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Energy transition

Nec temere, nec timide:
neither timidly nor rashly

ORLEN

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Instead of an introduction: or why the Latin phrase *nec temere, nec timide* is the guiding motto for the energy transition?

Nec temere, nec timide translating to *neither timidly nor rashly*, is a Latin maxim best known as the motto of Gdańsk (but used also as the slogan of the Danish naval academy). While its exact origin is not entirely clear, it appears in Book III of Aristotle's "Nicomachean Ethics", which mentions that a man guided by virtue is neither a coward nor a rash man, but a brave man.[1]

Nec temere, nec timide should thus be our guiding motto on the energy transition journey, which is to lead us to the goal of climate neutrality by 2050. We have only 27 years to go before Europe's economy must be fundamentally transformed, which leaves little scope or time for grave mistakes. One consequence of misguided and rash decisions that cause, for instance, a drastic increase in the cost of such basic services as heating or transport, could be social resistance, preventing any further transition efforts.

Even now we are confronted with the consequences of ill-considered decisions, as many EU countries have switched from coal not only to renewables (as planned), but also to natural gas imported from Russia, without bearing in mind the need for energy security. Therefore, our point is that the energy transition should be a bold, but not a rash process. A new energy mix does incorporate economic benefits, but they will not materialise if we do not address certain issues, including the systemic consequences of intermittent renewable energy generation.

But then again, we cannot evoke security or the magnitude of the challenge to postpone the necessary transition. Every year of delay undermines our chances of halting the temperature rise and achieving the goals of the Paris Agreement. This challenge is particularly acute for power generation, a sector characterised by very long asset lifecycles. The current situation is partly an effect of decisions taken years or even decades ago. Similarly, decisions made today will affect the system in 2030, 2040 or 2050. Overinvestment in traditional sources could result in stranded assets or, in a worse case scenario, failure to meet the carbon reduction targets and its implications for climate change. The war, which is being fought here and now, makes us focus on current threats and on the search for quick solutions. However, it does not affect in any way the relevance of the long-term challenges brought by climate change, which, considering the maturity cycle of innovative technologies, need to be addressed today in order to secure the availability of affordable energy in several decades.

The war in Ukraine has brought home the truth that Europe has been dependent on Russian fossil fuels for far too long. We can hear voices coming from all parts of the continent that we are now at a turning point. This, on the one hand, is a huge challenge – for states, businesses and consumers alike. States have an enormous role to play in the regulatory sphere, companies need to redefine their business models and open up widely to innovation, while consumers will have to switch to different home heating methods, for example. The transition is also an opportunity for all these groups: states will be able to gain independence from fossil fuels and thus more easily ensure energy security, companies can explore new, more profitable areas of business, while consumers will enjoy lower overall costs.

Getting there, however, will not be possible without strategic prudence. This is why we propose to put the *nec temere, nec timide* maxim at the very centre of energy transition thinking.

We have already found out the hard way that the path to climate neutrality is not as easy and straightforward as it may have seemed. As the European community, we need to take a more pragmatic approach, without discarding our ambition and courage. We will not be given a second chance.

1 Aristotle, "Nicomachean Ethics", translated by W. D. Ross.

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Between Scylla and Charybdis,

or the energy transition dilemma

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Russia's military invasion of Ukraine has thrown the energy markets across the globe into disarray. Europe has been the target of deliberate attempts to cause shortages of natural gas since 2021, with supplies to several countries completely cut off. This situation is posing challenges to our ability to ensure that sufficient energy supplies are available for both households and industry, while bracing Europe for a recession looming ahead in the wake of the war.

Shortages of gas have also led to a resurgence in coal-fired power generation with an unavoidable side-effect of much higher carbon emissions. Moreover, under the current model that shapes energy prices (called 'merit order'), the soaring price of natural gas has pushed both electricity and heat prices across many EU countries to extreme highs.

The situation now facing the energy markets can be compared to the dilemma known from Homer's "Odyssey", where the protagonist has to pass through a narrow strait to be able to continue his journey. Threats await him on both sides of the passage, like the two mythical sea monsters called Scylla and Charybdis. Thanks to his own dexterity, but also to Circe's reasonable advice, Odysseus eventually manages to navigate the hazards and is able to sail on.

Challenges of the energy transition

We are facing massive challenges. On the one hand, we will continue to face the risk of being blackmailed over energy supplies by Russia, whose intention is to force EU governments into abandoning sanctions. On the other hand, there is a serious risk that the energy transition might be derailed because of the unfolding crisis.

When security comes under threat, especially when natural gas supplies are insufficient to meet demand, individual countries may begin to pursue their own interests, disregarding the communal good. We must be aware that undermining the unity and causing a rift between EU countries is one of Russia's primary goals. In the short run it would weaken the common front and approach to sanctions, but its long-term effect would be to slow down the pace of the energy transition and shift away from Russian energy imports.

