make pivotal choices to avoid locking the region into a carbon-intensive energy future. Myanmar, Cambodia and Laos face the greatest pressure of meeting the fast-growing energy demand, while Indonesia, the Philippines and Vietnam experience relatively less demand growth.

While traditional fuel sources, including gas and coal, will continue to be important for many years to come, the development of alternative energy sources remains a core driver for the region's growth. Philippines, Thailand and Cambodia are among the world's top 20 investors in new coal capacity. Clean supercritical and ultra-supercritical coal technology is being advocated, with Chinese enterprises making notable investments in the region. However, the higher cost of clean coal technologies makes renewables a viable alternative.

Myanmar, Indonesia, Philippines, Thailand and Vietnam are exploring opportunities for building LNG import terminals. Indonesia and Philippines have the world's second and third largest installed geothermal capacity and additional unexploited reserves. The two largest developed economies of the region, Australia and New Zealand, are well known for their governments' policies on renewables. New Zealand receives 85% of its electricity supply through renewable sources and aims to achieve 100% renewable electricity by 2035, while Australia is working towards a Climate Change Action Plan that aims to achieve a target of 50% electricity generation through renewables by 2030.

Countries such as Indonesia, the Philippines and Vietnam have pyramid-shaped population distributions that enable them to enjoy a "demographic dividend" for the coming decades. The highest rate of population aging in the region is found in Thailand.

In Southeast Asia, 65 million people are still without electricity, and 250 million rely on solid biomass as a cooking fuel. Universal access is expected by the early 2030s, using a wide range of fuels and technologies as well as both centralised and decentralised solutions. Because of strong political will, Malaysia has been able to progress in its energy access journey at a distinctively fast pace in the last decade and can provide lessons for other countries in the region. A policy drive to electrify rural areas increased the electrification rate of Malaysia from 66% in 2009 to 94% in 2015.

A fundamental challenge faced by many countries in Asia Pacific is lack of clear energy policies. Thailand, Vietnam and Indonesia have adopted feed-in-tariffs (FiTs) for solar wind projects, but investment response has been mixed.

Overall, there are growth opportunities in Asia-Pacific's energy and environment industry through collaborating with start-ups, using of AI and blockchain, and addressing sustainability. For instance, Equis Energy, which held more than 180 assets comprising over 11 GW of capacity across Australia, Indonesia, Philippines, Thailand and other countries, was acquired in 2017 for USD 5 bn – one of the largest renewable energy generation acquisitions in history.

REGIONAL PATHWAYS TO 2040 – KEY HIGHLIGHTS

Modern Jazz

In **Modern Jazz**, digititalisation drives changes in demand patterns, and countries adopt innovative technologies to improve affordability, reliability and environmental sustainability.

Digitalisation leads to automated transportation, such as autonomous buses and taxis, in Australia, New Zealand, Singapore and Malaysia. The building industry in the Asia-Pacific region is driven by a new Smart City framework developed by a consortium of Chinese technology giants. Island-scale energy developments, including micro-wind and micro-hydro power generation, flourish in Indonesia, supported by innovative blended financing, Islamic financing, and private sector financing for micro-grids that, in some cases, transform rural electrification.

New business models for micro-grids emerge, and the growing interest in distributed energy and micro-grids threatens the conventional power supply chain. Many countries join the bandwagon for investments in distribution grid management (DGM). Singapore invests heavily in R&D projects, particularly in electricity grid infrastructure. The Grid 2.0 initiative to consolidate the country's gas, solar and thermal energy into a single network is one such example. Smart grids and data analytics continue to allow the country to enhance energy supply stability and sustainability by monitoring electricity disruptions and facilitating use of renewable energy.

Digititalisation disrupts energy management in buildings. In particular, the Facility Management (FM) market witnesses significant growth, especially in Thailand, Indonesia and Vietnam. These FM markets are driven by green buildings, smart city projects and new buildings.

Utilities strive to be more resilient in response to water scarcity caused by increasing extreme weather conditions. A focus on the energy-water nexus becomes critical. In the water industry, an increasing number of tenders are rolled out through PPPs in Vietnam, whereby water treatment facilities and water distribution, metering and sanitation systems are key opportunity areas for water EPCs. Digitalisation and anything-as-a-service (XaaS), such as meter-as-a-service, improves water service efficiency in Asia Pacific.

In **Modern Jazz**, electrification in Asia Pacific almost doubles in two decades and reaches 28% in 2040. While contribution of coal in power generation in 2040 decreases to 18% from 30% in 2020, the region increases its reliance on gas by one-fourth in comparison to 2020 and reaches 56% by 2040. The share of solar and wind in power generation more than doubles to 10% in 2040.

Unfinished Symphony

In **Unfinished Symphony**, regional integration and global cooperation are critical to meeting the challenge of a secure and sustainable energy supply in Asia Pacific countries. Regional and bilateral grid and pipeline networks are further developed between countries. Existing examples of these include grid connections between Indonesia-Singapore, Thailand-Laos and Vietnam-Cambodia, and bilateral pipeline connections between Indonesia-Singapore, Malaysia-Thailand and Thailand-Myanmar. Major energy users seek to leverage opportunities for greater electrification of transport and digitalising customer experience.

The ASEAN Plan of Action for Energy Cooperation establishes additional multilateral energy trading schemes. China, too, supports regional energy trade, as a regional grid could allow for excess hydropower from Yunnan province to reach foreign markets. ASEAN Power Grid (APG) addresses regional clean energy goal and offers the dual benefits of deeper energy and economic integration as well as the amplification of ASEAN's influence in the global economy and environment.

