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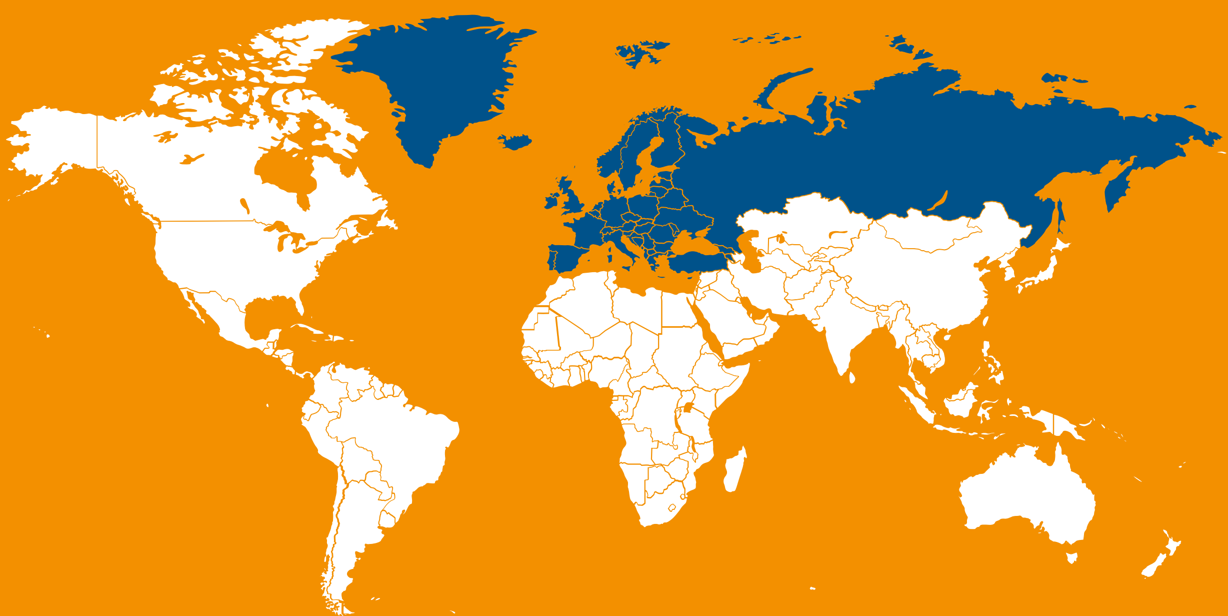
World Energy Scenarios | 2019



EUROPEAN REGIONAL PERSPECTIVE

In collaboration with 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

The scenarios provides 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.

These regionally focused scenarios are is produced using a World Energy Council framework, that was developed by the Council and its scenarios partners, Accenture Strategy Energy and the Paul Scherrer Institute.

The report is following a medium-term time horizon of 2040 and focuses on European region, which includes EU31, Eastern Europe and Russia. It explores three plausible pathways for a region in Modern Jazz, Unfinished Symphony and Hard Rock futures, provides comparative analysis, and a broader view on 'how to use' the scenarios.

The regionally focussed scenarios were informed by insights from 15 deep-dive regionally focussed leadership interviews, regional workshops in Paris, Berlin and Tallinn, and wide experts' engagements.

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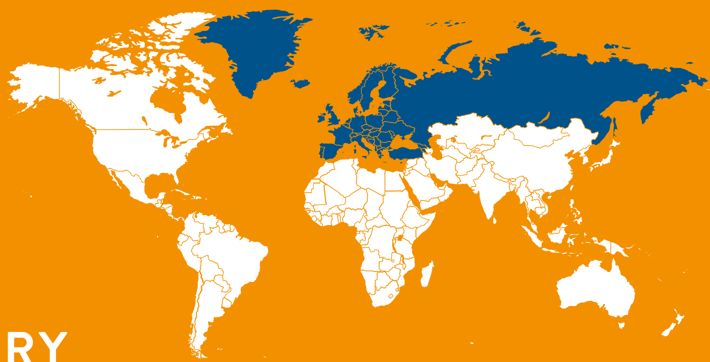


EXECUTIVE SUMMARY

The European region[1] comprises over 30 national energy systems, including some of the world's largest importer-exporter nations. There is increasing diversity in the overall energy mix, which includes community/district and industrial heating; centralised and decentralised electricity grids; hydrocarbon molecules; and renewable, hydro and nuclear power generation. Compared with other regions, the European region is also well endowed with both new and ageing national and cross-border energy infrastructures.

Whilst the future of energy cannot be predicted with any degree of precision, managing successful energy transitions necessitates a bigger-picture perspective.

The exploratory scenarios contained in this report describe three plausible alternative pathways for European regional energy systems. None of the scenarios is the preferred or most likely future. Instead, the set of scenarios can be used by energy leaders to engage constructively with uncertainty and to better prepare for emerging systemic risks and new opportunities.

The three scenarios indicate the following as the main challenges facing European energy transition leaders.

1 EUROPEAN ENERGY SYSTEMS ARE ALREADY APPROACHING AN INVESTMENT CLIFF.

All the three scenarios assume that an an increase in energy investment will be forthcoming, but none of them delivers the full vision of successful energy transition and the achievement of the Paris Agreement. Despite the relative wealth of its highly industrialised urban societies, the global abundance of cheap capital and an increase in green finance, it is a challenge to attract the investment needed to manage and maintain existing systems, decommission or repurpose (where it makes sense), build new infrastructures and manage stranding of assets. It is clear that a mix of public-private investment will be required, and yet there is no certainty that adequate investment will be forthcoming.

2 NEW GLOBAL GROWTH OPPORTUNITIES ARE EMERGING IN ENERGY, WHILST GEOSTRATEGIC COMPETITIONS ARE INTENSIFYING.

Recent years have seen a re-emergence of old and new political tensions, including between the West and Russia, which will affect the future of gas in Europe. In parallel, new opportunities for accelerating global energy transition are emerging, including new pathways for global clean energy trade. As more and more European nations explore new energy for prosperity opportunities associated with power-to-X and the hydrogen economy, will timely, pan-European energy cooperation be forthcoming?

3 DIGITAL ENERGY COMPETITIVENESS IS KEY TO A NEXT ERA OF REGIONAL PROSPERITY.

Digitalisation is a key feature in all the three scenarios, but pace of change and scale of impact varies considerably among the scenarios. The impact of digitalisation is increasing in every part of all types of energy value chains. Digitalising gains include increased resource and energy efficiency through digital design, digital manufacturing, digital distribution, digital maintenance,

[1]European region includes EU 31,Eastern Europe and Russia. Please see the annex for additional definition.

smart systems integration and business information management. Digitalisation is facilitating the rise of active, data-empowered consumers across Europe. As a result, value is migrating from resources to the attributes of power (energy-plus services) and to new demand aggregators, including new and non-traditional market entrants. The continued fall in the cost of renewable energy technologies and the expected fall in the costs of battery storage are also enabling a new phenomenon of renewable communities and net-zero carbon cities across the region. In turn, the increasing democratisation in energy is creating new challenges associated with the fragmented privatisation of supply and storage infrastructure, including visibility, reliability and cyber security of hybrid electricity grids.

4 EUROPEAN SHARED VALUES IMPLY THAT THERE CAN BE NO ENERGY TRANSITION WITHOUT SOCIAL INVOLVEMENT AND PUBLIC ACCEPTANCE.

All the three scenarios highlight different facets of the shift to a more democratic and consumer-centric energy system shaped by active consumers, active citizens and active local communities. The recent phenomenon of the Gilets Jaunes movement in France highlights the growing demand for a socially just and fair transition. In the UK, in order to meet the nationally declared climate emergency, citizens will need to be engaged in discussions about the role of low-cost domestic nuclear power and the potential need for greater reliance on more diverse energy imports in a post-Brexit era. Similarly, achieving the German Energiewende means that citizens and small and medium-size companies will bear a large share of the upfront costs. This situation is unlikely to be socially acceptable for more cost-sensitive consumers in other European countries. The full costs of transition to a sustainable energy future must become more transparent and must be shared more fairly throughout the whole of society.

5 NEW ECONOMICS OF WHOLE SYSTEM TRANSITION ARE NEEDED THAT AVOID INCREASING EMOTIONAL REACTIONS AND ESTABLISH A LEVEL PLAYING FIELD IN THE CONSIDERATION OF ALTERNATIVE NET-ZERO CARBON TECHNOLOGIES TRANSITION PATHWAYS.

The scenarios can be used to explore whole energy system transition costs and the inevitability of new winners and losers. Whole energy system transition costs are not the same as marginal cost pricing. Despite increasing digital transparency, however, the development of true cost accounting (inclusion of costs of reliability, reflection of social and environmental externalities, calculation of co-benefits, etc.) is not straightforward. Achieving a pragmatic way forward will involve education and awareness-raising among consumers and the many and increasingly diverse set of actors involved in energy transition within and beyond the energy sector.

6 DEVELOPING INTEGRATED ENERGY-INDUSTRIAL STRATEGIES AND PROMOTING SECTOR-COUPLING POLICIES ARE PIVOTAL IN ENABLING AFFORDABLE AND DEEPER DECARBONISATION, IN PARALLEL WITH CREATING JOBS AND STRENGTHENING REGIONAL ECONOMIC COMPETITIVENESS.

The scenario narratives direct attention to how energy transition in the European region is being shaped by global developments and, in particular, the journey called the ‘Grand Transition’, which implies wider and fundamental shifts beyond the world of energy, e.g., socio-economic transformation to post-normal, post-industrial and so-called Creative Society; the shift to a circular economy; the rise of prosumers and a shift in social norms from ownership to sharing. In this wider context, the links between energy transition and industrial competitiveness and transformation are in flux, and there is an opportunity to look beyond traditional policy trade-offs and to leverage new synergies and co-benefits. Integrated policy pathfinding using the Council’s Energy Policy Trilemma Index in combination with these European Regional Scenarios can help identify new policy options for improving both competitiveness and purchasing power. Other world regions are more pragmatic in this regard. Europeans can be both pragmatic and creative in progressing more effective and innovative energy-industrial policy.

7 THERE IS A NEED TO BUILD NEW CAPABILITIES IN DYNAMIC RESILIENCE AND CROSS-SCALE GOVERNANCE IN ORDER TO SECURE THE BENEFITS OF GLOBAL AND LOCAL FLOWS OF CLEAN, RELIABLE AND AFFORDABLE ENERGY FOR EVERYONE, ANYTIME, ANYWHERE.

The role of national governments in energy security policy is shifting. The geopolitics of energy are broadening beyond oil and gas, and systemic risks of decentralised and renewable energy systems include extreme weather events and cyber crisis. At what level should decisions about energy security and resilience be made? Some decisions are best made at the pan-European level; others at the local community level. Europe promotes a policy rhetoric of subsidiarity – now it needs to effectively translate this into practice.

RECOMMENDATIONS

Meeting these seven challenges will require different and collaborative action from key energy transition leaders across the region, including:

Policy makers should:

- Engage citizens in honest discussions of whole energy transition costs and re-localisation of new market designs
- Promote integrated policy pathfinding in relation to energy-industrial development
- Promote sector-coupling strategies to achieve socially affordable and deeper decarbonisation
- Develop proactive energy infrastructure action planning, including repurposing of pipelines to progress hydrogen mandates

Energy business leaders should:

- Leverage digitalisation to help identify and secure new co-benefits and synergies, e.g., smart systems integration, switching supply and storage

Climate finance and investment community should:

- Promote technology neutrality in financing net-zero carbon pathways

Macro risk management should:

- Seek/encourage investment
- Focus on regional integration of pipelines and grid to enhance dynamic resilience

The Council promotes and uses plausibility-based, technology-neutral scenarios to support well-informed, globally inclusive and better quality strategic dialogue and decision-making and to forge a shared understanding of common energy challenges.

ABOUT THE FULL REPORT

The main section of the full report presents the three regional storylines to 2040, with supporting comparative analysis of energy sector implications; additional country focused insight; and illustrative, model-based quantification. There is also a section on 'how to use' the scenarios, describing how business leaders 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; (4) redesign energy businesses.

INTRODUCTION

The World Energy Council's European scenario project began with research that included horizon scanning across the Council's network of European energy experts. This was followed by more than fifteen deep-dive interviews with a diverse selection of regional energy leaders. The Council members then convened to co-create stories of the ways the Council's 2016 'Grand Transition' scenarios might play out in the European region by 2040. The resulting European storylines were developed in a series of workshops in London, Paris, Berlin and Tallinn. The workshops were followed by illustrative quantification.

The three plausibility-based energy transition pathways are designed to help leaders test deeply held beliefs and assumptions that would otherwise remain implicit. The pathways describe what *could* happen rather than what *will* happen. The exploratory and participatory scenario-building methodology is intended to help develop different Perspectives on energy-related challenges, changes and contexts that characterise the strategic energy landscape of the European region.

In addition to presenting three European narratives to 2040, 'Regional perspective for Europe to 2040' explores the potential role of disruptive innovation in accelerating a successful energy transition and is intended to serve as a starting point for a deeper dialogue among regional energy members and stakeholders to support various regional energy agendas.

THE 2016 'GRAND TRANSITION' SCENARIOS

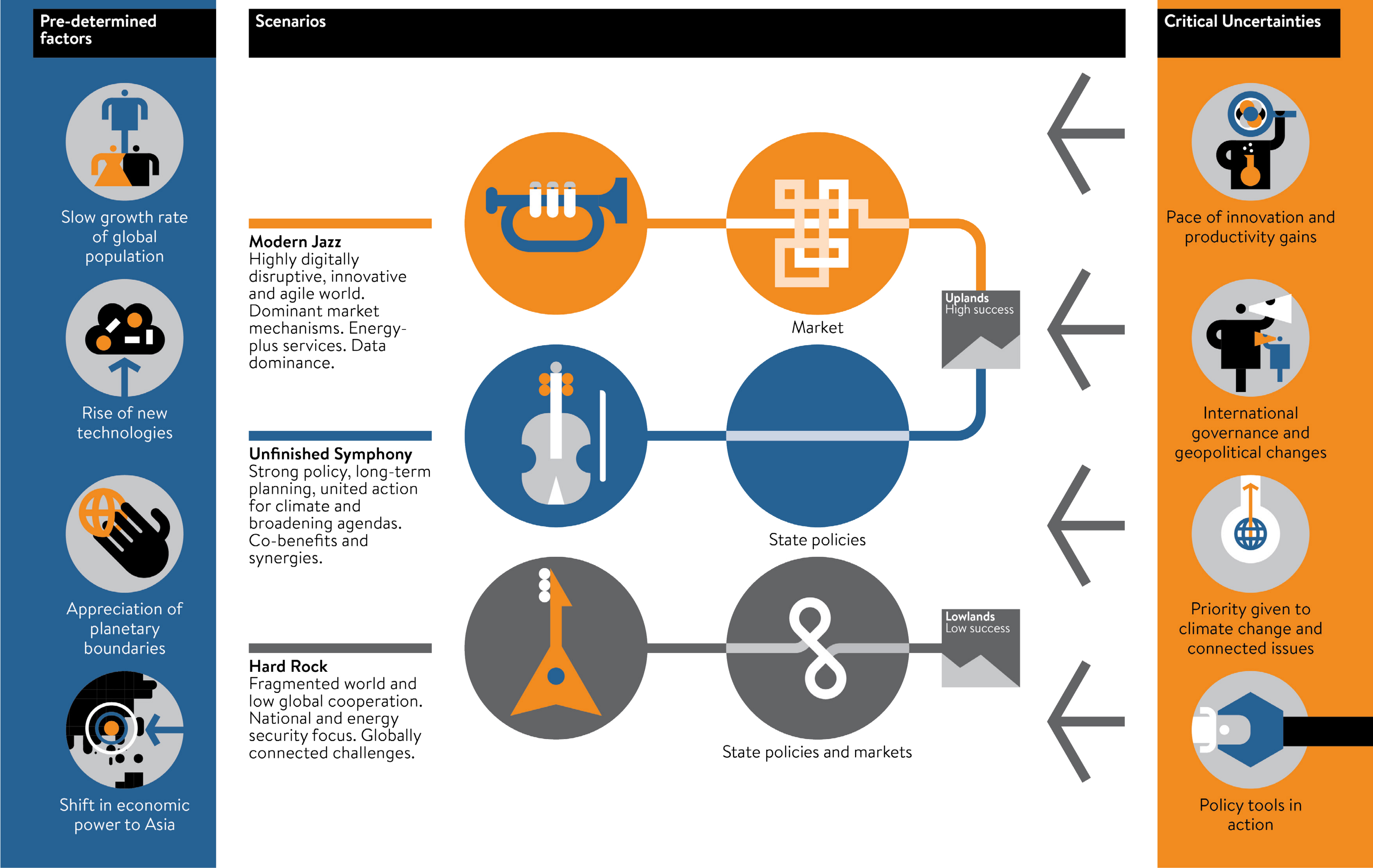
Since 2010, the Council has been developing World Energy Scenarios to help its member better navigate the global energy transition. The Scenarios report published by the Council in 2016 recognised that worldwide energy systems are undergoing faster and more fundamental changes than ever before, and that these developments are shaped, in turn, by a larger global context. The journey to this new world was called the 'Grand Transition'.