Therefore, we must first of all take measures to alleviate the risk of energy blackmail, while taking care to ensure that the energy transition does not falter and EU citizens are not dissuaded from the process.

The Scylla of energy blackmail

What can we do? The target of transitioning into a net-zero energy system will require massive investments in new infrastructure, including energy generation, storage and transmission assets, over several decades to come. Given the huge costs of the transition, a major challenge is to ensure that the right energy assets are developed in the right place and at the right time. The thing is to deliver the energy transition optimally in terms of related costs and social impacts.

2022 has shown that the current energy transition model calls for a revision. In 2019, the European Council made a commitment to achieving carbon neutrality by 2050. Since then, many businesses have followed suit, including the ORLEN Group as the first of Central Europe's fuel producers. Today it has become clear that – while the transition process itself and the chosen directions are right – we need to address the issue of bottlenecks that are hampering its progress.

The current approach of exiting as quickly as possible the most carbon-intensive generation assets, mainly coal-fired power plants, and replacing them with renewable energy sources, entails certain systemic costs. In practice, many countries have failed to quickly manage the transition from coal to renewables as planned – what happened was that they switched from coal to gas imported from Russia, disregarding the issue of energy security. In consequence, the seasonal rise in the volume of gas consumed in power generation and for district heating, with no common LNG market in the EU and without a diverse mix of gas supply sources, is a major element underlying the current price crisis in Europe.

We cannot blame the whole problem on Russia's war and Russia, because the energy crisis had first struck before the war, in September 2021, and concerned the LNG market.

If we do not change our approach to the transition, we are likely to face similar fluctuations in the prices of electricity, heat and energy commodities every autumn and winter.

Inconvenient facts

We have to swallow a bitter pill: errors in designing the common gas market, especially putting national interests over the communal good and the lack of cooperation, have made EU economies far more vulnerable to energy blackmail than they might be had a common gas market in Europe been developed. The existing infrastructure interconnections are inadequate – what we have is more like so many fragmented systems.
In hindsight, one could say that our situation in Europe would be completely different not only if we could manage in a coordinated way the East-West gas flows, but also if we could use LNG terminals in Spain to transmit gas to, for instance, Germany. We are yet to have a serious discussion on how to restore lost gas reserves, but this will not always require building new gas storage infrastructure.

Sometimes energy security can be achieved at a lower cost, for instance by making LNG terminal capacity available to other countries, or transmitting LNG further when needed.

In the short term, managing gas supplies will require coordination and cooperation. The International Energy Agency has warned that, under the worst-case scenario, Europe could be short of a staggering 30 bcm of gas in 2023. If national egoisms prevail, external gas suppliers will have the upper hand in dictating prices to individual EU members. In the absence of mechanisms for joint gas purchases by the EU as a whole, it is possible that individual countries will be competing for gas, which in turn will push up its prices.

In 2023, many countries will seek to accelerate efforts to diversify fossil fuel supplies with a view to bolstering their energy security. The goal is clear: if energy security is under threat here and now, we must restore it in the first place, and only then think of transition toward an energy secure future. However, this is only a makeshift. For the transition to be successful, it is best to choose solutions that will work both in the short and long term. This means that such accelerated transition will be secure if the replacement of fossil fuels with other types of energy is coordinated internationally or at least regionally.

As regards social challenges, we must design a system that would consistently take the burden off the most vulnerable consumers, who are most at risk of energy poverty, while systemically shifting to cheaper and less carbon-intensive solutions in the power and heat generation sectors. We must not fool ourselves into believing that market forces will magically do the job, because they do not work effectively on shrinking markets. Without an attractive proposal and support system, the transition project is doomed to failure, both on the social level (by aggravating energy poverty) and in political terms (by fuelling populism and offering arguments for lifting the sanctions, a move already advocated in some EU countries).

Coordination and cooperation are key

What we need in the long term is EU-wide coordination: it is critical to match an expansion of gas infrastructure capacity with demand to prevent wasting money on stranded assets. In addition, an excessive (relative to actual needs) increase in the supply of gas production and transport capacity within a few years, confronted with diminishing demand for gas in Europe, would again make gas attractive as a transition fuel, increasing its consumption in the long term and reducing the pressure to lower carbon emissions and move away from gas imports.

A challenge for 2023 is to strike a balance between emergency measures designed to avoid severe gas shortages in the coming months and preventing excessive investments in fossil fuel infrastructure in the coming years so as not to raise the costs of the transition and slow down the pace of shifting away from fossil fuels.