Indonesia remains an important producer of coal as well as an exporter to its Southeast Asian neighbours and India. Island nations, like the Philippines, improve energy security by supplementing diesel-based generation with nuclear and LNG.

Regional cooperation to mobilize capacities, knowledge, technology and investment as well as to establish regional markets becomes an essential part of the sustainable energy transition. Revenue models increasingly shift from product- to customer-centric solutions.

Share of electricity in final energy reaches 28% by 2040, an increase of 80% in two decades. The solar and wind share in electricity generation increases more than twice, reaching 12% by 2040. The share of gas in electricity reaches 52%.

Hard Rock

In **Hard Rock**, multilateral energy trade is stymied by anxieties about protection of domestic energy industries, differences in electricity prices and contractual problems. Governments look at inward measures to diversify their energy mixes.

Fossil fuels remain the dominant energy source for Indonesia. To encourage diversification of energy sources, the government provides incentives, although deployment of efficient low-carbon technologies is slow. Increasing energy production to enhance energy security and reduce reliance on energy imports remains a key challenge for countries like Thailand. Brunei continues to rely primarily on oil and natural gas.

By 2018, only one example of multilateral trade between Laos, Thailand and Malaysia had moved forward. Progress from 2018 is slow in **Hard Rock** because political difficulties are not addressed until the economics of trade become too attractive to be ignored. As a result, national energy plans are increasingly focused on high-demand countries with a demand-supply gap like Thailand, Vietnam, Cambodia, Myanmar and Laos.

A few countries with targeted financial investment strengthen their national initiatives. For instance, Sarawak becomes a pioneer in Malaysia's energy transition as hydrogen-powered buses make inroads in the region.

Although many countries in Asia Pacific have abundant hydro, wind, solar or biomass, high costs, lack of necessary investment levels and unclear policies remain barriers to higher levels of integration for renewables. The electrification rate reaches 17% by 2040 with 6% of it derived from solar and wind, double from their share in 2020. The gas share in power generation decreases to 27% in 2040.

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GLOSSARY

%	Percent
°C	Degrees Celsius
AfCFTA	African Continental Free Trade Area
AfDB	African Development Bank
AI	Artificial Intelligence
APG	ASEAN Power Grid
AR	Assessment Report
ASEAN	Association of Southeast Asian Nations
AUC	African Union Commission
BEV	Battery Electric Vehicles
BIMSTEC	Bay of Bengal Initiative for MultiSectoral Technical and Economic Cooperation
bn	Billion
BRI	Belt and Road Initiative
CAGR	Compound Annual Growth Rate
CCGT	Combined Cycle Gas Turbines
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation and Storage
CE	Circular Economy
CEO	Chief Executive Officer
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CoDs	Constellation[s] of Disruptions
DAP	Diammonium Phosphate
DGM	Distributed Grid Management
EJ	Exajoules
EPC	Engineering, Procurement and Construction
ETS	Emissions Trading Scheme
EU	Europe
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
FDI	Foreign Direct Investment
FiT	Feed-in-Tariff
FM	Facility Management
G20	Group of Twenty
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GMM	Global Multi-Regional MARKAL Model
Gt CO_2	Giga Tonnes (of CO_2)
GW	Gigawatt
HVDC	High Voltage Direct Current
ICE	Internal Combustion Engine
ICT	Information and Communications Technology
IEA	International Energy Agency
IMF	International Monetary Fund
IP	Intellectual Property
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return

LAC	Latin America and the Caribbean
LNG	Liquified Natural Gas
MARKAL	MARKet ALlocation
MENA	Middle East and North Africa
MER	Market Exchange Rate
mb/d	Million Barrels per Day
MI	Mission Innovation
Mn	Million
MTBE	Methyl Tert-Butyl Ether
MToE	Million Tonnes of Oil Equivalent
NDCs	Nationally Determined Contributions
NEPAD	The New Partnership for Africa's Development
NGO	Non-Governmental Organisation
O&G	Oil and Gas
OECD	Organisation for Economic Co-operation and Development
P2X	Power-to-X
PIDA	Programme for Infrastructure Development in Africa
PPP	Public Private Partnership
PSI	Paul Scherrer Institute
PV	Photovoltaic
R&D	Research and Development
RCP	Representative Concentration Pathway
RGGI	Regional Greenhouse Gas Initiative
SDGs	Sustainable Development Goals
SIEPAC	Central American Electrical Interconnection System
SINEA	Andean Electrical Interconnection System
SMR	Small Modular Reactors
SMR	Steam Methane Reforming
t CO_2	Tonnes (of CO_2)
TCPs	Technology Collaboration Programmes
TEPCO	Tokyo Electric Power Company
TPES	Total Primary Energy Supply
TW	Terrawatt
TWh	Terrawatt Hours
UAE	United Arab Emirates
UHV	Ultra-High Voltage
UN	United Nations
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
USD	United States Dollar
USC	Ultra-Supercritical
VC	Venture Capital
WES	World Energy Scenarios
WGII	Working Group II
WTO	World Trade Organisation
XaaS	Anything-as-a-Service
yr.	year