There are an infinite number of possible pathways in the context of the Grand Transition. The Council focused on clarifying three relevant, challenging and plausible pathways, each of which reflected the same set of predetermined factors but which placed a different emphasis on how critical uncertainties might play out.

To ensure consistency of internal assumptions, each of the three scenarios was quantified using a global, multi-regional energy system model. All three of the 2016 scenarios were affirmed by the Council as still relevant through a worldwide horizon-scanning process conducted in 2018.

Modern Jazz represents a 'digitally disruptive', innovative and globally market-driven world in which gains are increasingly privatised. **Unfinished Symphony** is a world in which more 'intelligent' and sustainable economic growth models emerge as the world aspires to a low-carbon and more renewable energy future. **Hard Rock** explores the consequences of inward-looking national security priorities that contribute to weaker and unsustainable global economic growth.

Council's World Energy Scenarios Framework



WHAT HAS CHANGED SINCE 2016?

What has changed most dramatically since 2016, for the world in general and for Europe in particular, is the perceived speed of change itself – sudden shifts in social norms (e.g., from car ownership to sharing), an accelerating pace of digitalisation of the energy sector and other sectors, exponential data abundance, commodity price volatility, political volatility and increasing frequency and severity of extreme weather events.

These rapid changes are interacting and leading to unexpected disruptions in global value chains and national energy systems, which are incurring new costs of reliability. Many countries, companies, cities and communities are struggling to keep pace and to learn how to enable a successful energy transition.

With digitalisation, value continues to migrate along the energy value chain, from ownership of resources to electrified services, which are increasingly provided by new and non-traditional demand aggregators.

In turn, the rapid penetration of intermittent renewable energy supplies creates new challenges, including systems integration management, smart demand, grid volatility and 'on-demand' storage (hourly, daily, seasonal), while the rise of energy prosumers is challenging both the visibility of the grid to network operators and the economics of network infrastructures as more energy production, supply and storage assets are privately owned, and effective policy reform to ensure a sustainable and fair remuneration of assets tend to lag behind.

The dramatic decline in the costs of solar energy, coupled with the global abundance of natural gas and LNG, is challenging the economics of coal and the role of oil in energy security and raises the possibility of local job losses. Job losses on top of rising inequalities trigger social and political volatility. In turn, global cooperation becomes strained.

Proactive policies on data protection and ownership in regions such as Europe are paving the way for the continued acceleration of digitalisation in energy and yielding huge productivity and efficiency in the nuclear, oil and gas industries. However, the proliferation of physical-cyber interfaces increases cyber security risks and costs.

Meanwhile, the increasing frequence and impact of extreme weather events – droughts, floods and forest fires – have exposed the fragility and vulnerability of all types of energy supply. Despite the economic rationale for cross-border cooperation in the search for enhanced resilience via regional integration of electrical grids and pipeline systems, political support has waned, while public acceptance issues are growing.

The global policy drive towards decarbonisation has moved down a gear as some nation states in other world regions reduce their commitments to the UNFCCC Paris Agreement. As climate momentum continues to build, a global social movement has emerged in response to the so-called 'climate emergency', demanding carbon neutrality. At the same time, the social affordability of accelerating the pace of decarbonisation is moving up the political agenda in several regions.

While new investment has been attracted to finance new renewable energy developments and develop a more entrepreneurial energy culture that links venture capital and start-up energy entrepreneurs, such new investment is also needed to maintain and safely operate existing infrastructures. However, the investment gap in meeting climate change commitments remains significant.

Meanwhile, the global multi-lateral trading system continues to shrink. The intensification of geo-strategic competitions is notable, not only between the US and China, but also within the West and between the West and Russia. Geopolitics are broadening beyond oil and gas and other physical resources to include technology and data.

EUROPEAN-SPECIFIC OPPORTUNITIES AND CHALLENGES

European countries are wealthier than most countries in other regions, despite suffering lower macro-economic growth rates than the rest of the world, and its largely urban citizens are more environmentally aware. But Europe is challenged by a rapidly ageing and mostly urban population.

The EU energy sector is import-dependent and highly efficient. Despite the relatively higher cost of imported energy, the EU maintains global market leadership in petrochemicals, specialty chemicals and engineering products and some clean energy technologies such as wind and nuclear. Its global industrial leadership position on sustainable development is increasingly challenged by new competitors, especially US digital and fintech entrepreneurs, China's electrified transport revolution and investment in battery innovation and collaborative innovation between the Middle East and Japan in relation to hydrogen pathways.

Energy demand is growing more slowly than GDP in the European region, especially in industrial heat, commercial and freight transport fuels and petrochemicals. There is also growing demand for power for new uses, including electricity for cooling, electrified transport, data storage and Bitcoin mining. The drive for decarbonisation and decentralisation of energy is evident in many EU31 countries but not in Russia. Achieving the ambitious decarbonisation goals committed by the EU31 will require accelerating end-use electrification. Concerns are growing about the ability of the current market design of the EU electricity sector to enable an adequate level of capacity retention and new build. EU leadership in climate policies also carries challenges – for example, retro-fitting its built environment, given the strong sentiment against the use of fossil fuels; and maintaining investment in its well-developed but ageing energy infrastructure. Very few countries in the European region have developed energy infrastructure action plans to manage decommissioning, asset stranding and repurposing. Despite opportunities to transfer skills based on significant expertise in operating offshore oil and gas facilities to early mover advantages in offshore wind, the EU still depends on Russia for gas to meet growing demand for winter heating and summer cooling.

As European societies experience highly uneven gains from digital economy growth, they are demanding fairer outcomes and better job protection. There is wide recognition that achieving 'clean and socially just' energy transition in the EU will require the use of all technologies and innovation, such as carbon abatement solutions and more cost-effective policies. Despite concerns about runaway climate change and demand for action by governments, social willingness to pay for faster transition and NIMBYism in response to the visual pollution of renewable energy assets and overhead power lines have both increased.

The push for rapid decarbonisation by some large European states is raising new concerns about the material security that renewable revolution and reliable access to precious metals and rare earths. There is growing awareness some technological solutions are 'clean locally but dirty globally' when environmental impacts are considered on a life-cycle basis.

The EU is experimenting with policy innovation in facilitating waste recycling, circular economy models and promotion of the sharing economy. Recognition of the quickening pace of the new digital economy, the need for cooperation on cyber security challenges and regional leadership in developing data privacy regulations aside, there are also strong forces of inertia in Europe. Russia, meanwhile, is looking beyond the EU to secure its oil and gas export markets, leverage its nuclear expertise abroad and revitalise its space industry.

The European neighbourhood is characterised by growing political stresses and strains within and between countries. Brexit negotiations, increasing inequalities within countries and anti-immigration policies have led many governments to focus on national affairs. This growing nationalism has also created political challenges, including the rise of democratic populism and a return of the far right in European politics. New fault lines have developed between Europe and Russia over fake news and state-sponsored cyber security threats to national sovereignty. In response to these concerns, the European Commission has established some of the highest standards globally for privacy and private data management.

In an era of global gas abundance, cyber insecurity and a slow-down in global trade, new tensions in relations have emerged between Russia and the many other countries that make up the European region. It is less clear whether and how these new tensions will affect regional energy politics over the longer term.

HOW TO USE THESE SCENARIOS EFFECTIVELY

The main value of scenarios is derived from using them. As a set, these scenarios provide a clear, pre-decision framework aimed at helping energy leaders explore and navigate the broad and quickly shifting landscape of innovation that is impacting energy transition from within and beyond the energy sector. Section 3 provides four specific options for effective use, including for (1) leadership dialogue; (2) integrated policy pathfinding; (3) redesigning energy business; and (4) translating new energy visions into action and designing for disruption.

PART ONE

European Regional Scenarios

THE GRAND TRANSITION SCENARIOS AND THE EUROPEAN VALUES TRILEMMA

A closer look at the three scenarios in the context of the future of Europe raises the question of which values in the European 'Values Trilemma' – liberty, a good society, or national identity – European societies and governments will choose as the dominant key to the future.

In **Modern Jazz**, marketplace opportunities and an increasing priority on global competition for economic growth put an emphasis on liberty, with a rollback of some European rules and regulations that citizens and businesses have highlighted as needlessly restricting growth.

In contrast, **Unfinished Symphony** shows a world in which Europeans feel that the EU project of harmony and fairness to all – a good society – is worth making the necessary sacrifices, with greater integration being a major influence on the direction businesses, especially energy businesses, can take.

Issues of national identity shape the world of **Hard Rock**, with businesses in different parts of Europe beginning to develop in very different and sometimes contradictory ways.

MODERN JAZZ

Modern Jazz is a world featuring increasing but unevenly distributed speed of innovation, with an ever-present potential for bubbles and shocks. In this world, the market flourishes, in part because social institutions are more fluid and agile, with effective, robust, non-territorial networks. It is a story of exponential growth opportunities brought about by data-empowered consumers, accelerating cost reductions and increasing speed to global market.

At the national and European level, policy makers seem mired in arguments about the best way forward, although most agree that businesses need to be freer to experiment and innovate. This consensus leads to local, self-organising behaviour with an outward-looking emphasis. Rather than building on cooperation at the European policy-making level, businesses look to other types of institutions through which to collaborate, and citizens look to businesses to help solve problems, even at the social level.

City-to-city initiatives flourish, with opportunities for business innovation and connection and a search for markets outside Europe. **Modern Jazz** features a world of polycentric coalitions and intense international competition with uneven results at the local level. Energy security risks are increasingly outsourced to consumers, and new insurance mechanisms against market or supply failure are provided by global fintech markets.

One of the developments that speeds energy systems transition is innovation in the transport sector. One result is a significant drop in the cost of batteries, most of which come from abroad. At the local level, private passenger vehicle fleets contract because of congestion fatigue and the development of on-demand mobility services, both of which drive smarter integration of public transport systems and encourage working from home and ride-sharing.

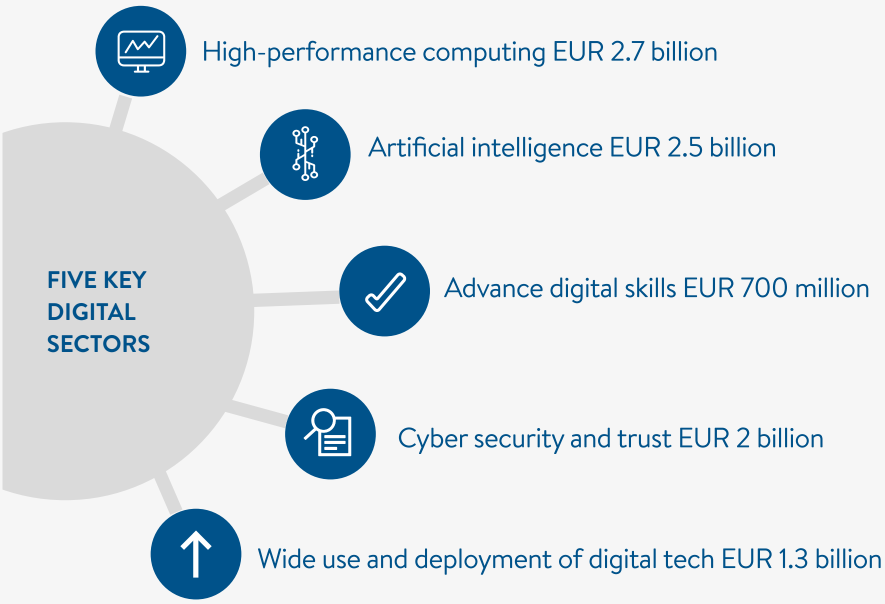
In other respects, too, this is a digital world in which agile first movers have an enormous advantage. Digital transformation of European business and society offers huge opportunities for growth and includes the fusion of advanced technologies such as the Internet of Things, big data, advanced manufacturing, robotics, 3D printing, blockchain technologies, artificial intelligence, the integration of physical and digital systems and the creation of smart products and services. The uptake of digitalisation increases everywhere, but gaps emerge between high tech and more traditional sectors as well as among large frontier companies and lagging small and medium enterprises.

PAN-EUROPEAN DIGITAL EUROPE PROGRAMME

Digital Europe is a new programme and part of the 'Single Market, Innovation and Digital' chapter of the EU's long-term budget proposal.

An overall budget of **EUR 9.2** billion is proposed for 2021-2027 to shape and support the digital transformation of Europe's societies and economies.

Current status: public consultation on the direction of the first two years of its new, seven-year Digital Europe infrastructure plan.



Source: European Commission, Investing the Future Digital Transformation

The relative lack of regulation of innovative digital businesses means that some new and non-traditional US and Chinese innovators move more nimbly than incumbent European energy firms along a growth path towards monopoly. At the same time, the rapid development of local, zero marginal cost renewable power and off-grid solutions reduce the economic case for new investment in a pan-European grid. Even in this low-margin world, however, locally produced energy, especially renewable electricity and shale gas, can be profitable.

Sustainability in **Modern Jazz** is encouraged through value-adding services, which deliver co-benefits in terms of cost, health and sustainability. An implicit price on carbon is one of the many 'ethical internalities' priced into services, with the market left to decide which pathway to pursue for the best results. As end-use electrification accelerates, there is greater vulnerability to demand-side shocks. New global storage solutions tailored to the needs of urban consumers are developed through intense competition between digital majors, state-owned energy companies and 'moonshot' philanthropy. The developments in energy blockchain registries and certification allow for financial consequences to be estimated for emissions associated with energy production versus fuel use versus battery materials, and for production versus waste recycling. Even so, the road to carbon pricing is not a smooth one.

This is a consumer-driven, digitally transparent, agile and adaptable world of much greater energy efficiency, in which new investments in innovation are monetised very quickly. Policymakers let the market decide, intervening mainly to offer incentives for innovation. These innovations in services and efficiency as well as in technology make progress towards the 'Clean Energy for All Europeans' but they do not deliver the full ambition, in part because of policy volatility. In 2030, the savings in primary energy would be about 27% (compared to the 2007 EU-baseline projections for 2030), and approximately 32% in greenhouse gases emissions in 2030 compared to 1990.

There is great variability in pricing as well as more stress on decentralised cyber security than on conventional energy security, but there is also increased cyber crime, identity theft and disruptive fake news. Corporations are held liable for data privacy – the larger the firm and the greater the monopoly position, the larger the demand by consumers for data protection and cyber security audits.

In the world of **Modern Jazz,** social cohesion is not the key concern, and national identity falls far behind self-authorship. A new era of energy abundance for prosperity unfolds, and economic value migrates from manufacturing volume to value-adding services.

UNFINISHED SYMPHONY

In this world, challenges from within and outside the EU, including the threat of another global financial crisis and recession, draw the European states closer together – but with a difference. Brexit has highlighted the unhappiness of many citizens, not just those from the UK, with what they perceive to be the heavy-handed and ineffective EU leadership.