Any projects to expand transmission capacity should therefore be driven by demand forecasts based on EU decarbonisation scenarios.
In particular, the need to invest in new gas infrastructure must be strongly supported by an actual supply gap, taking into account any expected decline in demand. What this means in practice is that, in the short term, it is probably better to accept increased production from existing gas fields as well as higher emissions.

The Charybdis of a slowing pace of the transition

Even if we manage to steer clear of the Scylla of energy blackmail, or at least cushion its impact, we must nevertheless face the Charybdis of decelerating the transition process. The challenge of ensuring an optimum and efficient mix of renewables is complex, because we are moving away from fossil fuels to unproven low-carbon technologies, some of which are completely new, their commercial worth having yet to be proven. Major investments are required in different areas of the energy system, many of which take a long time to implement and even longer to pay back.

In principle, European countries should step up their efforts related to the energy transition and investments in renewables. At present, though, they all want to invest in the same technologies, including green hydrogen, offshore wind power and solar PV. The first conclusion is that, considering the availability and flows of capital, EU members must coordinate their respective energy reforms. The absence of such coordination, especially in terms of public support, has prompted many investors to move their businesses to those EU countries where cheap public finance is still available. This, in turn, increases the total cost of expanding renewable energy sources.

What can we do to counter this trend? The answer is that we need coordination and, above all, monitoring of the fossil fuel markets for the available reserves and capacity. But this comes at a cost. And the result will not be stranded assets, but a necessary surplus capacity that can be quickly brought on stream – an insurance policy of sorts. Without such monitoring globally, let alone sharing information on investment plans in the EU vs the rest of the world, we run a very high risk of further energy shortages.

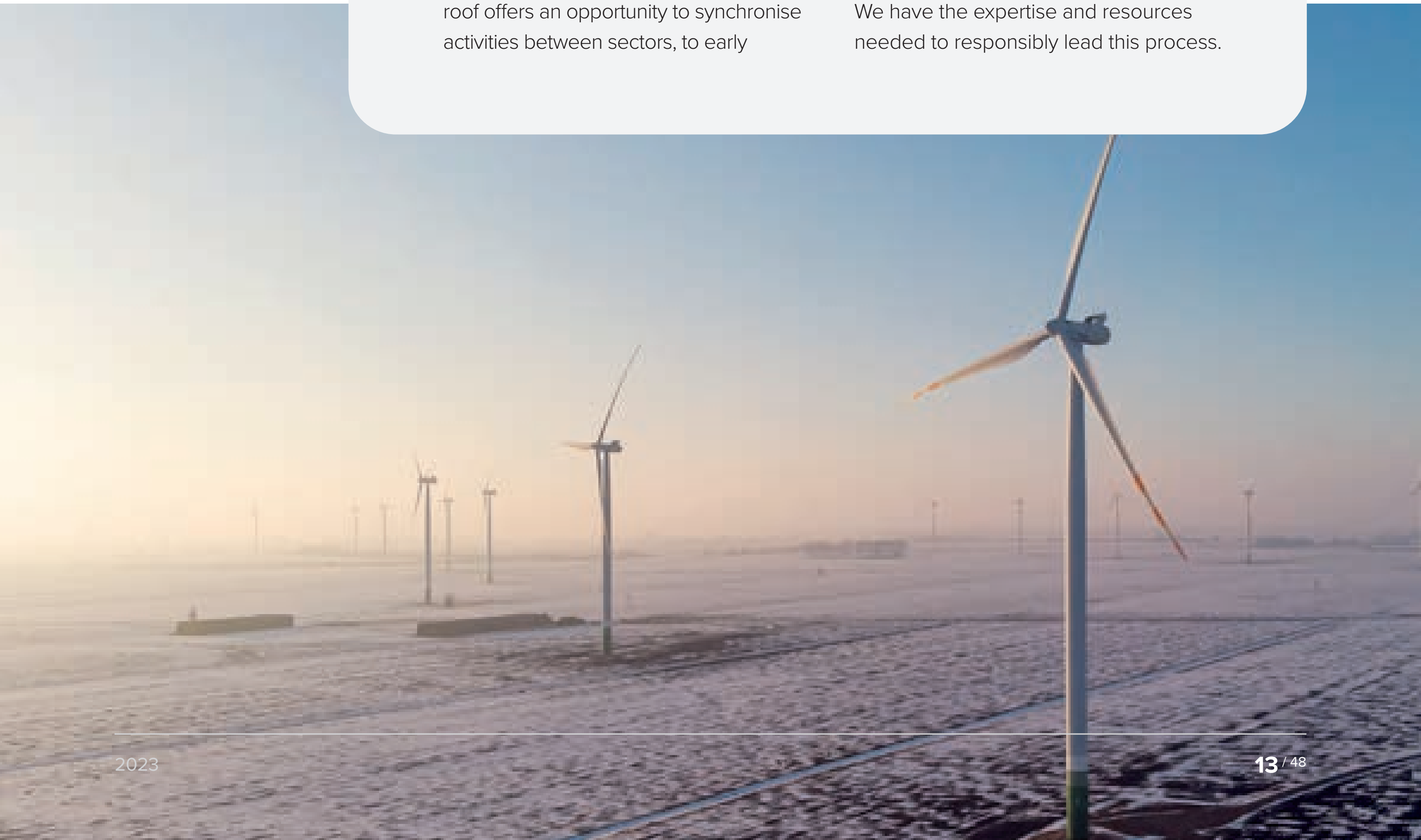
The energy transition is a shift from fossil fuels towards renewables. In an ideal world, such transition should take place in a coordinated manner so as to avoid costly tensions leading to hikes in the prices of fossil fuels, electricity and heat. But this is a tall order because of the difficulty in synchronising, by means of economic mechanisms, a smooth transition between shrinking and growing markets. Who would want to invest in the former when there are huge incentives to invest in the latter?