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METHODOLOGY

PROCESS

- Series of interviews with selected energy leaders
- 2-day Orientation Scenarios workshop in London
- Global scenarios comparison review to benchmark Council' scenarios to peers
- 100+ deep-dive interviews with global energy leaders focused around 14 themes that will have an impact on energy system to 2040
- Regional workshops in Paris, Berlin, Tallinn, Abu Dhabi
- 2-day Global Scenarios weaving workshop in London
- Building and iterating between global narratives, system maps, comparative analysis on energy implications and regional perspectives
- GMM MARKAL modelling to support narratives and reflect disruptive potential of scenarios
- Launch of the refreshed scenarios at the 24th World Energy Congress in Abu-Dhabi on 9-12 September

USING SCENARIOS IN DRIVE FOR IMPACT

THE GLOBAL MULTI-REGIONAL MARKAL MODEL – AN OVERVIEW

The scenarios were quantified using the Global Multi-Regional MARKAL Model (GMM). GMM is a tool used to quantify and enrich the scenario storylines developed by the World Energy Council. GMM's detailed technology representation enables the model to provide a consistent and integrated representation of the global energy system, accounting for technical and economic factors in the quantification of long-term energy transitions.

The model is driven by input assumptions reflecting the scenario storylines and applies an optimisation algorithm to determine the least-cost, long-term configuration of the global energy system from the perspective of a social planner with perfect foresight. GMM belongs to the family of MARKAL (MARKet ALlocation) type of models, where the emphasis is on a detailed representation of energy supply, conversion and energy end-use technologies (a so-called 'bottom-up' model).

GMM is a technologically detailed cost-optimisation model that has been developed by the Energy Economics Group at the Paul Scherrer Institute (PSI) over a number of years (Rafaj, 2005; Gül et

al., 2009; Densing et al., 2012, Turton et al, 2013, Panos et al. 2015, Panos et al. 2016, Volkart et al. 2018, Kober et al. 2018). The World Energy Council joined as a model partner to support continued development and dissemination of the model with the goal of improving transparency, accessibility and credibility of global energy scenario modelling. In this regard, the Council and PSI have developed GMM into a fully open source model available to all Council members (subject to licensing). Such tools do not seek to model directly the economy outside of the energy sector, which is represented as a set of exogenous inputs to the model based on a coherent scenario storyline. GMM is applied to identify the least-cost combination of technology and fuel options to supply energy services using a market-clearing optimisation algorithm. This algorithm simultaneously determines equipment investment and operating decisions, and primary energy supply decisions for each region represented in the model to establish equilibrium between the cost of each energy carrier, the quantity supplied by producers, and the quantity demanded by consumers. Additional information about the model and its methodology can be found at the Paul Scherrer Institute's website.[4]

GEOGRAPHIES

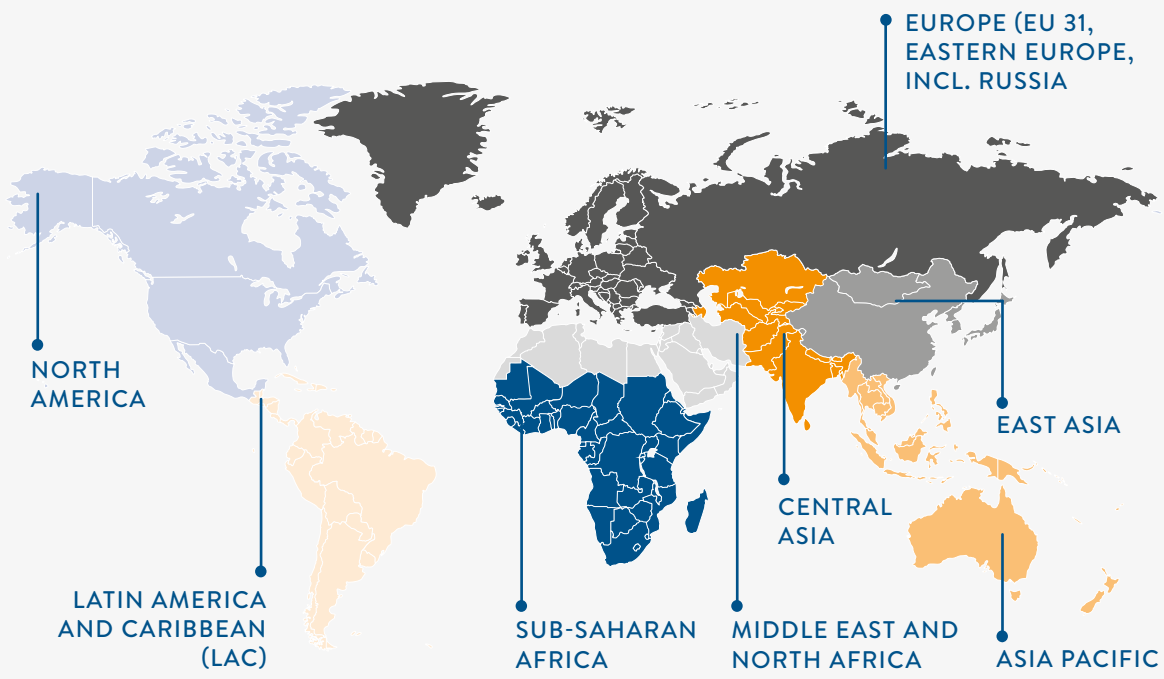
PSI's model contains 17 world regions. For the purpose of this report, the World Energy Council highlights eight world regions that have the most significant impact on the energy sector, shown in the figure below. Major countries are modelled as separate regions: Brazil, China, the European Union[5], India, Russia and the US. Aggregated regions include: Eastern Europe[6]; South and Central Asia (excluding India); the developed far East (Japan, Korea and Taiwan); Australia and New Zealand; Latin America together with the Caribbean (excluding Brazil and Mexico); the Gulf Cooperation Countries; other Middle Eastern countries; North African countries; Canada together with Mexico; Sub-Saharan Africa; and Southeast Asia and the Pacific (excluding Australia and New Zealand). For each region, scenario assumptions influence the dynamics of demand and supply technologies (cost, efficiencies and availability). The regional and technology differentiation leads to a large-scale optimisation model, which represents in detail the energy system of each region from resource extraction and imports to energy conversion, use and exports. Trade among the regions, based on bilateral trade links and global markets, is also endogenously represented in the model.