The dissatisfaction reaches such a crescendo that new approaches to intelligent subsidiarity are enabled as part of European policy as well as in response to citizen demands for a clean and just energy transition and affordable decarbonisation policies that mitigate the impact of energy transition, especially on the poor. Subsidiarity, a long-standing principle in the European project of building harmony and a just society, moves from policy rhetoric into reality at all levels (local, national and European). Decision-making is realised at a level where it is more efficient, resulting in different measures and approaches being adopted in pursuit of shared goals and more explicit and efficient definition and distribution of responsibilities between States and the European Union. For instance:

- responsibility to the States in the energy mix, the organisation of the electricity sector as currently illustrated by the US and direct targeted transfers, tax reforms, etc.
- responsibility to the EU level in matters such as global issues like Gt CO_2 regulation, energy independence or R&D policy
- responsibility of a new pan-European agency – the European Digital Economy and Energy Resiliency Agency (DEERA) – for coordinating energy matters, innovation and new industrial policy

The symphony remains intact – it's just that the old bureaucratic leader has been 'fired', and a new conductor is leading in a different way.

The new subsidiarity allows targets to be set for the whole of the region, 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.

The energy system is a pivot to a new era of sustainable growth for the region, although different states put varying degrees of emphasis on balancing the energy trilemma and integrating energy policies with other priorities such as job creation, deep decarbonisation and industrial policies. Keeping everyone playing the same tune is a challenge in many areas. For companies, another challenge is to determine what they can do best at the national level and where it is advantageous to engage the EU as a whole.

By 2023, DEERA creates a network of battery innovation hubs, quickly followed by regional innovation hubs on the new hydrogen economy and later, on advanced nuclear. At the same time, DEERA mainstreams a broader sustainability agenda that succeeds in maintaining a high level of decarbonisation through enabling cooperation among EU members as well as countries such as Norway, Russia and the UK.

INFRASTRUCTURE ACTION PLANNING – NETHERLAND CASE

In 2016 Energie Beheer Nederland B.V (Dutch government entity) released a Netherlands industry-wide action plan to address energy infrastructure decommissioning

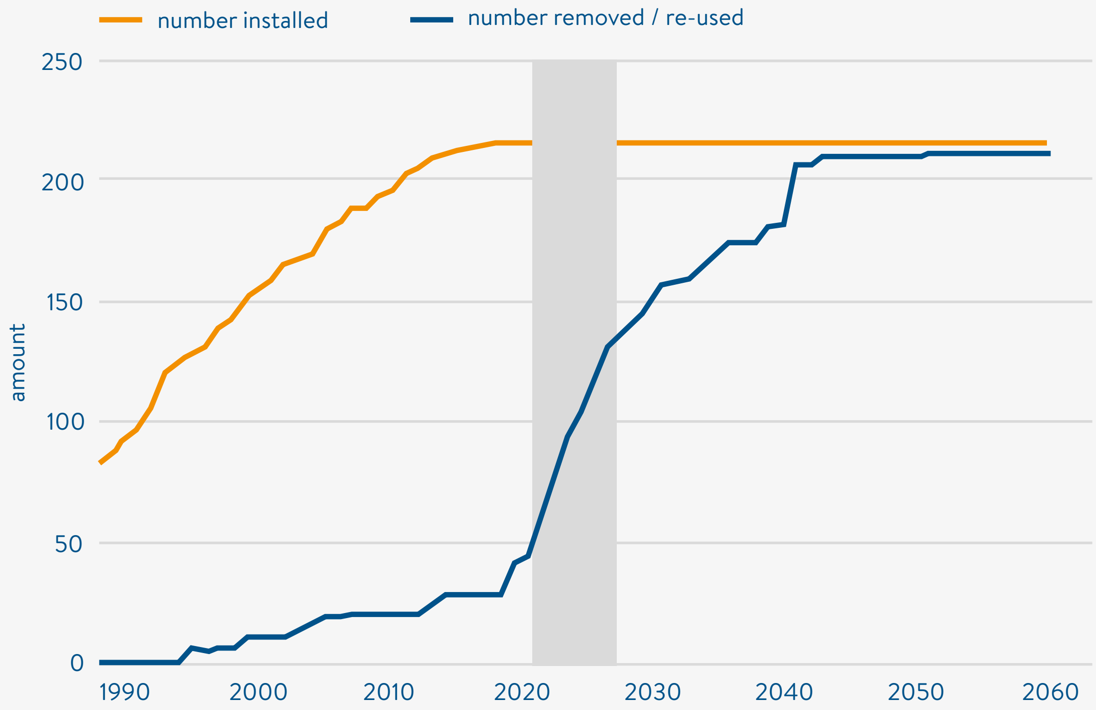
It aims **'to ensure a safe, efficient and effective decommissioning of Dutch offshore infrastructure'.**

The plan sets out a long-term vision for an integrated approach to decommissioning as well as a **20-year specific plan** to optimise the decommissioning of approximately 1**50 offshore platforms and 1,800 active wells.**

One of the goals is to reduce the costs of safe and environmentally friendly decommissioning in the Netherlands by 30%.

In 2017 NexStep, National Platform for re-use and decommissioning, was established by the Energie Beheer Nederland to implement the action plan.

The Cumulative Number of Installed and Removed Offshore Infrastructure Items in Netherlands



Source: Energie Beheer Nederland, NexStep

Opportunities for sector-coupling are seized, partly as a route to affordable emissions reductions. The single electricity market is enabled through reforms, primarily in anticipation of the push for global grid developments by other regions. In **Unfinished Symphony,** almost everyone can see the benefits of better and varied connectivity across Europe and of integrating policies to help create circular economies. Reform of market design ensures electricity security by providing long-term signals for all plants (existing and new).

Industrial strategy varies from State to State, but almost all countries put a strong emphasis on R&D, helped by support from the European Network of Clean-Tech Centres. Some are more successful than others in creating nodes of innovation, particularly in the increasingly globally connected cities. Given these different pathways of development, opportunity is unevenly distributed, but the cultural emphasis on strong social safety nets means that while countries may vary in their levels of innovation, they do not vary as much in their levels of individual inequality.

The European project is a constant struggle of ensuring regulations are at the right level. Climate targets and new building standards are two key drivers of collaborative innovation between energy and chemicals in developing new materials, recycling wastes and reducing emissions. As different nations try out different solutions, DEERA attempts to synthesise the learning from each so that the best practice is quickly shared and – partially because of the more nimble world of intelligent subsidiarity – quickly adapted.

There are some unexpected consequences of the new subsidiarity of **Unfinished Symphony**. Coal and nuclear, for example, are phased out in some countries more slowly than expected – coal because innovative carbon mitigation methods allow coal use to meet targets while maintaining profitability; and nuclear because innovation in large-scale batteries and the material intensity of the global acceleration in the renewables revolution is constrained by resource bottlenecks even with the strong recycling policies implemented in this scenario.

Unfinished Symphony is a world in which innovation is based on diversity and multiplicity rather than on speed. Market risk is the real danger in this scenario. But by 2040, public trust in new European institutions, significant progress in relation to the UNSDGs and climate targets, clean liquids pathways and new models of economic development form a virtuous circle of increasing prosperity and flourishing communities.

HARD ROCK

In **Hard Rock**, EU citizens become more and more dissatisfied with suffering from heavy-handed, top-down bureaucracy on the one hand and from being negatively impacted by immigration and global market forces on the other. Right-wing, nationalistic candidates win surprising victories in many countries and insist on going their own way in an increasingly #mefirst world shaped by Brexit, 'America First', growing pressure from China and a disruption of the global trading system. The ties that hold the Union together begin to fray, and the result is a surprising growth of inequality among countries. Individuals revert to their own identities and cultures which, in many cases, are not geographic.

The **Hard Rock** world is a world of low trust, more bilateral cooperation between countries, uneven productivity gains and lower global GDP growth. As the era of cheap and easy credit comes to an end, European governments face tough limits on investment and emphasise local security as part of national flag-waving. Increasing barriers to data-sharing make it more difficult to empower consumers.

Electric vehicles flourish in some states, but the development of autonomous vehicles is stalled, again because of the lack of data-sharing. Most countries emphasise local security and systems resilience rather than whole systems transition, but even so, efficiency improves slowly, driven by regionally higher prices and localised innovation.

In this world, the free movement of people is both a curse and a blessing because talent moves to the richer areas that have somehow managed their energy systems more effectively, without the frequent blackouts that other regions are beginning to suffer. The warping of the fabric of Europe is seen most starkly in stronger bilateral relationships with the US, Russia and China; these bilateral relationships go far beyond cheap gas (US-Poland), new nuclear (UK-China), cross-border gas pipelines (Russia-Germany) and massive electrical grids (Russia-Baltics) to include new coal deals. And while there is bilateral cooperation and a greater reach of new regionalism into Europe, there is much less multilateral cooperation.

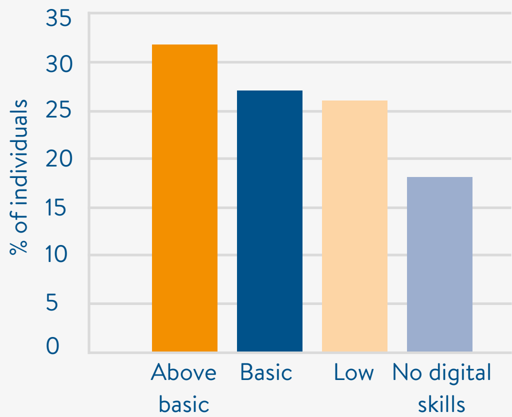
Within the region, there are green countries and brown countries, but generally, the absence of a single energy market in Europe does not increase the number of blackouts. Concerns for lower local pollution often go hand in hand with decarbonisation of the national energy mix, as do concerns for security of supply and dependence on imports of fossil fuels. However, limited development of cross-border infrastructure agreements and the breakdown of the multilateral order, slows the pace of global clean energy trading.

Youth unemployment becomes more urgent on the European agenda. Massive job losses following the 2008 Great Financial Crisis are compounded by the growth of joblessness in the digital economy and the lack of decent jobs. Digitalisation and technological skills obsolescence also raise concerns about whether the European workforce is adequately prepared for the Fourth Industrial Revolution.

ENERGY JOBS AND SKILLS GAPS IN EUROPE

EUROPE: DIGITAL SKILLS GAP

With the increasing pace of digitisation in the energy industry, one of the most significant challenges facing the sector is the technology skills gap (ICT) that is stalling digital progress. Almost half of the Europeans lack basic digital skills, such as using a mailbox or editing tools or installing new IT devices.



UK IN FOCUS: ENERGY AND UTILITIES SECTOR

In the power industry, there is a high un-met demand for technical skills, particularly IT and electrical engineering skills, against a backdrop of low STEM subject uptake at advanced levels. In addition, an ageing workforce poses another challenge. Bridging the gap requires developing an agile workforce that can respond to changing energy generation profiles.

people are employed in the energy sector and utilities sector across the UK

of the workface will retire within **ten years** requiring **221,000 new recruits.**

Source: European Commission, Digital Scoreboard 2017; Energy and Utilities Workforce Renewal and Skills Strategy:2020

As action on the Paris Agreement wanes, global climate change momentum builds, and Europeans experience more frequent and severe extreme weather events. National policy imperatives focus on climate change adaptation. The challenge of securing southern and eastern borders escalates as the water crisis in neighbouring regions triggers mass migration along regional corridors from Africa and the Middle East. With less cooperation, other priorities and limited economies of scale, energy becomes more expensive.

In **Hard Rock**, challenges are exacerbated by a declining and ageing European population attempting to deal with a growing and young population on its southern and eastern borders. In this and other areas, it is clear that EU institutions are becoming more and more irrelevant to local communities, member states and the world at large.

PART TWO

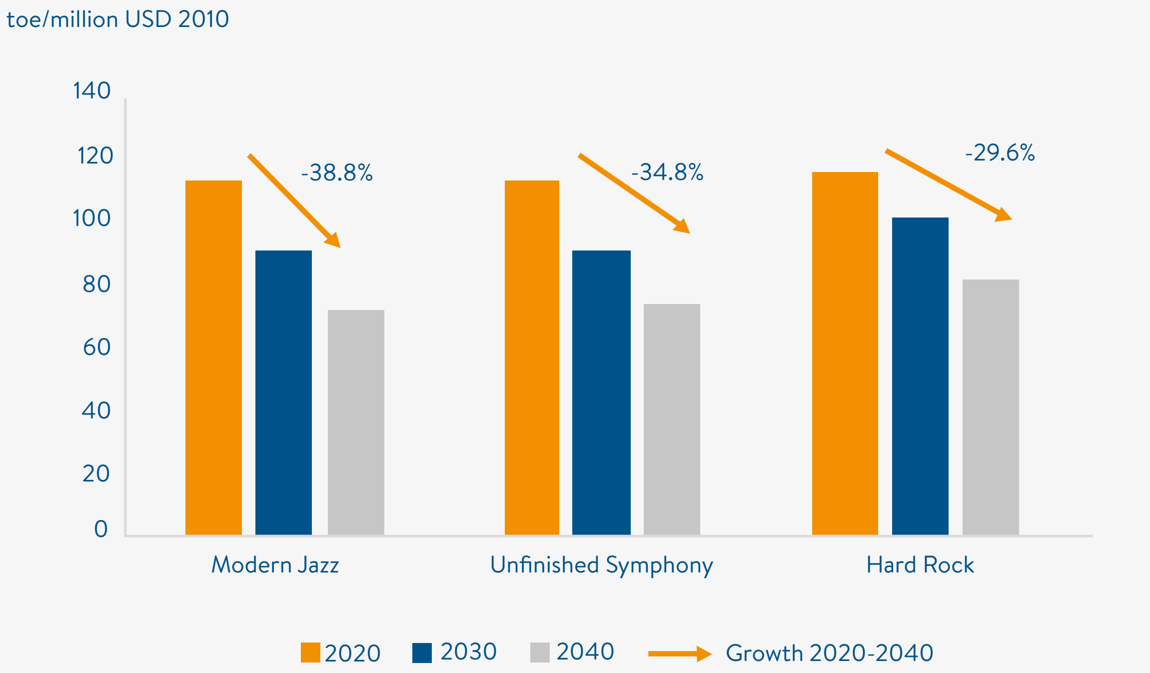
Energy Implications

This section lays out the expected modelled outcomes for each of the scenarios to allow users to more easily compare and contrast them and is designed to complement the scenarios narratives, providing a link to the scenario modelling.

ENERGY INTENSITY

Energy intensity improves throughout the projection period in all the three scenarios; however, the regions within Europe witness varied improvements. Eastern Europe experiences an increase in energy intensity before decreasing post-2030 under the **Hard Rock** scenario.

Figure 1. Primary Energy Intensity (toe/million USD 2010)



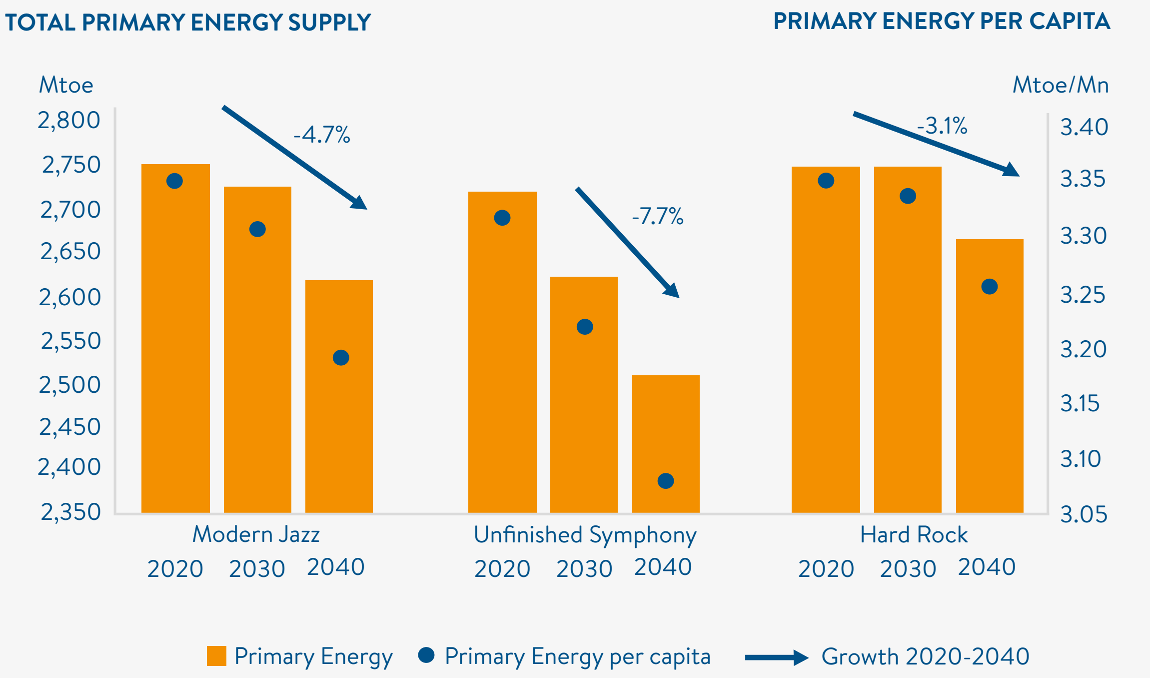
Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

- **Modern Jazz:** Eastern Europe and Russia have high energy intensity initially and observe slow convergence with EU 31.
- **Unfinished Symphony:** Decline in energy intensity in Eastern Europe and Russia converges faster with EU 31 in the long term compared to **Modern Jazz**.
- **Hard Rock:** In EU 31, existing policies are sufficient to secure a faster decline in energy intensity than in the past. In contrast, in Eastern Europe and Russia, there is a deceleration compared to past trends as these geographies start from relatively high initial levels of energy intensity and do not currently have strong energy efficiency policies in place.