Transition bottlenecks

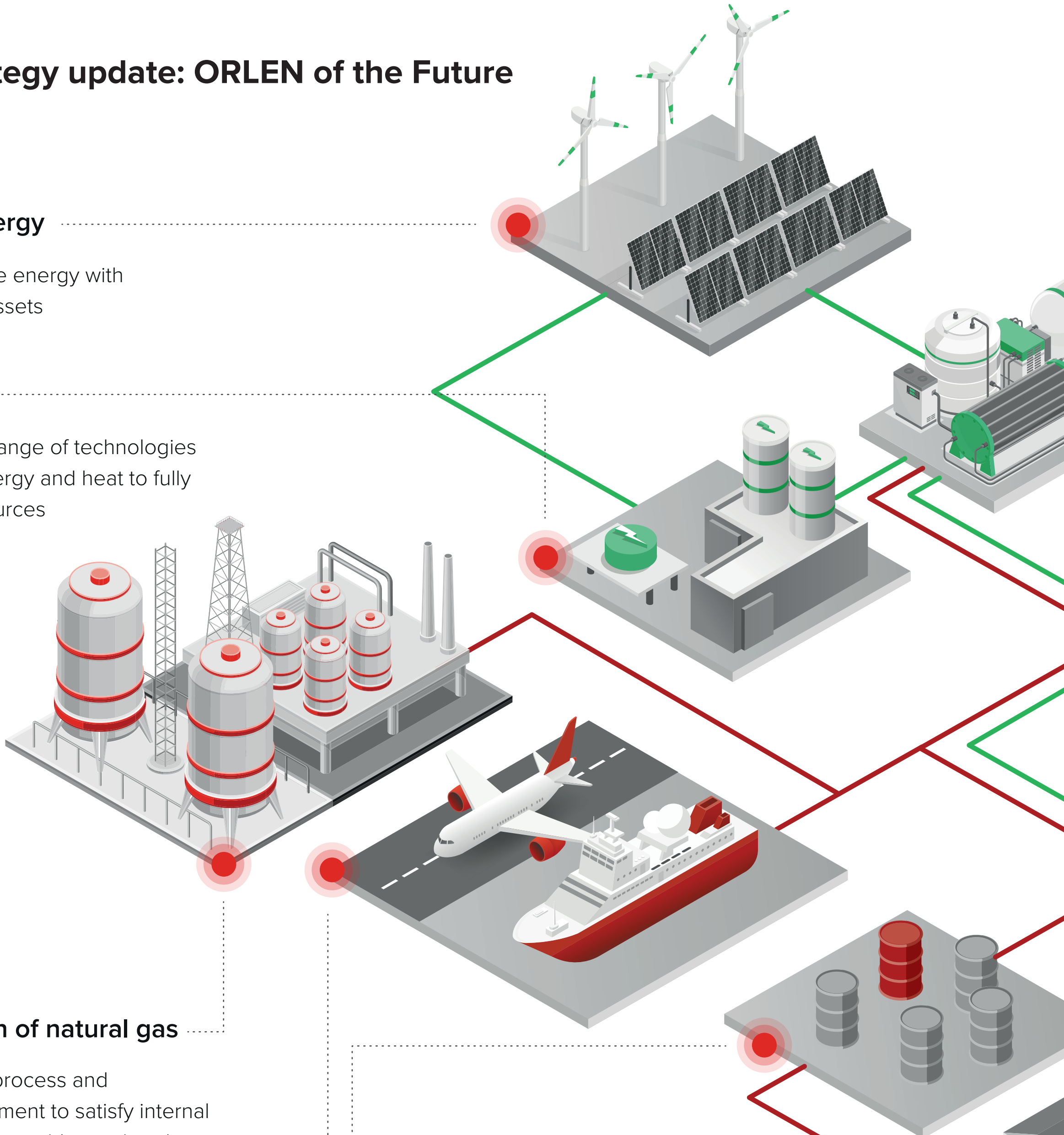
The transition is also challenging because the pace of the shift from fossil fuel to renewable assets should match the pace of end user demand switching to green energy sources.