[4] PSI provides a fundamental view on methodology used and tools on their website: www.psi.ch/eem/methods-and-tools

[5] Including Norway, Switzerland and Iceland

[6] Albania, Armenia, Belarus, Bosnia and Herzegovina, Georgia, North Macedonia, Moldavia, Serbia, Turkey, Ukraine, Kosovo and Montenegro

REGIONAL BREAKDOWN FOR MODELLING



CALIBRATION OF ENERGY DEMANDS, TECHNOLOGIES AND ENERGY RESOURCE POTENTIALS

The GMM model is calibrated to recently published statistics for the year 2010. This calibration covers current demands for each energy subsector, the technology and fuel shares and estimates of current costs and efficiencies of technologies. A primary source used for much of the calibration of fuel production and consumption is the IEA's Energy Balances (IEA 2015a). To ensure a better representation of developments since 2010 (up to the year 2015), the model uses additional statistics for recent years for which reliable data are available (EIA, 2015; BGR, 2016; IEA, 2015b; see Turton et al., 2013 for further references). For the near-term calibration until 2020, national and regional outlooks are also taken into account (e.g., AEO 2018 for the US, EU-Trends 2016 for the EU31, China's five-year national plan, India's five-year national plan, and several others).

SUPPLEMENTARY DATA TABLES

Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

Table 1. Modern Jazz Economic Indicators

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Population (million)	7,372	8,163	8,541	9,200	9,762	10,213	0.7%
GDP (trillion USD 2010 MER)	76	105	124	171	229	300	3.1%
GDP per capita (USD 2010 MER)	10,263	12,920	14,467	18,555	3,489	29,355	2.4%
Car ownership (cars/1000 people)	NA	NA	168	198	238	264	NA
Primary Energy Intensity (toe/Million USD 2010 MER)	178	145	128	95	71	54	-2.6%
Final Energy Intensity (toe/Million USD 2010 MER)	129	103	91	68	52	40	-2.6%

Table 2. Modern Jazz Primary Energy Supply (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	13,486	15,309	15,771	16,251	16,297	16,160	0.4%
Coal	3,826	3,796	3,618	2,918	1,730	1,433	-2.2%
Oil	4,272	4,695	4,666	4,191	3,902	3,433	-0.5%
Gas	2,937	3,798	4,168	5,087	5,660	5,325	1.3%
Nuclear	616	788	850	977	1,156	1,241	1.6%
Biomass	1,310	1,372	1,417	1,597	1,859	2,173	1.1%
Hydro	327	404	421	472	523	562	1.2%
Other renewables	193	458	630	1,010	1,466	1,993	5.3%

Table 3. Modern Jazz Total Final Consumption by Sector and by Fuel Source (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	9,761	10,828	11,200	11,581	11,844	11,892	0.4%
Industry	3,119	3,570	3,720	3,926	3,935	3,893	0.5%
Transport	2,704	2,993	3,047	3,010	3,138	3,187	0.4%
Residential/commercial	3,097	3,299	3,433	3,569	3,608	3,555	0.3%
Non-energy uses	841	966	1,000	1,076	1,163	1,257	0.9%
Coal	1,499	1,136	1,116	1,067	985	841	-1.3%
Oil	3,852	4,182	4,161	3,734	3,508	3,146	-0.4%
Gas	1,406	1,648	1,751	1,823	1,676	1,546	0.2%
Electricity	1,739	2,329	2,574	3,281	3,876	4,394	2.1%
Heat	270	284	279	272	268	262	-0.1%
Biomass & biofuels	1,053	1,071	1,075	1,062	1,056	1,073	0.0%
Other	27	175	241	340	473	631	7.2%

Table 4. Modern Jazz Transport by Fuel Source (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	2,941	2,994	3,047	3,010	3,138	3,187	0.2%
Electricity	42	72	102	258	400	570	6.0%
Hydrogen	0	5	11	58	127	194	16.0%
Liquid fuels - fossil	2,707	2,698	2,689	2,386	2,230	1,932	-0.7%
Liquid fuels - biogenous	96	112	128	172	209	306	2.6%
Gaseous fuels- fossil	93	102	112	128	144	168	1.3%
Gaseous fuels - biogenous	2	4	5	8	29	17	4.6%
Other (coal)	0	0	0	0	0	-	NA

Table 5. Modern Jazz Power by Fuel Source (TWh)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	24,072	31,898	35,069	44,085	51,493	57,898	2.0%
Coal	9,341	10,457	10,050	7,741	2,886	2,139	-3.2%
Coal (with CCS)	-	-	-	34	105	264	NA
Oil	990	897	819	669	597	526	-1.4%
Gas	5,561	8,247	9,849	15,650	20,561	20,257	2.9%
Gas (with CCS)	-	-	-	68	296	1,115	NA
Nuclear	2,571	3,055	3,294	3,787	4,484	4,811	1.4%
Hydro	3,903	4,695	4,900	5,488	6,085	6,540	1.2%
Biomass	527	833	923	1,401	1,998	2,567	3.6%
Biomass (with CCS)	-	-	-	-	-	-	NA
Wind	840	2,187	2,968	4,991	6,964	9,523	5.5%
Solar	256	1,345	2,000	3,643	6,195	8,821	8.2%
Geothermal	80	146	192	307	466	599	4.6%
Other	2	37	75	306	856	736	14.7%