PRIMARY ENERGY CONSUMPTION

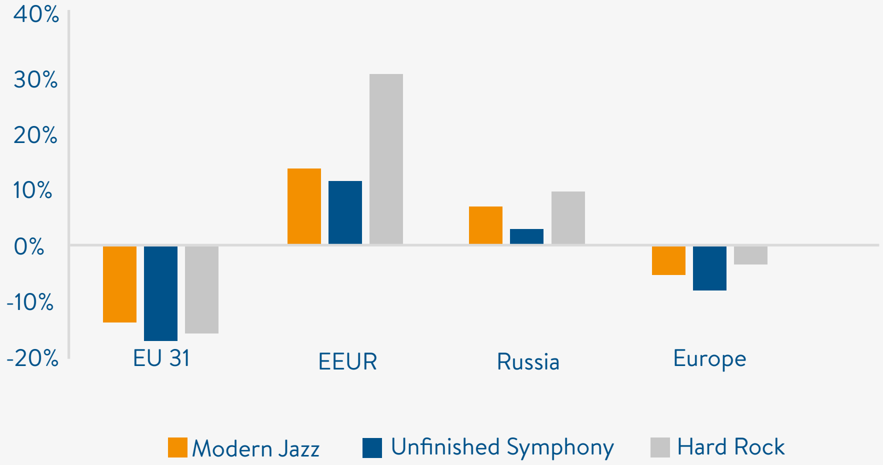
Primary energy consumption continues to decline in all the three scenarios for the region overall. However, Eastern Europe experiences an increase in primary energy consumption in all the three scenarios before declining post 2040, when efficiency gains partially offset the increase in energy consumption created by high economic growth in the region. There is a shift from fossil-based primary energy consumption towards renewables, although fossil fuels remain the dominant source of primary energy even in 2040. The share of gas increases the most in **Modern Jazz**. Nuclear power expands the most in **Unfinished Symphony** and is driven by decarbonisation policies and governmental support. In **Hard Rock**, nuclear power is more dominant than in **Modern Jazz,** as nuclear contributes to energy security, but less dominant than in **Unfinished Symphony** due to capital limitations and the use of domestic energy sources.

Figure 2. Total Annual Primary Energy Supply (Mtoe) and Primary Energy per Capita (Mtoe/Mn)



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

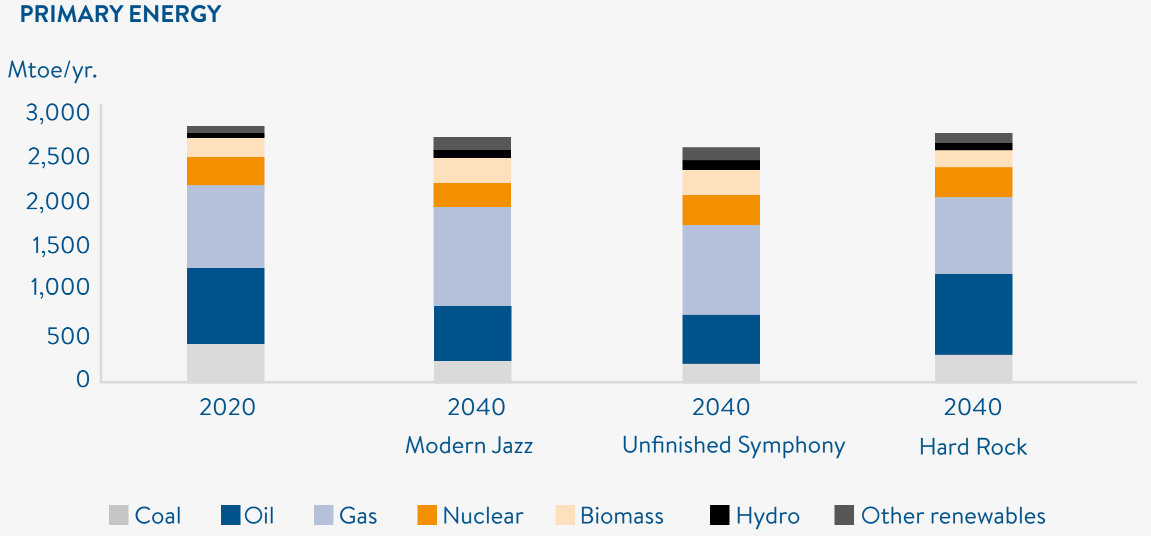
Figure 3. Primary Energy Absolute Growth 2020 to 2040 (%), Regional Breakdown



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

- **Modern Jazz**: Reduction in primary energy consumption is driven by legislation until 2020/2025, after which, it is driven by market trends and technology improvements. Oil does not represent the largest share in primary energy demand after 2025, as digital transformation enables smart mobility and reduction in battery costs drives the demand for electric vehicles. Gas is widely utilised for stationary demands and power generation. Nuclear and hydro retain their share in the energy mix, while wind and solar combined, triple their contribution between 2020 and 2040.
- **Unfinished Symphony**: Reduction in primary energy consumption is driven by decarbonisation and energy efficiency policies. Gas consumption remains constant and displaces coal in power generation. The share of nuclear and hydro only slightly increases by 2040, compared to 2020, since the hydropower potential in the region is already almost fully exploited. Major nuclear capacity expansion occurs mostly in Eastern Europe and Russia. Availability of sustainable bioenergy emerges as a critical factor for water supply and food security, since its use increases by two-thirds in 2040 compared to 2020 levels.
- **Hard Rock:** Primary energy consumption per capita declines for EU 31 but continues to increase for Russia and Eastern Europe. The continued consumption of oil throughout the projection period is attributable to the failure of planned transport policies. Gas consumption in Russia peaks in 2040, beyond which, because of increasing carbon prices, it is displaced by an increasing uptake of renewables. The development of hydropower stagnates, mainly because exploitation of the remaining potential is limited and costly. Uptake of wind and solar lags, but domestic bioenergy grows as a way to reduce import dependency.
- Fossil fuels continue to meet most of the primary energy demand across all the three scenarios.

Figure 4. Annual Primary Energy by Source (Mtoe/yr.)

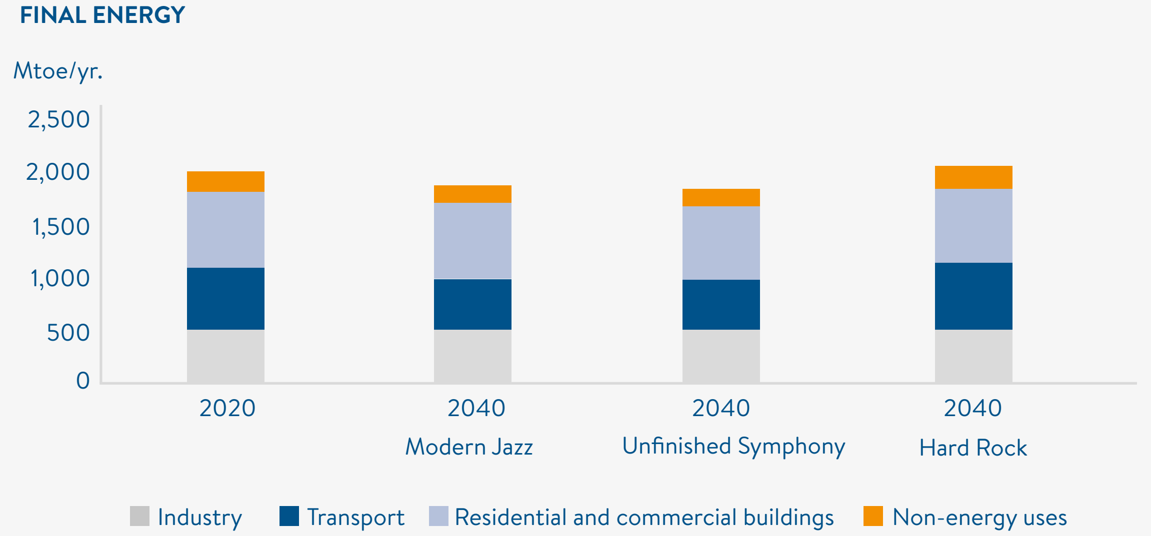


Please note that 'Other renewables' comprise Wind, Solar PV, Solar thermal and Geothermal
Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

COMPARISON OF SCENARIOS ACROSS DEMAND SECTORS

This section explores outcomes across the three scenarios for each of the three energy demand sectors: transport, residential and commercial and industrial.

Figure 5. Final Energy by Demand Sector (Mtoe/yr.)

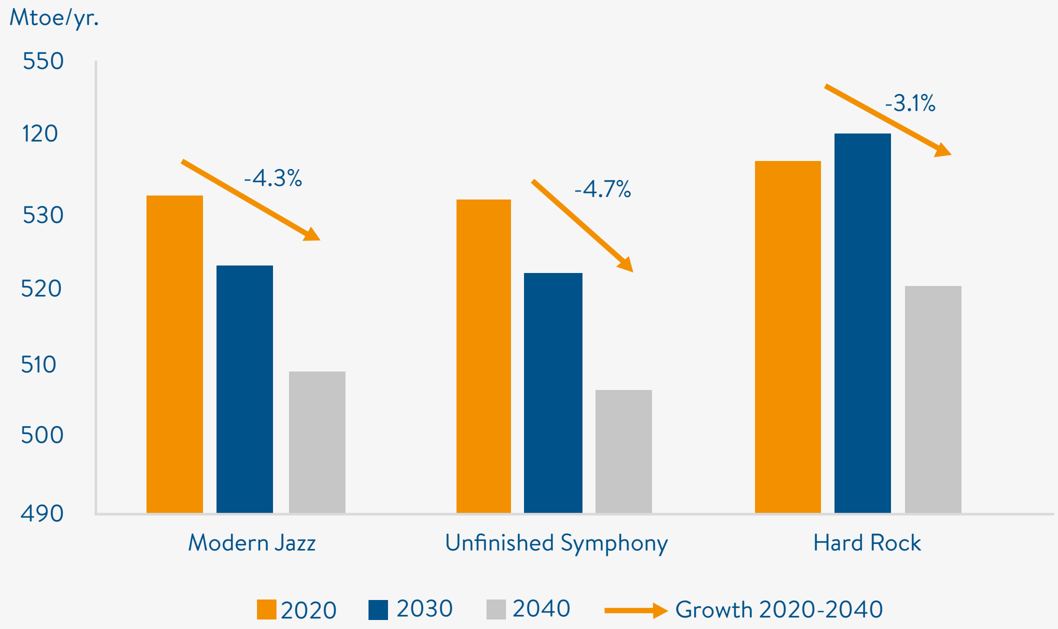


Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy
Please note that the Non-energy uses are dominated by industrial feedstocks (e.g., for petrochemical production). The energy carriers are oil (crude oils and oil products, such as additives, ethane, naphtha), gas and coal.

INDUSTRIAL SECTOR

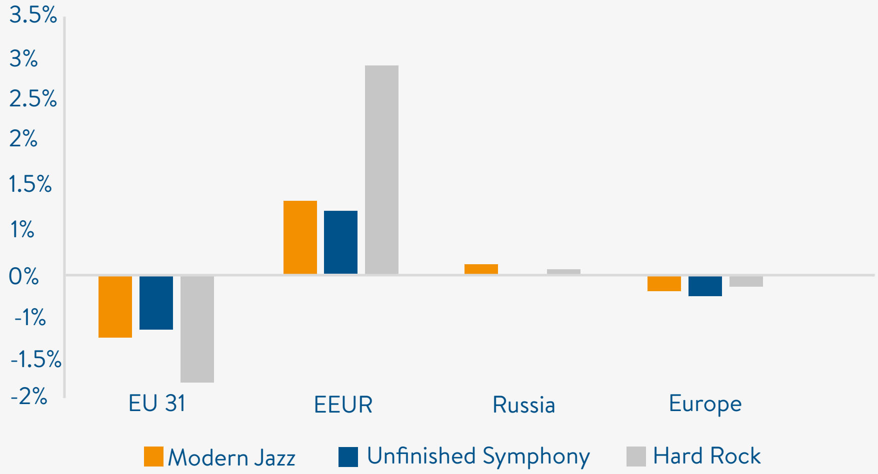
- **Modern Jazz**: Industrial activity recovers and follows a slowly increasing pace. There is a decoupling in the growth of energy consumption and activity in the sector, as innovation and advanced manufacturing facilitate new capital investment to increase penetration of energy-efficient technologies, while digitalisation drives substantial structural changes to higher value-added and lower energy intensity products. Energy consumption in industry shifts away from coal and oil and switches to gas, biomass and wastes and especially, electricity.
- **Unfinished Symphony:** While industrial activity increases, energy-efficient technologies, the circular economy and structural changes to higher value-added and less energy-intensive products, weaken the correlation between the growth of energy consumption and activity in this sector. Driven by higher carbon prices, energy consumption in industry shifts away from coal and oil and switches to gas, renewables and electricity.
- **Hard Rock:** Slowdown of the economy reduces the activity in industrial sectors, especially in EU 31, where products are of high value. Decoupling of the growth of energy consumption and the industrial activity in the EU continues, while industry remains energy-intensive in Eastern Europe and Russia. Gas and electricity displace coal and oil in industrial processes due to efficiency gains, but at slower rates than in **Modern Jazz** and **Unfinished Symphony.**

Figure 6. Final Energy Consumption from Industry (Mtoe/yr.)