When we look at the transition in terms of the need for coordinated action, the benefits of consolidating Poland's energy assets under the ORLEN brand become evident. As a Group, we have strengthened our position in power generation, fuel production and gas. Today, these are transition bottlenecks, but they are also the money making sectors. Integrating these assets within a single industrial organisation boosts its investment capacity, and well-targeted projects accelerate the transition from fossil fuels to renewables. Having fossil fuels and renewables under the same roof offers an opportunity to synchronise activities between sectors, to early identify any transition bottlenecks and to debottleneck the process through investments. The absence of such coordination not only raises the transition costs but, as we can see, poses a threat to energy security.

To recap and refer to the dilemma signalled at the beginning: in 2023, the energy transition will find itself between the Scylla of energy blackmail and the Charybdis of forces decelerating its pace, both at the EU level and within our region. The ORLEN Group is well aware of the challenges ahead. What is more, we have already taken active steps to stave off the consequences of energy blackmail and we have tools to contribute to bolstering the region's energy security. We will also look to actively invest in the energy transition. We have the expertise and resources needed to responsibly lead this process.



Vision of the strategy update: ORLEN of the Future



GREEN POWER

Wind and solar energy

Integration of renewable energy with advanced power grid assets

Energy storage

Deployment of a wide range of technologies for storing electrical energy and heat to fully leverage renewable sources

ADVANCED LIQUID FUELS

Leading production of natural gas

Low-carbon extraction process and contract-based procurement to satisfy internal needs and domestic demand (natural gas)

Aviation and maritime transport

Manufacture of renewable fuel products (bio and hydrogen derived fuels)

Bio-based feedstock

Co-processing and blending of bio-based feedstock to replace conventional crude oil

CUTTING-EDGE PETROCHEMICAL AND REFINING PRODUCTION

Efficient refineries

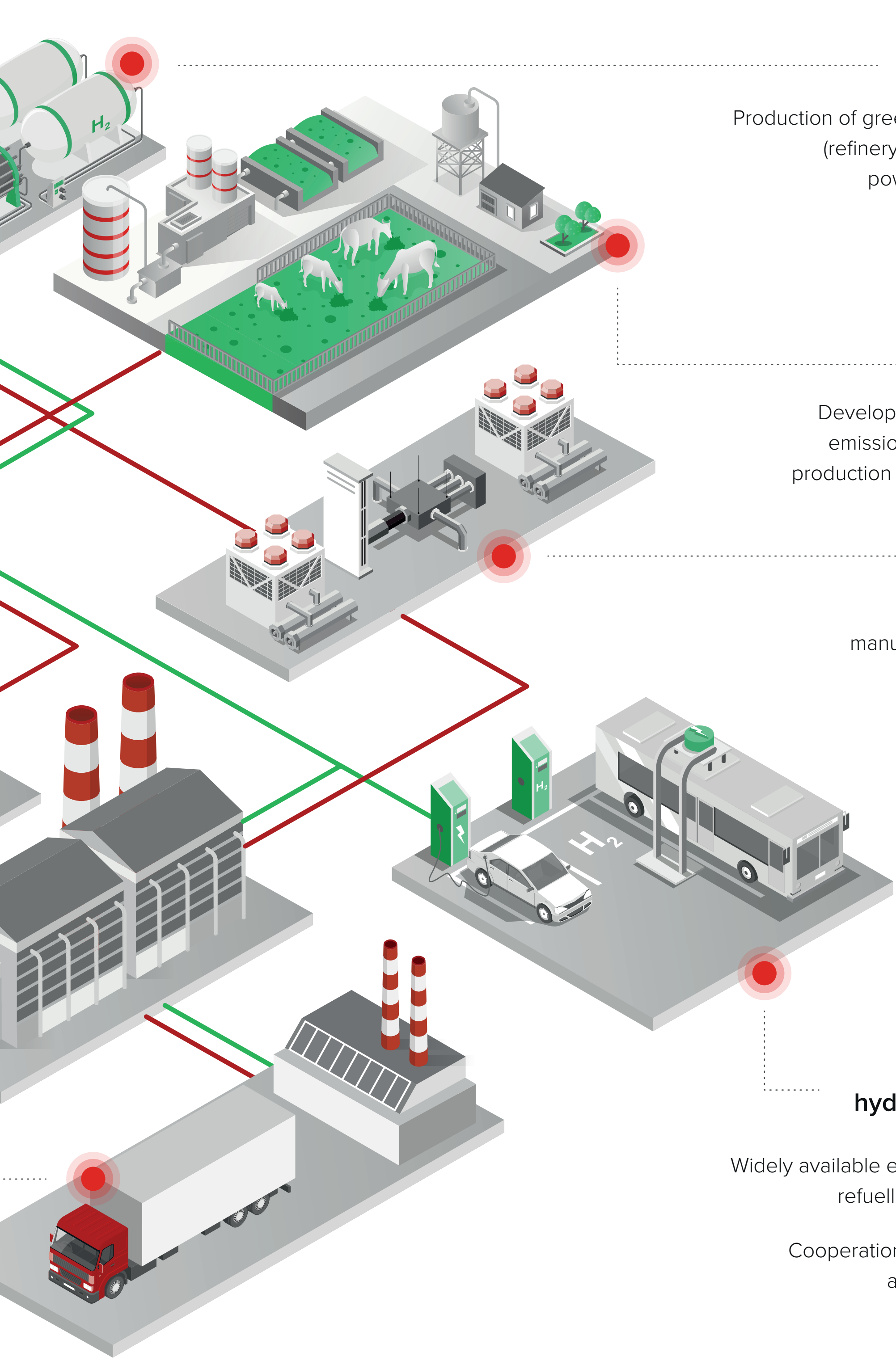
State-of-the-art crude oil processing with Europe's lowest emissions footprint