Table 6. Modern Jazz Carbon Emissions

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
CO_2 emissions ($GtCO_2$/yr)	31	35	35	33	28	22	-0.7%
CO_2 capture ($GtCO_2$)	0	0	0	0	1	2	NA
CO_2 per capita (tCO_2)	4	4	4	4	3	2	-1.4%
CO_2 intensity ($kgCO_2$/USD 2010)	0	0	0	0	0	0	-3.7%

Table 7. Modern Jazz Coal in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	3,826	3,796	3,618	2,918	1,730	1,433	-2.2%
Sub-Saharan Africa	100	101	107	97	45	25	-3.0%
MENA	15	12	13	9	2	1	-5.0%
LAC	31	23	14	6	3	1	-7.2%
North America	406	349	285	167	94	73	-3.7%
Europe	457	355	318	239	151	118	-3.0%
Central Asia	425	655	730	798	595	534	0.5%
East Asia	2,231	2,183	2,042	1,453	666	525	-3.2%
Asia Pacific	162	117	110	148	174	155	-0.1%

Table 8. Modern Jazz Oil in TPES by Region (mb/d)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	80	88	87	78	73	64	-0.5%
Sub-Saharan Africa	2	3	3	3	4	4	1.6%
MENA	8	10	10	10	10	9	0.3%
LAC	6	7	7	7	6	5	-0.2%
North America	19	20	19	17	14	12	-1.1%
Europe	17	15	14	11	8	7	-1.8%
Central Asia	5	7	7	8	9	8	1.0%
East Asia	17	19	18	16	14	12	-0.7%
Asia Pacific	6	8	8	7	7	7	0.1%

Table 9. Modern Jazz Gas in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	2,937	3,798	4,168	5,087	5,660	5,325	1.3%
Sub-Saharan Africa	26	60	88	159	232	284	5.5%
MENA	481	551	575	641	643	623	0.6%
LAC	134	175	195	278	284	262	1.5%
North America	798	965	1,062	1,093	980	847	0.1%
Europe	820	944	980	1,055	1,044	937	0.3%
Central Asia	187	352	446	600	794	812	3.3%
East Asia	315	425	465	795	1,213	1,109	2.8%
Asia Pacific	174	326	357	466	471	452	2.1%

Table 10. Modern Jazz Nuclear in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	616	788	850	977	1,156	1,241	1.6%
Sub-Saharan Africa	3	3	2	3	3	5	0.8%
MENA	1	4	4	4	8	37	9.0%
LAC	6	8	9	8	7	7	0.6%
North America	246	226	225	225	224	226	-0.2%
Europe	305	276	273	263	263	254	-0.4%
Central Asia	11	35	52	83	116	127	5.5%
East Asia	45	234	282	387	529	577	5.9%
Asia Pacific	-	1	2	4	6	8	NA

Table 11. Modern Jazz Biomass in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	1,310	1,372	1,417	1,597	1,859	2,173	1.1%
Sub-Saharan Africa	377	347	359	376	402	436	0.3%
MENA	1	4	8	23	52	73	11.4%
LAC	132	162	175	215	268	381	2.4%
North America	125	137	139	151	198	216	1.2%
Europe	173	211	223	275	314	338	1.5%
Central Asia	237	221	219	234	274	280	0.4%
East Asia	134	177	180	196	209	276	1.6%
Asia Pacific	133	113	113	126	143	174	0.6%

Table 12. Modern Jazz Hydro in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	327	404	421	472	523	562	1.2%
Sub-Saharan Africa	9	14	17	24	34	46	3.7%
MENA	3	4	5	5	5	4	0.7%
LAC	58	81	86	98	104	110	1.4%
North America	57	63	65	66	69	70	0.5%
Europe	69	75	76	80	86	91	0.6%
Central Asia	20	26	29	37	51	52	2.2%
East Asia	96	119	119	130	137	143	0.9%
Asia Pacific	15	21	25	32	38	46	2.6%

Table13. Modern Jazz Other Renewables in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	193	458	630	1,010	1,466	1,993	5.3%
Sub-Saharan Africa	2	7	11	35	100	158	9.8%
MENA	1	26	38	83	134	184	11.6%
LAC	7	20	27	40	60	87	5.8%
North America	33	67	95	141	200	279	4.8%
Europe	52	83	99	137	177	221	3.3%
Central Asia	9	53	85	167	251	358	8.6%
East Asia	64	190	258	371	476	601	5.1%
Asia Pacific	24	12	17	36	69	106	3.4%

Table 14. Unfinished Symphony Economic Indicators

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Population (million)	7,372	8,163	8,541	9,200	9,762	10,213	0.7%
GDP (trillion USD 2010 MER)	76	101	116	153	198	249	2.7%
GDP per capita (USD 2010 MER)	10,263	12,376	13,533	16,624	0,240	4,407	1.9%
Car ownership (cars/1000 people)	NA	NA	160	188	225	272	NA
Primary Energy Intensity (toe/Million USD 2010 MER)	178	147	129	98	77	61	-2.3%
Final Energy Intensity (toe/Million USD 2010 MER)	129	104	92	71	55	43	-2.4%