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

Figure 7. Final Energy Consumption from Industry CAGR, 2020-2040, Regional Breakdown

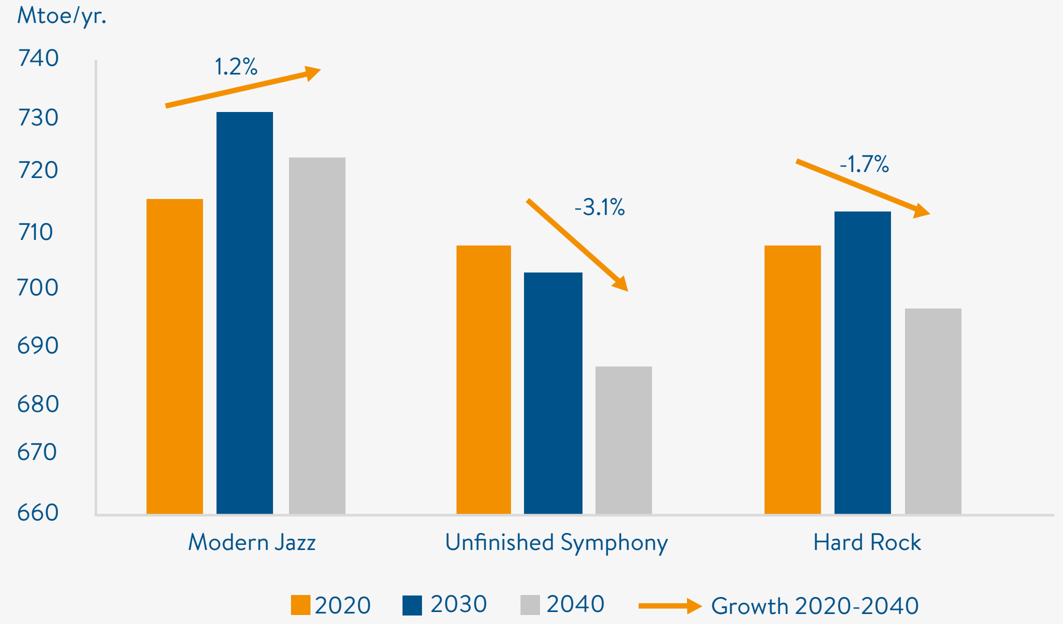


Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

RESIDENTIAL AND COMMERCIAL BUILDINGS SECTOR

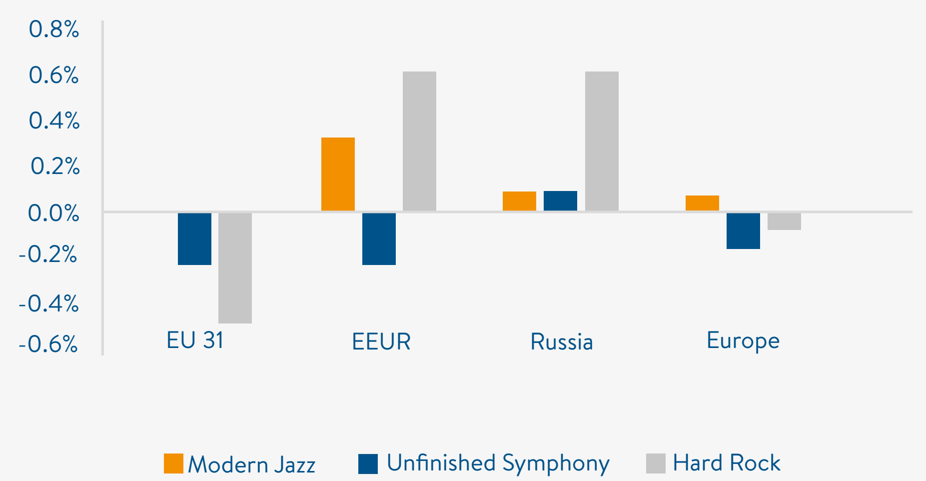
- **Modern Jazz**: Energy demand decouples from income growth more than would be suggested by the extrapolation of past and current trends, due to changes in the consumer behaviour, upgrading of the energy characteristics in buildings and use of more efficient equipment (e.g. lighting, electric appliances, cooling and heating). Oil use in the sector declines, and gas maintains its market share as comfort levels increase. The largest relative increase is in electricity, driven by electrification of space heating and increasing digitalisation in homes, including network-enabled digital appliances. In the commercial sector, significant efficiency gains are brought about by digital productivity, both for heating and electric-specific consumption, which more than offset increasing sectoral activity.
- **Unfinished Symphony**: Cost-effective efficiency gains are achieved by improving energy efficiency of buildings and end-use equipment. Barriers – societal, financial and behavioural –in the electrification of heating are lifted to a large extent after 2030; by this time, the cost competitiveness of heat pumps over conventional gas boilers increases, resulting in significant electrification of the residential sector. In the commercial sector, energy consumption declines as electrification achieves efficiency gains that offset increased sectoral activity, which, at the same time, assists in the sector's decarbonisation.
- **Hard Rock**: Affordability of energy is a key concern, especially in Eastern Europe and Russia, where a strong link between energy demand and income growth prevails. This determines the choice of affordable energy carriers as domestic prices rise due to faster depletion of domestic resources and import taxes. Gas becomes the dominant fuel for space heating in regions with good resource availability, displacing oil. The electrification of heat stagnates, as the cost-effectiveness of heat pumps does not significantly improve due to low carbon prices. Capital limitations and lower replacement rates of the ageing electricity supply infrastructure increase the cost of electricity for consumers.

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



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

Figure 9. Final Energy Consumption from Residential and Commercial CAGR, 2020 to 2040, Regional Breakdown

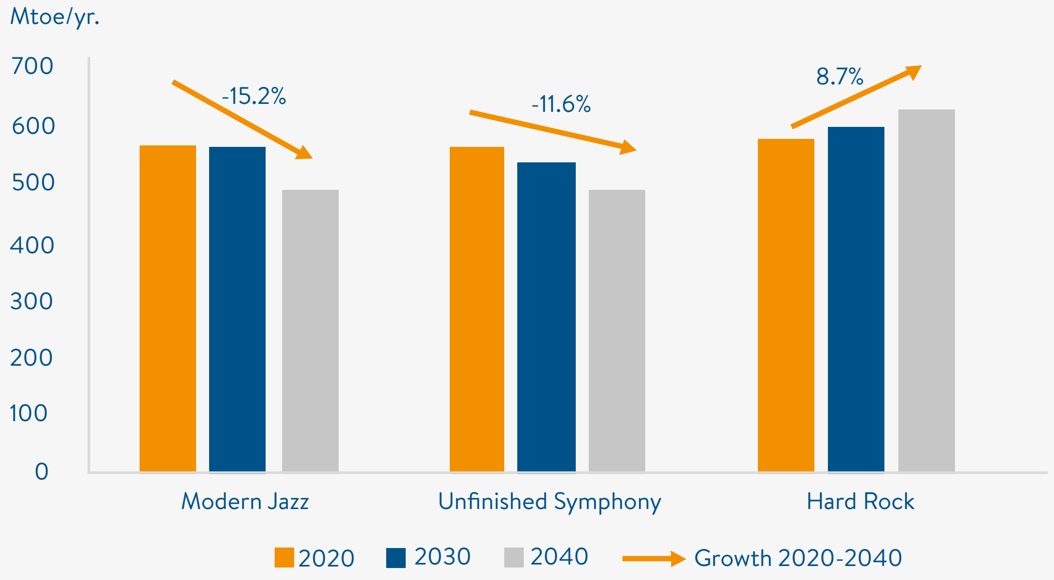


Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

TRANSPORT

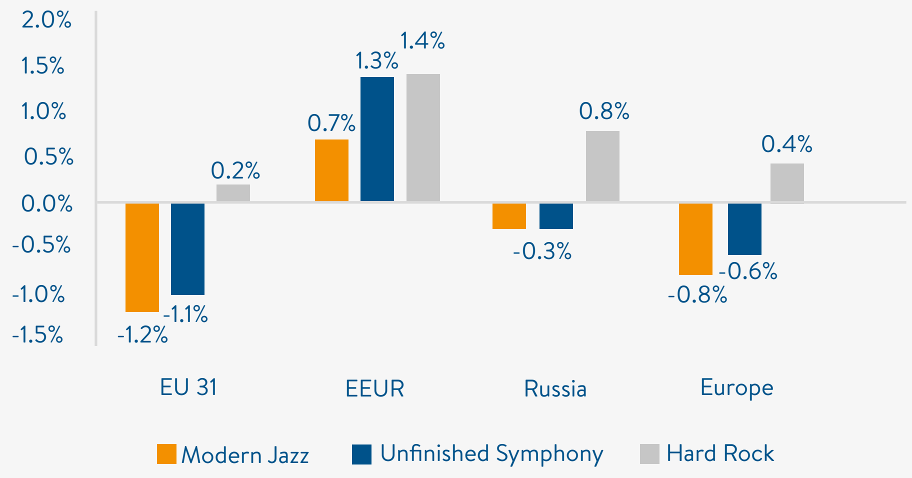
- **Modern Jazz**: Creation of smart mobility services slows down the growth of passenger cars and increases public road transport. In addition, the historical correlation of freight transport with economic activity weakens significantly over the projection horizon, as 3D printing develops rapidly and better localised and optimised distribution channels, such as optimised route planning, emerge. The digital transformation of passenger transport leads to a decoupling of energy consumption and activity, which intensifies in the post-2030 period. Driven by the significant drop in the cost of batteries, electric vehicles dominate urban mobility, while in long distance road transport, biofuels and hydrogen begin to displace oil after 2030.
- **Unfinished Symphony**: There is a profound transformation to less energy-intensive and non-fossil-based mobility. A significant decline in battery costs helps to achieve cost parity between electric vehicles and internal combustion engine vehicles before 2030, while electric trucks, also equipped with overhead catenary lines, start to be competitive with diesel from the mid-2030s. In this context, the majority of urban passenger mobility and short distance freight transport is electrified. Biofuels provide a low carbon alternative for long distance road transport by 2040, while electricity and hydrogen options also begin to emerge by then.
- **Hard Rock**: Oil products retain their dominant share in transport energy consumption, since vehicles based on alternative powertrains do not achieve cost parity with internal combustion engines. Planned policies promoting public transport and smart mobility are not implemented, and large-scale development of alternative transportation modes does not occur due to the high cost of new infrastructure. The development of local markets shortens the distances for freight transport and helps to reduce energy consumption. However, the link between transport activity and energy consumption remains strong throughout the projection period, especially in Eastern Europe and Russia.

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



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

Figure 11. Final Energy Consumption from Transport CAGR, 2020-2040, Regional Breakdown



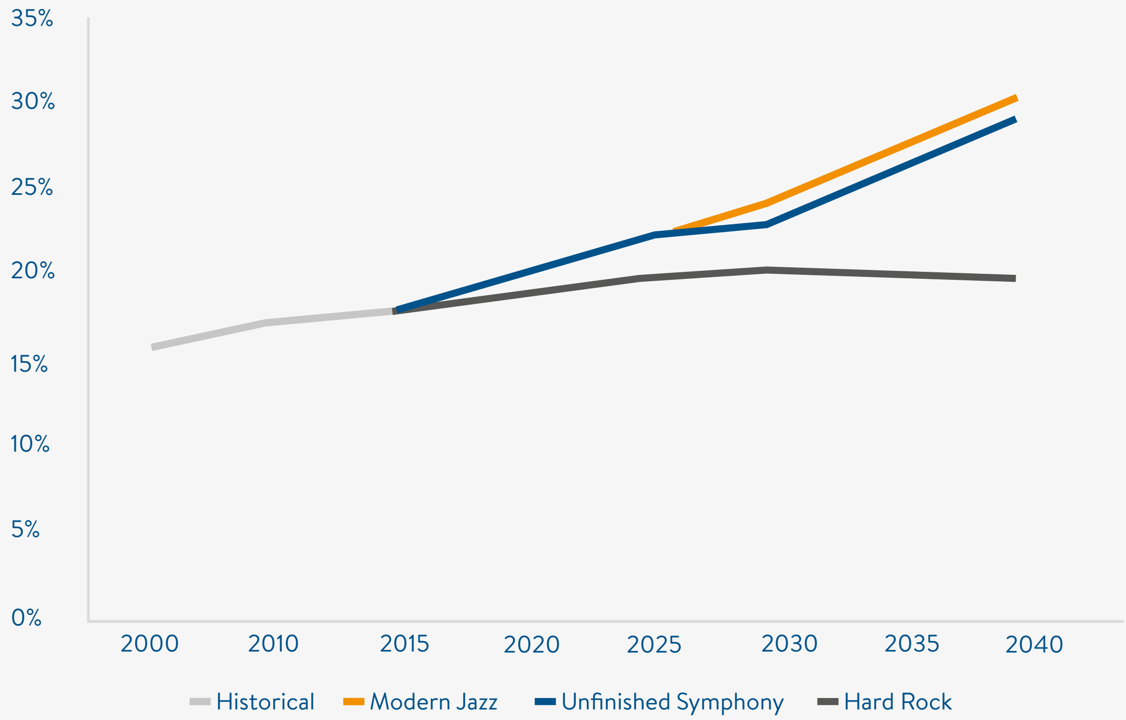
Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

In **end-use sectors**, efficiency is supported by technology improvement and better design, higher material efficiency (lighter materials for products such as cars, buses, and appliances, which in turn reduces industry energy demand), significant retrofit of buildings and significant levels of electrification of vehicles.

The **power generation** sector undergoes a profound shift towards low-carbon sources in **Modern Jazz** and **Unfinished Symphony**. In **Hard Rock**, power generation remains fossil-based, mainly locked in until 2030 by current investment plans. Uptake of CCS begins after 2025 in **Modern Jazz** and **Unfinished Symphony**, but its distribution among the different European regions is very uneven. In contrast, CCS does not play a role in **Hard Rock** as climate change mitigation policies are limited.

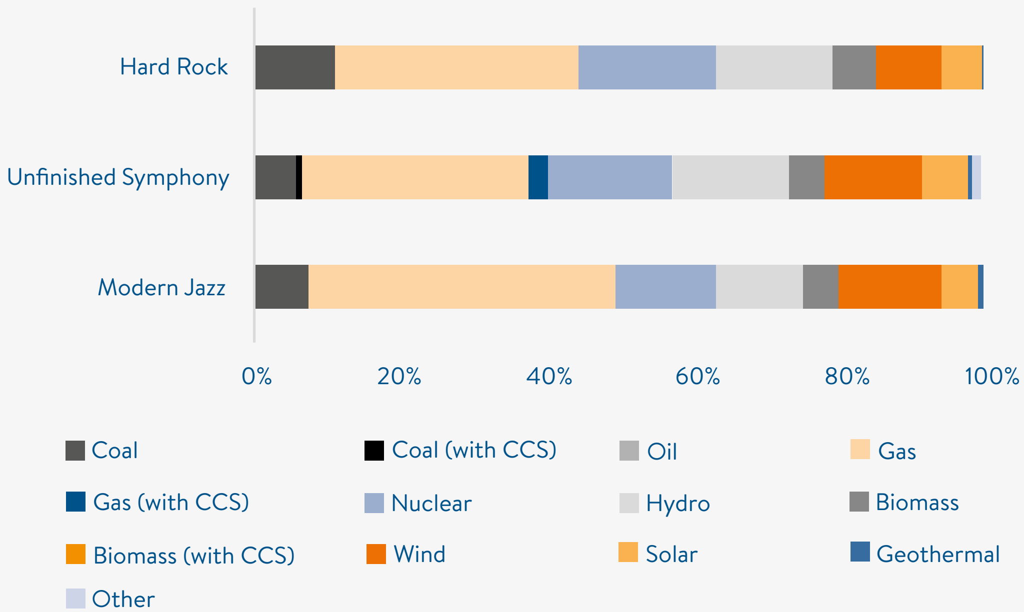
- **Modern Jazz**: The electrification of stationary and mobility demand in Europe reaches 30% in 2040. While digital devices such as the 'Internet of Things' result in increased demand for storage and data processing, the implications for electricity demand are only partially offset by efficiency improvements. The total electricity demand in Europe increases by 50% between 2020 and 2040.
- **Unfinished Symphony**: Overall, the electricity share in final energy consumption reaches 29% in 2040, as the increased use of electric devices and vehicles is partly offset by the increased energy efficiency of electric appliances, increased thermal integrity in the residential and service sectors and more rational use of energy across all sectors. The large-scale phase-out of conventional capacities, a more capital intensive power generation mix and the uptake of alternative fuels (for example, biofuels and hydrogen) lead to an increase in electricity costs which moderates growth in electricity demand.
- **Hard Rock**: Electrification of demand in 2040 remains similar to 2020 levels, at about 19%. There is only a 4% increase in electricity generation requirements between 2020 and 2040, leaving a small amount of headroom for renewables to step in and meet incremental demand. The low electrification rate is attributable to reduced activity in industry and services, lower incomes that slow capital stock turnover, the slow improvement of the cost-effectiveness of electric vehicles and heat pumps and the higher cost of electricity for consumers.