Advanced plastics

Supply of materials based on advanced recycling and bio-based feedstock

ELECTRICAL NETWORKS

PIPELINE INFASTRUCTURE



CLEAN HYDROGEN

Production of clean hydrogen

Production of green hydrogen for industrial applications (refinery processes, manufacture of fertilizers), power generation (storage) and transport

CLEAN HEAT

Use of biomass

Development towards biomass in areas where emissions are hard to abate (heat generation, production of high-temperature heat at refineries)

Carbon capture system

Capture and use of carbon dioxide to manufacture synthetic carbon neutral fuels, including BECCS or DAC

NEW MOBILITY

Electric vehicle charging and hydrogen refuelling infrastructure

Widely available electric vehicle charging and hydrogen refuelling infrastructure within each segment

Cooperation with cities and industrial centres with a view to decarbonising heavy industry

New transition-driven perspective on the energy markets

The ongoing energy crisis invites reflection on how the energy market is working. Many questions still remain unanswered but one thing is certain – our future energy system will differ from the system of the past.

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Energy/electricity demand will grow fast as more sectors of the economy are electrified with adoption of electric vehicles in transport, uptake of heat pumps in the municipal services sector and, possibly, hydrogen production. The progressing digitalisation and advancements in the IT sector will also contribute to growing energy consumption in the future.

Most of the demand will be covered by affordable renewable energy sources, which will change the sector economics by delivering abundant volumes of electricity under favourable weather conditions. Renewable energy will be complemented with expensive yet reliable zero- or low-carbon sources, such as nuclear energy or gas-fired power plants using the carbon capture and storage technology or biogas fuel, to fill the gap on the grid when renewables fall short.

The unprecedented increase in gas prices in the last 12 months has sent a major shock wave across the power systems in Poland and wider Europe. The soaring prices are translating into record-high energy bills. The gas crisis has prompted many customers to accelerate the shift away from imported fossil fuels used for electricity and heat generation in their energy mix.
The crisis has strengthened the case for decarbonisation. The economics has changed, and renewable sources are increasingly cost-effective. Energy can be cleaner and more affordable while lessening our reliance on foreign fossil fuels and enhancing our self-sufficiency through own natural resources.

Designing anew

In order to modernise Poland's economy, we need to face the challenge of redesigning our energy system. The key objective underlying our long-term investment plans is to achieve net zero emissions. Delivering on that goal will require massive investments in new infrastructure, including energy generation, storage and transmission assets, over several decades to come.

The energy transition is a complex process because we are moving away from fossil fuels to unproven low-carbon technologies, some of which are completely new to our economies. Major investments are required in different areas of the energy system, many of which take a long time to implement and even longer to pay back. Others need parallel investments in the transport sector.

In order to maximise investment efficiency, it is vital that the right energy assets are deployed at the right time in the right place. The thing is to deliver the energy transition optimally in terms of related costs and social impacts.

Challenges are many. For instance, carbon capture and storage (CCS) cannot be used in power generation, and hydrogen production cannot take place until relevant storage and transport facilities are put in place. New renewable energy projects cannot be placed in service until they are connected to the power grid, and the massive adoption of electric vehicles, solar PV installations and heat pumps will require upgrades to local power networks. Not to mention the practical aspects of project execution. In the current regulatory regime, preparing design documentation for a project often takes longer than its execution.