Table15. Unfinished Symphony Primary Energy (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	13,486	14,863	14,916	15,009	15,116	15,284	0.3%
Coal	3,826	3,425	3,023	2,114	1,083	785	-3.5%
Oil	4,272	4,480	4,237	3,430	2,859	2,382	-1.3%
Gas	2,937	3,611	3,780	4,390	4,820	4,498	1.0%
Nuclear	616	955	1,147	1,471	1,754	2,016	2.7%
Biomass	1,310	1,467	1,570	1,832	2,196	2,623	1.6%
Hydro	327	431	463	527	615	658	1.6%
Other renewables	193	493	696	1,245	1,789	2,320	5.7%

Table16. Unfinished Symphony Total Final Consumption by Sector and by Fuel Source (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	9,761	10,543	10,677	10,839	10,906	10,841	0.2%
Industry	3,119	3,496	3,593	3,693	3,684	3,655	0.4%
Transport	2,704	2,908	2,873	2,790	2,849	2,856	0.1%
Residential/commercial	3,097	3,238	3,299	3,411	3,392	3,305	0.1%
Non-energy uses	841	901	911	944	982	1,025	0.4%
Coal	1,499	1,051	985	845	675	482	-2.5%
Oil	3,852	4,010	3,834	3,188	2,703	2,266	-1.2%
Gas	1,406	1,562	1,578	1,525	1,484	1,390	0.0%
Electricity	1,739	2,322	2,562	3,367	3,918	4,439	2.1%
Heat	270	274	272	257	244	228	-0.4%
Biomass & biofuels	1,053	1,128	1,165	1,224	1,290	1,309	0.5%
Other	27	191	276	429	590	724	7.6%

Table17. Unfinished Symphony Transport by Fuel Source (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	2,941	2,908	2,873	2,790	2,849	2,856	-0.1%
Electricity	42	71	106	294	488	690	6.4%
Hydrogen	0	21	39	147	246	307	17.2%
Liquid fuels - fossil	2,707	2,592	2,472	2,007	1,662	1,272	-1.7%
Liquid fuels - biogenous	96	129	159	231	325	449	3.5%
Gaseous fuels- fossil	93	91	92	103	115	122	0.6%
Gaseous fuels - biogenous	2	4	5	9	12	17	4.6%
Other (coal)	0	0	0	0	0	-	NA

Table18. Unfinished Symphony Power by Fuel Source (TWh)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	24,072	31,817	34,930	45,519	52,698	59,082	2.0%
Coal	9,341	9,468	8,326	5,167	579	166	-8.6%
Coal (with CCS)	-	35	71	371	1,045	1,053	NA
Oil	990	771	493	264	162	92	-5.1%
Gas	5,561	7,727	8,953	13,611	10,728	3,956	-0.8%
Gas (with CCS)	-	38	77	547	5,437	10,793	NA
Nuclear	2,571	3,701	4,448	5,704	6,802	7,818	2.5%
Hydro	3,903	5,019	5,388	6,131	7,153	7,660	1.5%
Biomass	527	848	1,004	1,438	2,099	2,700	3.7%
Biomass (with CCS)	-	-	-	24	74	172	NA
Wind	840	2,335	3,236	5,602	8,275	10,786	5.8%
Solar	256	1,700	2,684	6,038	8,970	11,773	8.9%
Geothermal	80	138	180	330	559	859	5.4%
Other	2	35	70	290	815	1,253	16.1%

Table 19. Unfinished Symphony Carbon Emissions

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
CO_2 emissions ($GtCO_2$/yr)	31	33	31	25	17	11	-2.3%
CO_2 capture ($GtCO_2$)	0	0	0	1	4	7	NA
CO_2 per capita (tCO_2)	4	4	4	3	2	1	-3.0%
CO_2 intensity ($kgCO_2$/USD 2010)	0	0	0	0	0	0	-4.8%

Table 20. Unfinished Symphony Coal in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	3,826	3,425	3,023	2,114	1,083	785	-3.5%
Sub-Saharan Africa	100	85	70	53	25	28	-2.8%
MENA	15	6	8	4	3	3	-3.5%
LAC	31	19	13	9	6	4	-4.4%
North America	406	326	269	149	60	32	-5.5%
Europe	457	328	287	174	84	73	-4.0%
Central Asia	425	484	434	408	248	175	-2.0%
East Asia	2,231	2,056	1,841	1,220	620	420	-3.6%
Asia Pacific	162	120	99	96	37	50	-2.6%

Table 21. Unfinished Symphony Oil in TPES by Region (mb/d)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	80	84	79	64	54	45	-1.3%
Sub-Saharan Africa	2	2	2	2	2	2	0.1%
MENA	8	9	8	7	6	5	-1.0%
LAC	6	7	7	5	3	2	-2.3%
North America	19	19	17	13	11	9	-1.6%
Europe	17	14	13	11	8	7	-2.0%
Central Asia	5	7	8	7	6	6	0.2%
East Asia	17	18	17	13	10	9	-1.5%
Asia Pacific	6	7	7	6	6	5	-0.4%

Table 22. Unfinished Symphony Gas in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	2,937	3,611	3,780	4,390	4,820	4,498	1.0%
Sub-Saharan Africa	26	53	82	150	208	240	5.1%
MENA	481	557	592	625	685	707	0.9%
LAC	134	153	151	208	258	257	1.5%
North America	798	926	925	852	787	673	-0.4%
Europe	820	909	917	929	832	681	-0.4%
Central Asia	187	329	397	582	820	915	3.6%
East Asia	315	396	426	621	781	619	1.5%
Asia Pacific	176	288	289	423	449	406	1.9%