Figure 12. Electrification Rate of Final Energy Consumption (Electricity as % of Final Energy)



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

Figure 13. Sources of Electricity Generation in 2040 (TWh)



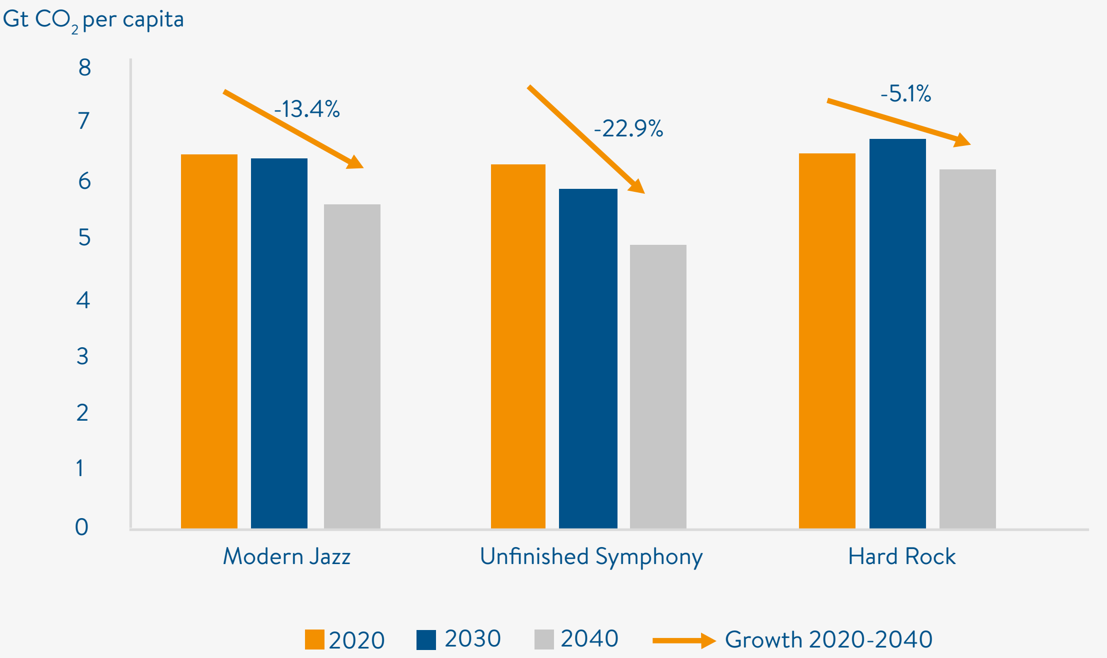
Source: The World Energy Council, Paul Scherrer Institute, Accenture Strategy

IMPLICATIONS FOR CARBON AND CLIMATE

Energy-related CO_2 emissions peak in 2020/2025 in **Modern Jazz** and **Unfinished Symphony** and in 2030 in **Hard Rock** and decline afterwards for all regions across Europe, including Eastern Europe and Russia.

- **Modern Jazz:** Energy-related CO_2 emissions peak in 2020/2025 and decline afterwards. EU 31 is in the driving seat for GHG emission reductions, achieving about 32% in 2030 compared to 1990 levels. However, the achieved reduction is below the target foreseen in the Clean Energy for All Europeans package, which implies that in order to achieve such reduction levels, additional measures should be implemented which go beyond the logic of the market and the growth-based world of Modern Jazz supported by the EU governments.
- **Unfinished Symphony:** Energy-related CO_2 emissions peak around 2020 and decline afterwards. The EU achieves roughly a 40% reduction in GHG emissions by 2030 compared to 1990 levels. At the same time, the reduction in primary energy consumption is about 28% by 2030, compared to the EU baseline projections of 2007. These outcomes suggest that the efficiency targets of the "Clean Energy for All Europeans" package, in contrast to the climate targets, are not met in the Unfinished Symphony scenario for the EU.
- **Hard Rock:** Energy-related CO_2 emissions continue to increase and peak in the 2030s in Europe as a whole, and in about 2025 in EU 31. Despite the reduction in emissions needed beyond 2040 in all European geographies, a drastic abatement of the emissions in the longer term would only be possible through large-scale deployment of negative emissions technologies.

Figure 14. Europe Carbon Emissions Per Capita (Gt CO_2 per capita)



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

PART THREE |

Additional Selected Insights

This section examines a number of energy challenges for further consideration, namely the German Energiewende, the French nuclear strategy, Russian gas to Europe, UK energy imports, Polish coal and H2/P2X developments in Europe.[2]

1. GERMAN ENERGIEWENDE

The full implementation of Germany's energy strategy is challenged in all scenarios in relation to emissions reduction renewable share and efficiency targets:

Table 1: Main Targets of Germany's Energy Strategy

	2020	2030
Nuclear phase-out		
	Completed by 2022	
Climate change mitigation targets		
GHG emissions (from 1990)	min -40%	min -55%
Renewable penetration targets		
Share in gross final energy consumption	18%	30%
Share in gross power consumption	min 35%	min 50%
Share in transport sector	10%	min 50%
Efficiency targets		
Primary energy consumption (from 2008)	-5.5%	-20%
Gross electricity consumption (compared to 2008)	-3.3%	-10%
Final energy consumption in transport (from 2005)	-10%	

The **climate targets** for 2020 and 2030 are not met in any scenario, although the phase-out of nuclear by 2022 occurs in all scenarios. The climate gap in 2020 — that is, the distance between the achieved reduction and the target – is between 6 and 15% points. **Unfinished Symphony** misses the target by the narrowest margin, while **Hard Rock** misses it by the largest margin; **Modern Jazz** lies in between, but closer to **Unfinished Symphony**. In 2030, Germany achieves reduction levels similar to the rest of the EU 31 (40% compared to 1990) in the **Unfinished Symphony** scenario and around 35% in the **Modern Jazz** scenario

[2]These insights are based on ex-post analysis and extrapolations of the European region's model results for topics relevant to the energy policy and challenges in the region. As such, the numbers reported in this section are indicative rather than firm forecasts.

(thus higher than the EU 31 average). The main reason for this outcome is the failure to achieve energy demand reduction and renewables targets in all sectors.

Renewable targets are also challenged in all scenarios. While the 2020 target regarding the share of renewables in power generation is over-achieved in all scenarios, the corresponding target in 2030 is missed by a narrow margin in **Unfinished Symphony** and **Modern Jazz** and by a much wider margin in **Hard Rock**. The target for the share of renewables in gross final energy consumption is achieved in all scenarios by 2020, but the target for 2030 is missed in all scenarios, and the corresponding share ranges from 20% to 25% across the three scenarios.

Finally, the **efficiency** targets are not met in any scenario. While the reduction of electricity consumption only just falls short of the target in all three scenarios, targets for the reduction of energy consumption for heating and transport are missed by a large margin.

In conclusion, the pathway for the achievement of energy and climate targets, especially in 2030, requires a combination of strategies and targets for each sector. Instead of ambitious targets to reduce overall energy consumption, a strong focus on specific sectors is necessary. The challenge of achieving the German energy transition needs to be addressed with policy measures that create an environment for a cost-effective way to meet the targets.

2. FRENCH NUCLEAR STRATEGY

The government's target of reducing the share of nuclear power in electricity generation to 50% is met around 2035 in all the three scenarios. By 2040, French net nuclear power capacity declines from the current 63 GW to about 39 GW in **Modern Jazz**, while in **Unfinished Symphony**, it drops to 42 GW and in **Hard Rock**, to 39 GW. By 2040, more than three-quarters of the existing nuclear capacity in France will be more than 40 years old. No new nuclear reactors are constructed in France by 2040 in any of the three scenarios, except the Flamanville 3 power plant, which is projected to start up in 2022.

3. RUSSIAN GAS TO EUROPE

Today, in the EU 31, which also includes Norway, Russia supplies about 60% of the region's total net imports of natural gas. While this share is largely retained in all three scenarios, over time the share of the EU 31 in Russian's exports declines. This is attributable to the reduction of the demand for gas in the EU 31 and the sharp increase of demand for Russian gas in China and India. Thus, in **Modern Jazz,** the share of the EU-31 in total Russian exports of natural gas declines from 70% today to about 50% by 2040, while in **Unfinished Symphony,** the EU 31 market absorbs about 45% of the Russian exports by then. In contrast, with higher domestic production and a decline of natural gas consumption in the EU 31 after 2030, the share of EU 31 in Russian exports drops to about 25% in 2050 in the **Hard Rock** scenario.

4. UK ENERGY IMPORTS

The main suppliers of fuels to the UK are within the EU 31, and in this context, only some basic qualitative analysis can be carried out. In 2017, the largest sources of coal imports were Russia (46%), the US (28%), Australia and Colombia (both 9%). However, the projected decline for coal in all the three scenarios will lead to a significant fall in imports of solid fuels by 2040.

Norway is the leading supplier, with a share of about 48% in UK imports in 2017, while imports from Nigeria and Russia have become less important. There is a declining trend in the contribution of Norway, as imports from OPEC countries increase in all scenarios for Europe. For oil products, Netherlands remains the largest hub of transport fuels, while aviation fuel mainly comes from the Middle East. Regarding imports of natural gas, Norway has a share of about 75% today, while the Middle East supplies another 15%. In the long term, the share of gas from the Middle East in UK imports is expected to increase in all scenarios, compensating for the reduced imports from Norway as gas production there peaks around 2025 and then gradually declines.

5. POLISH COAL

Today, the share of coal in total primary energy consumption in Poland is about 56%. In the **Modern Jazz** scenario, the share of coal drops to 23% by 2040. In **Unfinished Symphony**, environmental issues put additional pressure on Poland's dependence on coal, and the share of coal in primary energy is estimated to decline to 15% by 2040. In contrast, in the **Hard Rock** scenario, coal still accounts for one-third of total primary energy consumption. The power generation sector today has a coal power capacity of about 25 GW, of which more than half is expected to disappear by 2040, resulting in about 10 GW of remaining capacity. In the **Modern Jazz** scenario, coal power plants are gradually phased out due to depletion and stronger emissions standards, while no additional coal power plants are planned to be constructed in the country. Estimates show that in 2040, less than 10 GW of coal-fired generation will be in operation. In **Unfinished Symphony**, a faster phase-out of coal-fired power plants occurs as stronger Europe-wide climate policies make their operation unprofitable and as existing plants are decommissioned before the end of their lifetimes. Hence, the operating coal-fired capacity is estimated to be almost halved by 2040 in **Unfinished Symphony** compared to **Modern Jazz**. In contrast, in the **Hard Rock** scenario, coal still plays a role in power generation in the long term due to the absence of a strong climate policy; the coal power generation capacity totals 15 GW in 2040, which is in line with developments foreseen in the current Polish energy strategy.

6. HYDROGEN/POWER-TO-X DEVELOPMENTS IN EUROPE

The hydrogen economy mainly emerges in the **Unfinished Symphony** scenario and to some extent, in the **Modern Jazz** scenario, while in the **Hard Rock** scenario, the use of hydrogen as a significant energy carrier is slow to develop. The main drivers for the penetration of hydrogen in **Modern Jazz** and **Unfinished Symphony** are the innovation and diversification of energy portfolios, the penetration of renewables and climate policy. In **Modern Jazz**, about 1 EJ of hydrogen is produced in Europe in 2040, with 70% coming from gas steam reforming. Another 15% comes from electricity. The use of hydrogen occurs first in the transport sector, and after 2040, in co-generation for the joint production of electricity and heat. In **Unfinished Symphony**, stronger climate policy, the higher penetration of renewables and governmental support result in about 2 EJ of hydrogen by 2040. Roughly 40% of the hydrogen is produced from electricity, while another 40% is produced from gas steam reforming with CO_2 capture and storage. The rest is from biomass and coal with CCS. In the **Hard Rock** scenario, the penetration of hydrogen in the energy system is about 0.15 EJ in 2040, with almost all of it produced by gas steam reforming.

PART FOUR

Using Scenarios

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

– CHINESE PROVERB

The World Energy Council invests in the most effective use of all of its energy transition leadership tools, recognising the multiple barriers – including cognitive, cultural and capability constraints – that business leaders and government officials face when working with plausibility-based energy scenarios.

Using global 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. Purposes and users vary. 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 CONVERSATION – USING SCENARIOS TO CLARIFY STRATEGIC CHOICES AND IDENTIFY NEW AND BETTER OPTIONS FOR ACTION

Plausibility-based scenarios provide a platform for a 'safe space' for disagreement that facilitates strategic knowledge exchange 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 to 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 an icebreaker activity: What is the energy transition challenge that keeps you you awake at night?
- Present and briefly discuss findings from the **World Energy Issues Monitor.**

Step 2. Introduce 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 that 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 policymakers 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.

By developing a forward extrapolation of national policy performance, it is possible to develop a business-as-usual baseline and to explore the implications for making better progress by identifying new policy options that work 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 Regional 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 the greatest value for the lowest overall costs and the best fit for society.

Step 5. Build a new strategy

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

3 TRANSLATING VISION INTO ACTION: DESIGNING FOR DISRUPTION

A vision is a normative description of an imaginable 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 how they interact with each other leads to the discovery of new cross-cutting solution spaces that can used to enhance policy cohesion and/or to design new sector-coupling policies. The implementation of innovative, integrated policy options can be complemented by agile approaches that continue to enhance learning and help adapt policies as progress towards vision – or lack thereof – is achieved.

EXAMPLE OF TRANSLATION INTO VISION STRATEGIC GAME

Step 1. Agree a common priority – forge common ground

Participants select a specific theme as a common challenge and priority for action, e.g., new mobility, smart industry, consumer-centric system.

Step 2. Envision success

The energy leaders first reframe the problem into an opportunity space, e.g., New Passenger Mobility. Rather than 'fixing the carbon problem', new visions describe a new and different future that assumes low-carbon transport but adds other value propositions – for example, 'on-demand', 'seamless', 'integrated' and 'virtual' mobility services.

Step 3. Design for disruption

The participants then co-create different designs for constellations of disruptions by identifying which existing elements in each of the four building blocks – technologies, policies, social, business – might combine fastest in the context of their assigned scenario.

Step 4. Stress test

The participants then explore how the constellations of disruptions might scale in impact, by identifying feedback loops and clarifying the impact on the energy system. The resulting set of highly focused 'micro-narratives' complement the macro-narratives of the three regional scenarios.

4 RE-DESIGNING ENERGY BUSINESS

Energy companies, facing competition from beyond the energy sector, are developing new business models and using rapid, design-led action-learning cycles to bring to the market new products and services 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 from 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 rise of the energy prosumer and the emergence of a consumer-centric energy system underscores 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.'

To enable energy leaders' role as designers of disruption, the Council has developed a new micro-level disruptive thinking framework called 'Constellations of Disruptions' (or 'CoDs') that complements the macro-level disruptive thinking framework of scenarios.

'A constellation of disruptions is a combination of innovation accelerators that enable sudden and dramatic shifts in the "ways society operates" and that significantly disrupt energy supply and demand, as well as types of players and channels in the value chain.' – Accenture

Constellations of Disruptions[3] redirect attention from the first-order effects of improvements in a single technology to the non-linear interaction and impacts of a broader set of innovation accelerators – combinatorial technologies, policy and regulation, business models, social acceptability and behaviour change. A 'constellation', in turn, will trigger and scale, depending on feedback loops in the wider context. Energy leaders can explore how different CoDs might form, trigger and scale in each scenario - **Modern Jazz**, **Unfinished Symphony** and **Hard Rock** – and whether this is sufficient to close the gap with their preferred future, that is, their aspired vision.

Different methodologies for combining these macro (i.e., scenarios) and micro (i.e., CoDs) 'thinking framework disruptions' provide a way to explore the role of disruptive innovation in energy transition and were tried and tested as part of the three interactive dialogues in Paris, Berlin and Tallinn. Examples of the outcomes are shown in the Annex.

For more information on how to use the World Energy Scenarios 2019 to design for disruption see the Council's 'Designing for Disruptions'.

[3] Read more on Constellation of Disruption tool on a Council's 'Designing for Disruptions' concept note.