Transition requires coordination

Projects implemented to bring us closer to net zero emissions cannot be left uncoordinated – coordination and strategic planning at the national and local levels is needed to ensure optimal conversion of the entire infrastructure. Energy mix planning systems at the state level must operate effectively, and efficient coordination of the activities of national and international regulators and market players is of the essence. That cooperation between transmission network operators, distribution network operators and power generators is necessary for efficient capacity location is clear even today. And given the running investment projects, it will be even more important in the future.

We must be aware of how big a challenge offshore wind projects in the Baltic Sea and other investments are for the entire economy. The new renewable energy generation capacities are posing unprecedented challenges in the area of continuity of supply and system balancing.

The deployment of flexible renewable assets is hindered by delays in upgrading the transmission network needed to connect large renewable generation units, including offshore, to the grid and to transmit large volumes of energy to demand areas, and by challenges related to connecting local generation and storage assets to the distribution network.

Without common goals and consistent execution, our ambitious plans will be hard to implement. It should also be noted that a shift in the energy mix would require changes to the energy markets' operating conditions.

Renewable sources and lower costs

We are headed towards a system dominated by affordable yet intermittent renewable energy, with a system of relatively costly conventional generation, largely based on coal and gas, operating in parallel. Within a few decades it will be replaced by low-carbon alternative sources such as nuclear energy or gas turbines powered by biomethane and hydrogen. But in the near future these two different systems will operate alongside each other.

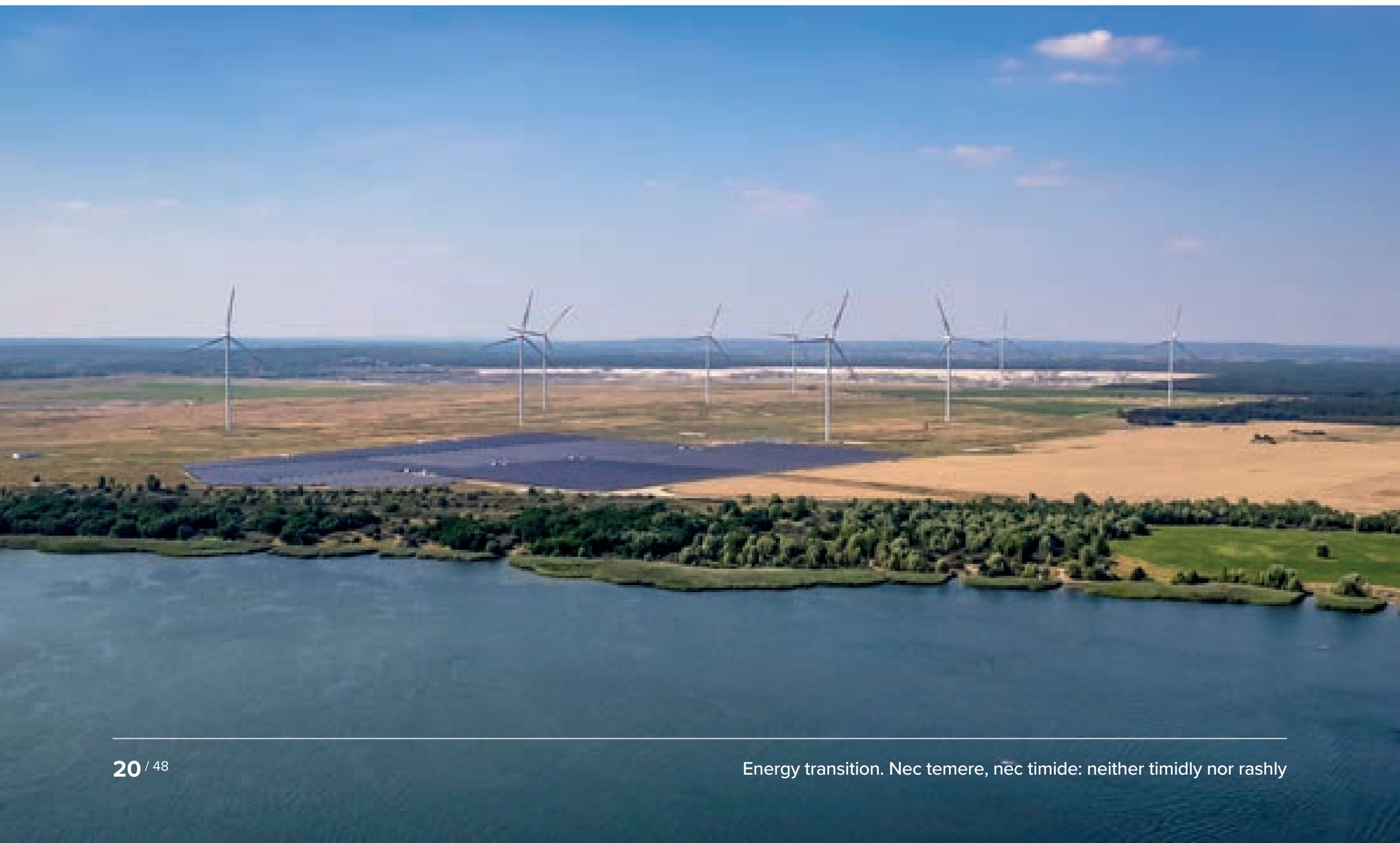
Designing a mix of various energy sources creates specific challenges for energy market mechanisms. One of them is the ongoing natural gas and raw materials crisis, which has thrown into relief the challenges related to the operation of the wholesale electricity market.