Table 23. Unfinished Symphony Nuclear in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	616	955	1,147	1,471	1,754	2,016	2.7%
Sub-Saharan Africa	3	5	6	10	17	28	4.9%
MENA	1	13	17	31	58	76	10.8%
LAC	6	9	11	13	18	21	3.0%
North America	246	229	229	237	247	265	0.2%
Europe	305	295	284	312	309	366	0.4%
Central Asia	11	54	83	177	274	313	7.7%
East Asia	45	346	510	678	812	921	7.0%
Asia Pacific	-	3	6	13	19	26	NA

Table 24. Unfinished Symphony Biomass in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	1,310	1,467	1,570	1,832	2,196	2,623	1.6%
Sub-Saharan Africa	377	351	367	407	475	515	0.7%
MENA	1	13	24	58	72	131	12.9%
LAC	132	171	188	228	317	444	2.7%
North America	125	138	141	160	183	235	1.4%
Europe	173	218	237	284	313	345	1.6%
Central Asia	237	265	280	317	351	389	1.1%
East Asia	134	193	210	223	294	343	2.1%
Asia Pacific	133	117	123	155	191	221	1.1%

Table 25. Unfinished Symphony Hydro in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	327	431	463	527	615	658	1.6%
Sub-Saharan Africa	9	17	22	32	45	61	4.3%
MENA	3	4	5	5	6	6	1.7%
LAC	58	85	94	104	111	116	1.6%
North America	57	67	68	71	74	76	0.6%
Europe	69	80	83	99	121	135	1.5%
Central Asia	20	30	34	45	60	78	3.1%
East Asia	96	124	129	134	153	134	0.7%
Asia Pacific	15	23	28	38	45	54	2.9%

Table 26. Unfinished Symphony Other Renewables in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	193	493	696	1,245	1,789	2,320	5.7%
Sub-Saharan Africa	2	11	19	49	97	157	9.8%
MENA	1	28	42	112	180	241	12.3%
LAC	7	21	30	50	72	92	6.0%
North America	33	67	97	156	221	299	5.0%
Europe	52	85	98	141	204	248	3.5%
Central Asia	9	58	95	197	297	398	8.8%
East Asia	64	209	296	498	638	763	5.6%
Asia Pacific	24	13	19	42	81	122	3.7%

Table 27. Hard Rock Economic Indicators

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Population (million)	7,372	8,163	8,541	9,200	9,762	10,213	0.7%
GDP (trillion USD 2010 MER)	76	98	110	138	168	200	2.2%
GDP per capita (USD 2010 MER)	10,263	12,005	12,911	14,970	17,191	19,591	1.4%
Car ownership (cars/1000 people)	NA	NA	183	213	248	284	NA
Primary Energy Intensity (toe/Million USD 2010 MER)	178	160	149	126	107	92	-1.4%
Final Energy Intensity (toe/Million USD 2010 MER)	129	115	108	94	81	71	-1.3%

Table 28. Hard Rock Primary Energy (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	13,486	15,704	16,390	17,411	17,880	18,485	0.7%
Coal	3,826	4,009	3,926	3,917	3,267	2,905	-0.6%
Oil	4,272	5,007	5,214	5,350	5,381	5,300	0.5%
Gas	2,937	3,547	3,791	4,123	4,516	4,770	1.1%
Nuclear	616	862	982	1,124	1,266	1,391	1.8%
Biomass	1,310	1,485	1,558	1,681	1,891	2,193	1.2%
Hydro	327	398	403	454	521	583	1.3%
Other renewables	193	396	517	762	1,038	1,342	4.4%

Table 29. Hard Rock Total Final Consumption by Sector and by Fuel Source (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	9,761	11,249	11,921	12,950	13,615	14,206	0.8%
Industry	3,119	3,617	3,802	4,204	4,458	4,674	0.9%
Transport	2,704	3,167	3,379	3,667	3,795	3,830	0.8%
Residential/commercial	3,097	3,407	3,592	3,774	3,928	4,123	0.6%
Non-energy uses	841	1,059	1,147	1,305	1,434	1,580	1.4%
Coal	1,499	1,189	1,207	1,282	1,300	1,222	-0.5%
Oil	3,852	4,454	4,692	4,865	4,904	4,823	0.5%
Gas	1,406	1,760	1,932	2,192	2,354	2,578	1.4%
Electricity	1,739	2,181	2,306	2,628	2,942	3,225	1.4%
Heat	270	325	348	393	396	396	0.9%
Biomass & biofuels	1,053	1,169	1,204	1,251	1,231	1,311	0.5%
Other	27	166	226	335	483	649	7.3%

Table 30. Hard Rock Transport by Fuel Source (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	2,941	3,167	3,379	3,667	3,795	3,830	0.6%
Electricity	42	48	62	92	118	169	3.1%
Hydrogen	0	2	3	10	17	30	11.3%
Liquid fuels - fossil	2,707	2,887	3,046	3,192	3,196	3,052	0.3%
Liquid fuels - biogenous	96	104	128	181	250	327	2.8%
Gaseous fuels- fossil	93	118	137	191	213	251	2.2%
Gaseous fuels - biogenous	2	4	1	0	1	1	-1.4%
Other (coal)	0	5	1	1	0	0	NA