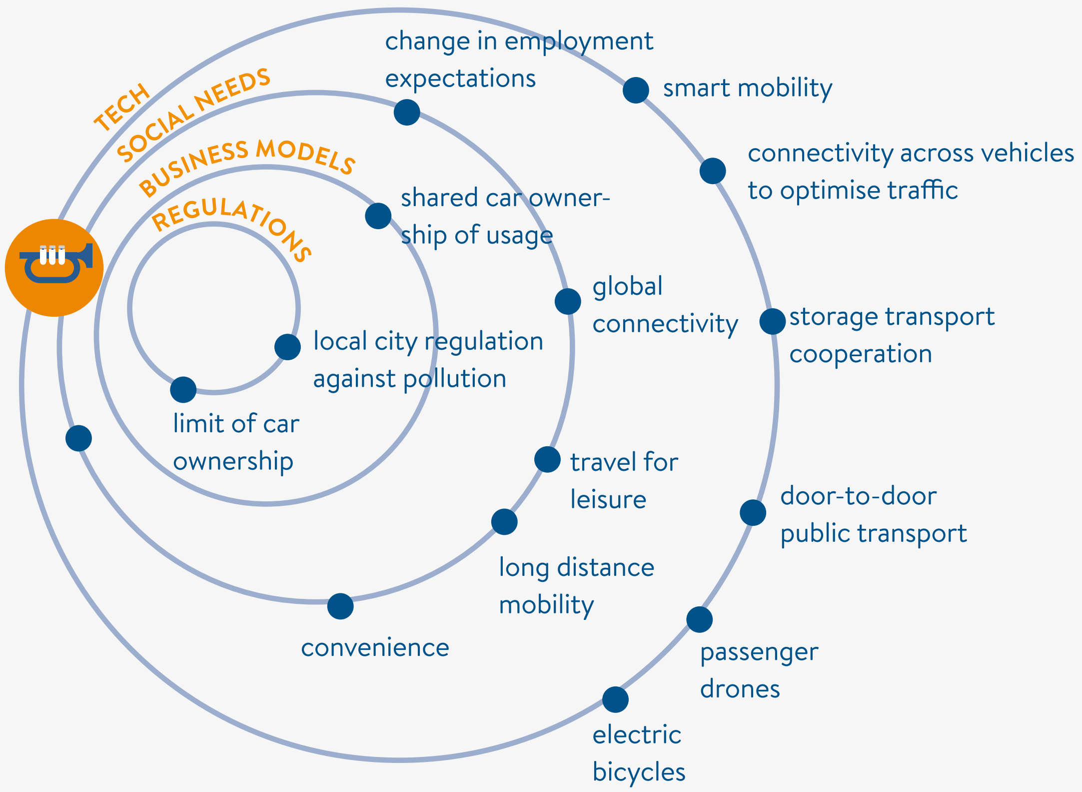
Annex

CONSTELLATIONS OF DISRUPTIONS

Illustrative design from European regional workshop in Paris.

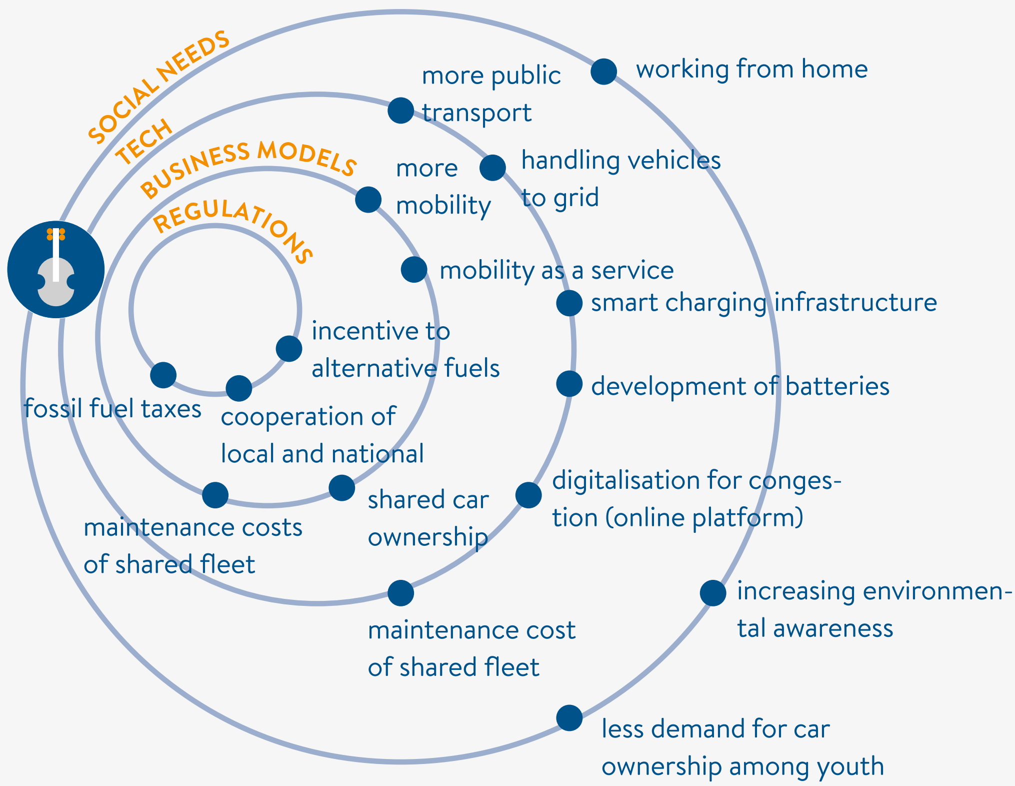
PASSENGER MOBILITY

In **Modern Jazz**, the changes in mobility are driven by technology development. Accelerated reduction in battery costs and progression in tech relating to connected vehicles creates cost incentives driving demand for EVs. Middle-class energy consumers have increasing access to smart devices, EVs and rooftop solar; this access, coupled with the desire to generate revenue, leads to peer-to-market (P2M) services – for example, EV owners sell battery capacity as storage 'prosumers' (production by consumers). This is enabled by permissioned and open-energy blockchain platforms that extend the P2M experience into other energy uses and attract new investment to energy-plus services and infrastructures. The rapid growth of peer-to-peer markets accelerates the development of a fully transactive, pan-European grid.



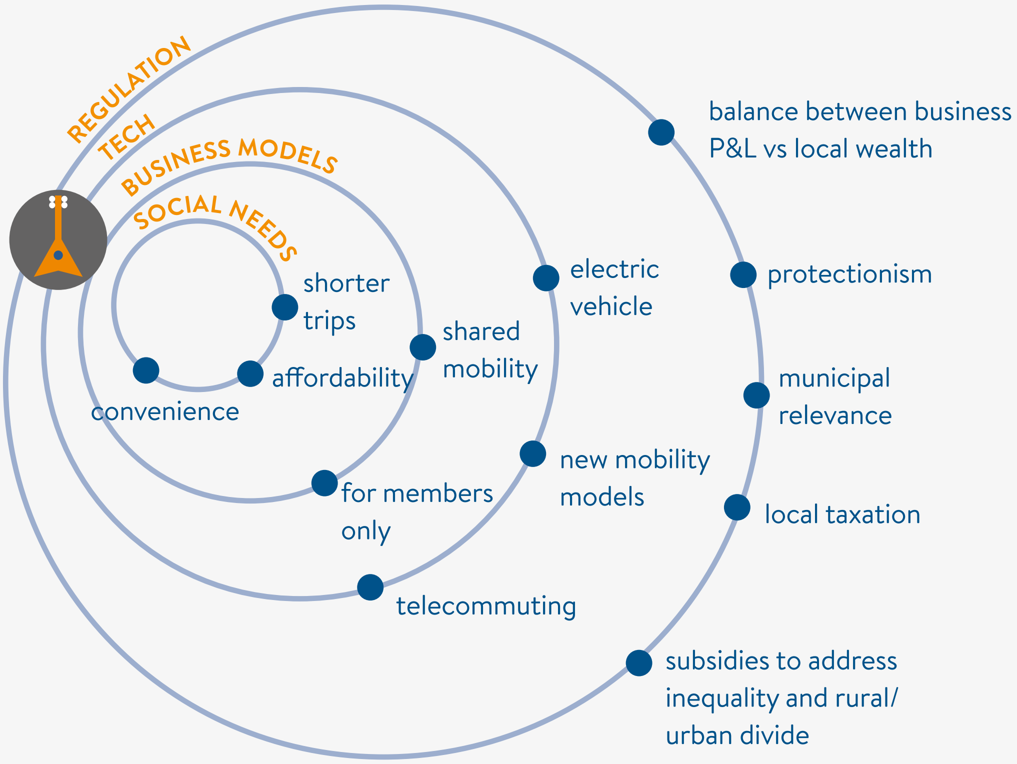
PASSENGER MOBILITY

In **Unfinished Symphony**, the need for social change triggers and supports changes in the market. The ever-louder voices of consumers and investors pushing for sustainable value chains supports the trend of displacing oil-based fuels. Shared car ownership models flourish. The progression of low-emissions zone regulations, incentives for alternative fuels and government support for charging infrastructure development drives the growth of EVs. Developments in telematics enable the capture and transmission of data from vehicles; this is enhanced by developments in 5G for improved data transfer, and coupled with progression in analytics, enables improved optimisation of vehicle operations and fleet management.



PASSENGER MOBILITY

In **Hard Rock,** regulation drives the main changes in passenger mobility – local taxation, subsidies, etc. Consumers seek affordable and convenient choices and favour sharing mobility. EV development is lower than in the other two scenarios, primarily due to lower economic growth/lower disposable incomes and a favourable policy environment for continued hydrocarbons consumption in some European countries. Unexpectedly quick progress in the cost reduction of battery technology and improved EV grid connection technology drive much more substantial uptake in EVs in this world.



GLOSSARY

%	Percent
°C	Degrees Celsius
AfCFTA	African Continental Free Trade Area
AI	Artificial Intelligence
BEV	Battery Electric Vehicles
bn	Billion
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
CO_2	Carbon Dioxide
CoDs	Constellation[s] of Disruptions
EJ	Exajoules
ETS	Emissions Trading Scheme
EU	Europe
EEUR	Eastern Eeurope
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
G20	Group of Twenty
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GMM	Global Multi-Regional MARKAL Model
Gt CO_2	Giga Tonnes (of Gt CO_2)
GW	Gigawatt
ICE	Internal Combustion Engine
ICT	Information and Communications Technology
IEA	International Energy Agency
IP	Intellectual Property
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
LNG	Liquified Natural Gas
MARKAL	MARKet ALlocation
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
NGO	Non-Governmental Organisation
O&G	Oil and Gas
OECD	Organisation for Economic Co-operation and Development
P2X	Power-to-X
PSI	Paul Scherrer Institut
PV	Photovoltaic

R&D	Research and Development
SDGs	Sustainable Development Goals
t CO_2	Tonnes (of Gt CO_2)
TPES	Total Primary Energy Supply
TW	Terrawatt
TWh	Terrawatt Hours
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
yr.	year

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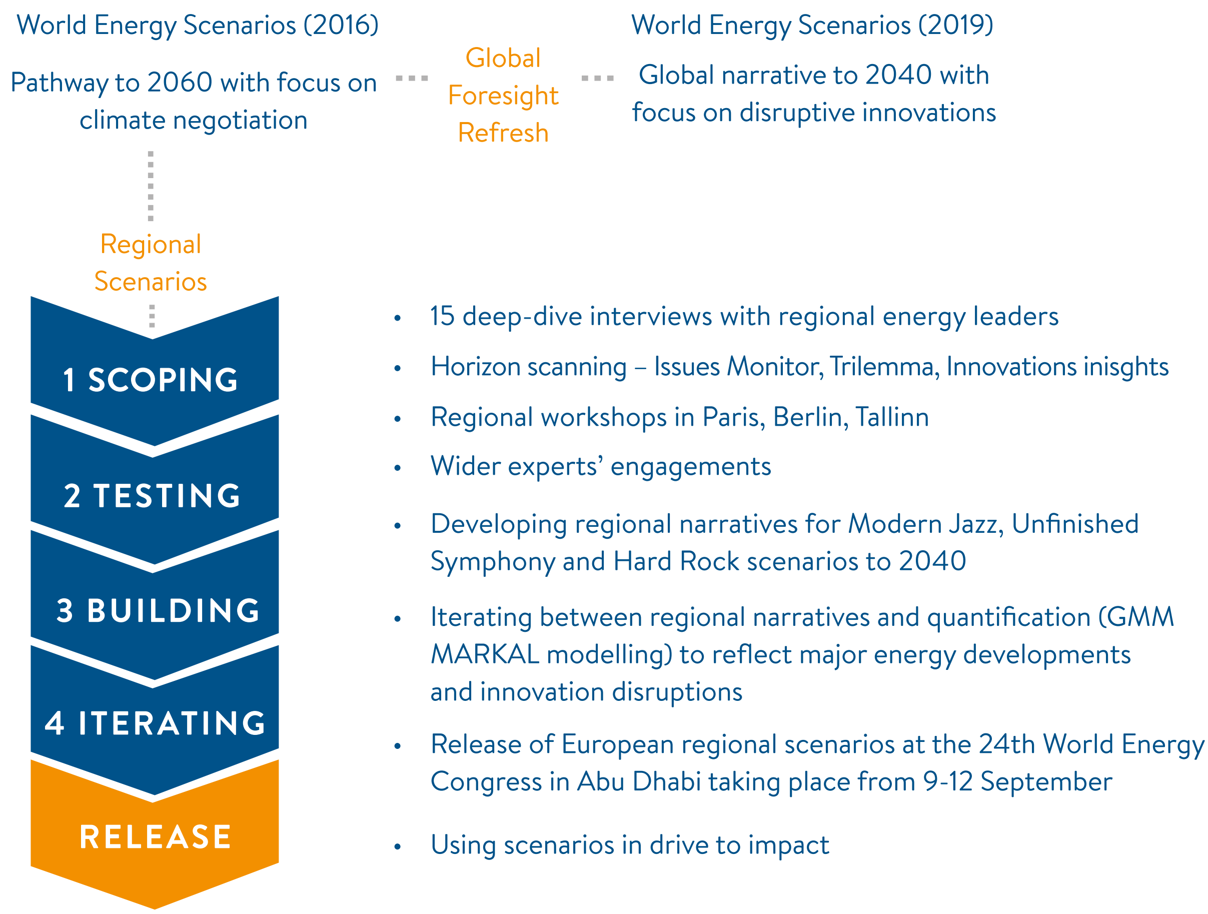
METHODOLOGY

PROCESS



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 a social planner's perspective with perfect foresight. GMM belongs to the family of MARKAL (MARKet ALlocation) type models, where the emphasis is on a detailed representation of energy supply, conversion and energy end-use technologies (i.e., 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 directly model the economy outside 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 on the Paul Scherrer Institute's website.[4]

GEOGRAPHIES

PSI's model contains seventeen world regions. For the purpose of this report, the World Energy Council refers to European region as EU 31[5], Eastern Europe[6] and Russia[7]. For each region, scenario assumptions influence the dynamics of supply and demand technologies (cost, efficiencies, 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 represented in the model.

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 sub-sector, the technology and fuel shares, 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 to 2020, national and regional outlooks are also taken into account (e.g. AEO 2018 for the US, EU Trends 2016 for the EU-31, China's five-year national plan, India's five-year national plans and several others).

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

[5] The EU-31 region includes the EU-28 member states plus Switzerland, Norway and Iceland.

[6] The Eastern Europe region includes the Republic of Turkey, Montenegro, the Republic of Kosovo, the Republic of Albania, the Republic of Serbia, Bosnia and Herzegovina, the Republic of North Macedonia, the Republic of Armenia, the Republic of Belarus, Ukraine, the Principality of Moldavia and Georgiane.

[7] The Russia region refers to the Russian Federation.

LIST OF FIGURES AND TABLES

FIGURES

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SUPPLEMENTARY DATA TABLES

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

Table 2. Modern Jazz Economic Indicators

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Population (million)	817	825	825	819	809	792	-0.1%
GDP (trillion USD2010 MER)	22	28	31	37	44	52	1.9%
GDP per capita (USD2010 MER)	27,188	33,377	36,990	45,209	54,613	65,135	2.0%
Primary Energy Intensity (toe/Million USD2010 MER)	125	99	89	71	56	45	-2.2%
Final Energy Intensity (toe/Million USD 2010 MER)	90	73	65	51	40	33	-2.2%

Table 3. Modern Jazz Primary Energy Supply (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	2,764	2,739	2,730	2,622	2,489	2,342	-0.4%
Coal	457	355	318	239	151	118	-3.0%
Oil	889	796	761	573	453	384	-1.8%
Gas	820	944	980	1,055	1,044	937	0.3%
Nuclear	305	276	273	263	263	254	-0.4%
Biomass	173	211	223	275	314	338	1.5%
Hydro	69	75	76	80	86	91	0.6%
Other renewables	52	83	99	137	177	221	3.3%

Table 4. Modern Jazz Total Final Consumption by Sector and by Fuel Source (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	2,004	2,002	1,987	1,876	1,775	1,687	-0.4%
Industry	530	535	523	510	490	480	-0.2%
Transport	578	557	561	481	447	415	-0.7%
Residential/commercial	702	728	731	723	687	649	-0.2%
Non-energy uses	194	183	172	162	150	143	-0.7%
Coal	199	108	94	76	62	50	-3.0%
Oil	795	724	691	523	413	353	-1.8%
Gas	434	451	438	42	393	360	-0.4%
Electricity	353	438	477	560	600	624	1.3%
Heat	166	173	169	160	157	151	-0.2%
Biomass & biofuels	102	96	98	104	111	114	0.3%
Other	2	14	20	30	39	35	6.7%

Table 5. Modern Jazz Transport by Fuel Source (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	553	557	561	481	447	415	-0.6%
Electricity	18	25	32	67	84	91	3.7%
Hydrogen	-	0	0	1	10	14	NA
Liquid fuels - fossil	477	466	455	324	241	198	-1.9%
Liquid fuels - biogenous	18	21	23	29	36	42	1.9%
Gaseous fuels- fossil	40	45	50	59	76	71	1.3%
Gaseous fuels - biogenous	-	-	-	-	-	-	NA
Other (coal)	0.2	0.1	0	0	0	-	NA

Table 6. Modern Jazz Power by Fuel Source (TWh)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	5,008	6,057	6,574	7,593	8,044	8,257	1.1%
Coal	1,116	945	853	565	234	133	-4.6%
Coal (with CCS)	-	-	-	7	22	41	NA
Oil	83	29	16	4	1	-	NA
Gas	1,184	1,986	2,418	3,202	3,349	2,829	2.0%
Gas (with CCS)	-	-	-	7	54	284	NA
Nuclear	1,166	1,072	1,059	1,018	1,019	985	-0.4%
Hydro	807	870	885	935	1,000	1,056	0.6%
Biomass	209	260	272	350	396	452	1.7%
Biomass (with CCS)	-	-	-	-	-	-	NA
Wind	318	651	781	1,070	1,362	1,705	3.8%
Solar	110	227	270	400	550	702	4.2%
Geothermal	15	18	21	29	39	48	2.6%
Other	-	-	-	5	17	22	NA

Table 7. Modern Jazz Carbon Emissions

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
CO_2 emissions ($GtCO_2$/yr)	5	5	5	5	4	3	-1.2%
CO_2 capture ($GtCO_2$)	0.0	0.0	0.0	0.0	0.1	0.3	NA
CO_2 per capita (tCO_2)	7	7	6	6	5	4	-1.2%
CO_2 intensity ($kgCO_2$/USD 2010)	0.2	0.2	0.2	0.1	0.1	0.1	-3.1%

Table 8. Modern Jazz Coal in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	457	355	318	239	151	118	-3.0%
EU31	260	192	157	100	64	52	-3.5%
EEUR	81	71	64	62	28	21	-3.0%
RUSSIA	116	92	97	77	59	45	-2.1%

Table 9. Modern Jazz Oil in TPES - Regional Breakdown (mb/d)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	17	15	14	11	8	7	-1.8%
EU31	12	12	10	7	5	5	-2.1%
EEUR	2	2	2	1	1	1	-1.9%
RUSSIA	3	3	3	2	2	2	-0.8%

Table 10. Modern Jazz Gas in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	820	944	980	1,055	1,044	937	0.3%
EU31	367	432	463	494	470	406	0.2%
EEUR	89	134	146	161	175	161	1.3%
RUSSIA	365	378	371	400	400	369	0.0%

Table 11. Modern Jazz Nuclear in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	305	276	273	263	263	254	-0.4%
EU31	230	196	190	169	161	148	-1.0%
EEUR	24	24	24	27	25	24	0.0%
RUSSIA	51	56	58	67	76	82	1.1%

Table 12. Modern Jazz Biomass in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	173	211	223	275	314	338	1.5%
EU31	154	162	161	171	176	182	0.4%
EEUR	10	19	24	42	57	59	4.0%
RUSSIA	8	30	38	63	81	97	5.7%

Table 13. Modern Jazz Hydro in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	69	75	76	80	86	91	0.6%
EU31	46	48	48	48	48	49	0.1%
EEUR	10	11	12	13	14	15	1.0%
RUSSIA	14	16	17	20	24	27	1.5%

Table14. Modern Jazz Other Renewables in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	52	83	99	137	177	221	3.3%
EU31	48	75	88	120	151	185	3.1%
EEUR	4	5	6	9	12	16	3.2%
RUSSIA	1	3	5	8	13	19	7.9%

Table 15. Unfinished Symphony Economic Indicators

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Population (million)	817	825	825	819	809	792	-0.1%
GDP (trillion USD 2010 MER)	22	27	29	34	40	46	1.6%
GDP per capita (USD2010 MER)	27,188	32,441	35,195	41,899	49,611	58,085	1.7%
Primary Energy Intensity (toe/Million USD 2010 MER)	125	100	90	73	58	48	-2.1%
Final Energy Intensity (toe/Million USD 2010 MER)	90	73	66	53	43	35	-2.1%

Table16. Unfinished Symphony Primary Energy (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	2,764	2,681	2,625	2,513	2,307	2,200	-0.5%
Coal	457	328	287	174	84	73	-4.0%
Oil	889	766	719	574	444	352	-2.0%
Gas	820	909	917	929	832	681	-0.4%
Nuclear	305	295	284	312	309	366	0.4%
Biomass	173	218	237	284	313	345	1.6%
Hydro	69	80	83	99	121	135	1.5%
Other renewables	52	85	98	141	204	248	3.5%

Table17. Unfinished Symphony Total Final Consumption by Sector and by Fuel Source (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	2,004	1,962	1,916	1,832	1,707	1,601	-0.5%
Industry	530	534	522	507	481	457	-0.3%
Transport	578	545	536	497	457	418	-0.7%
Residential/commercial	702	714	702	686	638	603	-0.3%
Non-energy uses	194	169	155	143	131	123	-1.0%
Coal	199	94	79	57	39	22	-4.7%
Oil	795	693	655	536	422	335	-1.9%
Gas	434	463	443	408	359	318	-0.7%
Electricity	353	423	446	523	575	612	1.2%
Heat	166	169	162	154	141	130	-0.5%
Biomass & biofuels	102	99	101	107	117	121	0.4%
Other	2	20	30	47	54	63	8.1%

Table18. Unfinished Symphony Transport by Fuel Source (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	554	545	536	497	457	418	-0.6%
Electricity	17	24	31	52	76	101	4.0%
Hydrogen	0	0	0	3	9	13	NA
Liquid fuels - fossil	481	460	439	360	279	208	-1.8%
Liquid fuels - biogenous	18	20	23	29	36	41	1.9%
Gaseous fuels- fossil	39	41	42	53	57	54	0.7%
Gaseous fuels - biogenous	-	-	-	-	-	-	NA
Other (coal)	-	-	-	-	-	-	NA

Table 19. Unfinished Symphony Power by Fuel Source (TWh)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	5,008	5,855	6,156	7,119	7,714	8,116	1.1%
Coal	1,116	863	706	397	48	18	-8.8%
Coal (with CCS)	-	7	13	55	117	187	NA
Oil	83	30	12	2	0	-	NA
Gas	1,184	1,732	2,025	2,200	1,726	1,047	-0.3%
Gas (with CCS)	-	12	25	208	379	403	NA
Nuclear	1,166	1,145	1,101	1,211	1,198	1,417	0.4%
Hydro	807	930	968	1,152	1,407	1,574	1.5%
Biomass	209	255	279	348	384	452	1.7%
Biomass (with CCS)	-	-	-	7	20	47	NA
Wind	318	605	676	936	1,445	1,767	3.9%
Solar	110	248	308	469	646	774	4.4%
Geothermal	15	20	25	40	65	88	3.9%
Other	-	10	19	92	280	341	NA

Table 20. Unfinished Symphony Carbon Emissions

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
CO_2 emissions ($GtCO_2$/yr)	5	5	5	4	3	2	-2.1%
CO_2 capture ($GtCO_2$)	0.0	0.0	0.0	0.2	0.4	0.5	NA
CO_2 per capita (tCO_2)	7	6	6	5	4	3	-2.0%
CO_2 intensity ($kgCO_2$/USD 2010)	0.2	0.2	0.2	0.1	0.1	0.1	-3.7%

Table 21. Unfinished Symphony Coal in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	457	328	287	174	84	73	-4.0%
EU31	260	173	145	64	37	37	-4.3%
EEUR	81	61	55	52	20	22	-2.9%
RUSSIA	116	93	87	58	26	15	-4.5%

Table 22. Unfinished Symphony Oil in TPES - Regional Breakdown (mb/d)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	17	14	13	11	8	7	-2.0%
EU31	12	10	9	7	6	4	-2.2%
EEUR	2	1	2	2	1	1	-1.8%
RUSSIA	3	3	2	2	2	1	-1.5%

Table 23. Unfinished Symphony Gas in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	820	909	917	929	832	681	-0.4%
EU31	367	431	446	449	379	312	-0.4%
EEUR	89	123	121	121	122	94	0.1%
RUSSIA	365	355	350	359	331	276	-0.6%

Table 24. Unfinished Symphony Nuclear in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	305	295	284	312	309	366	0.4%
EU31	230	208	190	181	170	185	-0.5%
EEUR	24	30	32	37	44	54	1.8%
RUSSIA	51	58	62	94	96	126	2.0%

Table 25. Unfinished Symphony Biomass in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	173	218	237	284	313	345	1.6%
EU31	154	160	161	167	174	186	0.4%
EEUR	10	23	31	51	58	62	4.1%
RUSSIA	8	35	45	65	82	98	5.7%

Table 26. Unfinished Symphony Hydro in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	69	80	83	99	121	135	1.5%
EU31	46	53	55	61	67	74	1.1%
EEUR	10	11	11	12	13	14	0.7%
RUSSIA	14	17	17	26	41	47	2.7%

Table 27. Unfinished Symphony Other Renewables in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	52	85	98	141	204	248	3.5%
EU31	48	73	83	113	166	197	3.2%
EEUR	4	7	10	16	23	30	4.6%
RUSSIA	1	4	5	11	15	21	8.1%

Table 28. Hard Rock Economic Indicators

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Population (million)	817	825	825	819	809	792	-0.1%
GDP (trillion USD 2010 MER)	22	26	27	33	38	43	1.5%
GDP per capita (USD2010 MER)	27,188	31,345	33,278	40,112	46,989	54,256	1.5%
Primary Energy Intensity (toe/Million USD 2010 MER)	125	106	100	81	69	60	-1.6%
Final Energy Intensity (toe/Million USD 2010 MER)	90	79	75	62	53	46	-1.5%

Table 29. Hard Rock Primary Energy (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	2,764	2,740	2,752	2,667	2,621	2,589	-0.1%
Coal	457	398	367	308	220	158	-2.3%
Oil	889	860	862	848	790	757	-0.4%
Gas	820	864	900	831	819	788	-0.1%
Nuclear	305	288	273	266	276	309	0.0%
Biomass	173	181	188	225	291	324	1.4%
Hydro	69	75	75	77	85	93	0.7%
Other renewables	52	75	87	111	139	160	2.5%

Table 30. Hard Rock Total Final Consumption by Sector and by Fuel Source (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	2,004	2,041	2,056	2,051	2,023	1,979	0.0%
Industry	530	545	541	521	511	503	-0.1%
Transport	578	581	595	630	634	612	0.1%
Residential/commercial	702	714	714	696	674	652	-0.2%
Non-energy uses	194	202	208	205	205	212	0.2%
Coal	199	126	120	103	84	71	-2.3%
Oil	795	784	794	794	741	682	-0.3%
Gas	434	435	425	422	411	402	-0.2%
Electricity	353	402	414	400	423	437	0.5%
Heat	166	178	176	191	194	197	0.4%
Biomass & biofuels	102	93	93	97	113	121	0.4%
Other	2	23	35	45	57	69	8.3%

Table 31. Hard Rock Transport by Fuel Source (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	567	581	595	630	634	612	0.2%
Electricity	18	20	22	29	34	45	2.1%
Hydrogen	-	0	0	0	0	1	NA
Liquid fuels - fossil	497	505	514	532	513	469	-0.1%
Liquid fuels - biogenous	15	16	17	25	38	41	2.3%
Gaseous fuels- fossil	37	39	40	44	49	56	0.9%
Gaseous fuels - biogenous	-	1	1	-	-	-	NA
Other (coal)	0.2	0.1	0	0	0	-	NA

Table 32. Hard Rock Power by Fuel Source (TWh)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	5,008	5,562	5,736	5,498	5,740	5,869	0.4%
Coal	1,116	1,034	890	593	332	258	-3.2%
Coal (with CCS)	-	-	-	-	-	-	NA
Oil	83	86	57	28	14	7	-5.4%
Gas	1,184	1,585	1,961	1,820	1,953	1,755	0.9%
Gas (with CCS)	-	-	-	-	-	-	NA
Nuclear	1,166	1,118	1,058	1,032	1,069	1,198	0.1%
Hydro	807	877	872	892	990	1,083	0.7%
Biomass	209	244	263	324	391	424	1.6%
Biomass (with CCS)	-	-	-	-	-	-	NA
Wind	318	416	413	511	618	708	1.8%
Solar	110	196	216	292	362	410	3.0%
Geothermal	15	6	5	4	3	3	-3.8%
Other	-	-	-	-	8	23	NA

Table 33. Hard Rock Carbon Emissions

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
CO_2 emissions ($GtCO_2$/yr)	5	6	6	5	5	4	-0.5%
CO_2 capture ($GtCO_2$)	0.0	0.0	0.0	0.0	0.0	0.0	NA
CO_2 per capita (tCO_2)	7	7	7	6	6	5	-0.5%
CO_2 intensity ($kgCO_2$/USD 2010)	0.2	0.2	0.2	0.2	0.1	0.1	-2.0%

Table 34. Hard Rock Coal in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	457	398	367	308	220	158	-2.3%
EU31	260	212	179	142	108	72	-2.8%
EEUR	81	90	96	99	66	50	-1.1%
RUSSIA	116	96	92	68	47	36	-2.5%

Table 35. Hard Rock Oil in TPES - Regional Breakdown (mb/d)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	17	16	16	16	15	14	-0.4%
EU31	12	11	11	11	10	9	-0.6%
EEUR	2	2	2	2	2	2	-0.6%
RUSSIA	3	3	3	3	3	3	0.6%

Table 36. Hard Rock Gas in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	820	864	900	831	819	788	-0.1%
EU31	367	363	370	267	262	257	-0.8%
EEUR	89	131	150	171	182	179	1.6%
RUSSIA	365	369	380	394	375	353	-0.1%

Table 37. Hard Rock Nuclear in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	305	288	273	266	276	309	0.03%
EU31	230	205	187	170	166	180	-0.5%
EEUR	24	29	30	31	33	36	0.9%
RUSSIA	51	55	56	65	77	93	1.3%

Table 38. Hard Rock Biomass in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	173	181	188	225	291	324	1.4%
EU31	154	145	143	146	157	163	0.1%
EEUR	10	21	27	41	68	73	4.5%
RUSSIA	8	15	19	38	66	88	5.5%

Table 39. Hard Rock Hydro in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	69	75	75	77	85	93	0.7%
EU31	46	49	49	49	49	47	0.1%
EEUR	10	10	10	10	11	12	0.5%
RUSSIA	14	16	16	18	25	33	1.9%

Table 40. Hard Rock Other Renewables in TPES - Regional Breakdown (Mtoe)

	2015	2025	2030	2040	2050	2060	% CAGR 2015-2060
Total	52	75	87	111	139	160	2.5%
EU31	48	65	74	88	104	113	1.9%
EEUR	4	6	8	13	20	27	4.4%
RUSSIA	1	4	5	10	15	20	8.0%

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