Table 31. Hard Rock Power by Fuel Source (TWh)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	24,072	29,927	31,536	35,722	39,593	43,012	1.3%
Coal	9,341	10,708	10,465	10,548	8,704	8,137	-0.3%
Coal (with CCS)	-	-	-	-	-	-	NA
Oil	990	1,046	912	741	646	594	-1.1%
Gas	5,561	6,635	7,245	8,376	10,605	11,070	1.5%
Gas (with CCS)	-	-	-	-	-	-	NA
Nuclear	2,571	3,342	3,808	4,357	4,910	5,394	1.7%
Hydro	3,903	4,627	4,686	5,286	6,063	6,786	1.2%
Biomass	527	793	912	1,136	1,610	2,017	3.0%
Biomass (with CCS)	-	-	-	-	-	-	NA
Wind	840	1,592	1,897	2,720	3,480	4,443	3.8%
Solar	256	1,076	1,477	2,328	3,150	3,943	6.3%
Geothermal	80	100	119	169	272	365	3.4%
Other	2	7	14	60	153	265	12.2%

Table 32. Hard Rock Carbon Emissions

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
CO_2 emissions ($GtCO_2$/yr)	31	36	37	38	36	34	0.2%
CO_2 capture ($GtCO_2$)	0	0	0	0	0	0	NA
CO_2 per capita (tCO_2)	4	4	4	4	4	3	-0.5%
CO_2 intensity ($kgCO_2$/USD 2010)	0	0	0	0	0	0	-1.9%

Table 33. Hard Rock Coal in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	3,826	4,009	3,926	3,917	3,267	2,905	-0.6%
Sub-Saharan Africa	100	113	113	146	183	216	1.7%
MENA	15	13	13	10	7	5	-2.4%
LAC	31	26	24	22	18	19	-1.1%
North America	406	308	299	187	111	64	-4.0%
Europe	457	398	367	308	220	158	-2.3%
Central Asia	425	599	683	1,003	1,039	1,027	2.0%
East Asia	2,231	2,345	2,202	1,962	1,372	1,136	-1.5%
Asia Pacific	3,826	4,009	3,926	3,917	3,267	2,905	-0.6%

Table 34. Hard Rock Oil in TPES by Region (mb/d)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	80	94	98	100	101	99	0.5%
Sub-Saharan Africa	2	3	3	4	7	9	3.4%
MENA	8	12	12	12	13	12	0.9%
LAC	6	7	8	8	8	8	0.8%
North America	19	20	20	18	16	14	-0.8%
Europe	17	16	16	16	15	14	-0.4%
Central Asia	5	8	9	12	14	14	2.2%
East Asia	17	20	21	21	19	18	0.2%
Asia Pacific	6	8	9	9	10	10	1.0%

Table 35. Hard Rock Gas in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	2,937	3,547	3,791	4,123	4,516	4,770	1.1%
Sub-Saharan Africa	26	30	43	62	89	123	3.5%
MENA	481	554	605	679	742	817	1.2%
LAC	134	186	192	224	249	266	1.5%
North America	798	1,024	1,063	989	1,019	1,035	0.6%
Europe	820	864	900	831	819	788	-0.1%
Central Asia	187	331	370	567	582	592	2.6%
East Asia	315	357	386	493	712	795	2.1%
Asia Pacific	176	202	230	277	305	354	1.6%

Table 36. Hard Rock Nuclear in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	616	862	982	1,124	1,266	1,391	1.8%
Sub-Saharan Africa	3	3	2	2	2	3	-0.4%
MENA	1	6	8	11	15	33	8.7%
LAC	6	9	10	10	9	14	2.0%
North America	246	225	224	227	228	236	-0.1%
Europe	305	288	273	266	276	309	0.0%
Central Asia	11	33	47	83	121	174	6.3%
East Asia	45	298	416	519	608	612	6.0%
Asia Pacific	-	1	2	4	7	10	NA

Table 37. Hard Rock Biomass in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	1,310	1,485	1,558	1,681	1,891	2,193	1.2%
Sub-Saharan Africa	377	392	413	445	455	504	0.7%
MENA	1	4	6	13	25	35	9.6%
LAC	132	168	188	222	286	358	2.2%
North America	125	127	134	151	169	188	0.9%
Europe	173	181	188	225	291	324	1.4%
Central Asia	237	298	301	319	315	362	0.9%
East Asia	134	196	204	182	201	234	1.3%
Asia Pacific	133	119	123	124	148	188	0.8%

Table 38. Hard Rock Hydro in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	327	398	403	454	521	583	1.3%
Sub-Saharan Africa	9	16	19	29	43	58	4.2%
MENA	3	4	4	4	4	4	0.6%
LAC	58	78	82	93	98	103	1.3%
North America	57	65	65	65	68	69	0.4%
Europe	69	75	75	77	85	93	0.7%
Central Asia	20	28	31	31	46	61	2.5%
East Asia	96	113	106	129	147	160	1.1%
Asia Pacific	15	19	21	26	31	36	2.0%

Table 39. Hard Rock Other Renewables in TPES by Region (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	193	396	517	762	1,038	1,342	4.4%
Sub-Saharan Africa	2	7	10	18	32	52	7.2%
MENA	1	24	33	55	85	115	10.4%
LAC	7	17	23	33	47	62	5.0%
North America	33	55	71	102	141	190	3.9%
Europe	52	75	87	111	139	160	2.5%
Central Asia	9	37	54	97	140	196	7.1%
East Asia	64	170	225	318	410	499	4.7%
Asia Pacific	24	11	15	27	44	68	2.4%

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