Wholesale prices are set based on marginal pricing, that is by reference to the cost of the most expensive plant serving demand on a market. In most European countries, these are power plants fuelled by high-cost natural gas, which is treated as a benchmark for energy prices. But gas power is much more expensive than renewable energy.

As the level of intermittent renewable energy generation in the system increases, in order to keep costs low, we need to maximise the use of low-cost renewable energy sources when they are available and reduce the use of more costly or polluting energy sources to the times when the sun is not shining and the wind is not blowing.

The snag is that our best locations to harvest renewable energy are geographically concentrated (in the Pomerania region or in the Baltic) far away from main business hubs.

Small nuclear reactors located near industrial facilities or on the site of coal-fired power plants could be one solution. Another would be an electricity market overhaul that is increasingly becoming a topic of discussion in Europe.



Problem solving

Typical of energy markets (and other markets for that matter), marginal pricing is widely considered to be the most effective pricing mechanism, raising profits for the cheapest suppliers and encouraging them to expand their business to a point where it is them who set the marginal price, thus reducing costs for all. But as the share of cost-effective renewable electricity sources expands in Poland, the previously effective approach may no longer be optimal.

A debate is being held in Europe on how to modify energy markets and adapt them to cope with the challenges posed by the existing system. Multiple solutions are available but they all boil down to establishing a market for intermittent renewable energy where prices are based on energy costs, and a wholesale market for non-intermittent energy where prices are set through marginal pricing. This would allow consumers to pay lower bills for renewable energy while at the same time providing an incentive to generate conventional energy necessary to balance the market.

An alternative approach with potential for faster effects would be increased use of contracts for difference, which pay a fixed price to low-carbon energy projects. The contracts already provide a key advantage relating to market splitting – instead of a marginal price, contract holders are paid a fixed price, which pays off when market prices are high, as is the case now, protecting consumers against market price increases. In Poland and other countries CfDs help with nuclear and offshore wind projects.

Combating geographical imbalances

We can already see that the rapid growth in renewables is likely to be concentrated in locations far from main demand centres. Extending the grid infrastructure would help address the challenge, but it is costly. If electricity demand could be aligned with the supply of affordable clean energy, the amount of required new network infrastructure and system costs would be reduced. This is simple in theory but in practice would require change to the established systems in which the markets have been operating for years.

One option would be to revive the discussion on splitting the wholesale electricity market into zones or nodes, which would allow price differentiation depending on location. The transition to 'locational marginal pricing' would encourage investment in flexible energy assets in the right places, as well as transmission of real-time signals, which would minimise system balancing costs. As in the case of wholesale market splitting, this would be a major market reform that would require time to design and implement. Other options include, but are not limited to, network charge rates changing over the day to encourage more efficient use of network capacity (flexible and dynamic pricing), the introduction of locational signals in the balancing market, and the wider use of flexibility markets to reduce specific network constraints. These options require discussion and evaluation.

Each of the issues mentioned above has to be addressed in order for the transition to succeed. All the options are available and feasible. The net zero strategy and safe system operation require thoughtful consideration, particularly when it comes to an energy market model and coordination of measures.

Energy transition, energy security, and affordable fuel:

how the energy crisis can help policymakers ‘thread the needle’

> **Two roads diverged in a yellow wood,**
> And sorry I could not travel both

Robert Frost (“The Road Not Taken”)

The original text was first written in August 2022. The translation has been abridged and updated with the authors’ consent.

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“Energy transition, energy security, and affordable fuel: how the energy crisis can help policymakers ‘thread the needle’”

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Spiking energy prices and the impact of the Russia-Ukraine war on global energy markets highlight the centrality of energy to our modern economy. Any political leader who is seen as failing to deliver affordable, reliable energy to their constituents will not survive in office long enough to successfully tackle climate change. But the evidence shows that society and policymakers don’t need to approach this as an “either-or” proposition. Instead, it is essential to acknowledge the reality of the energy system today, even as we rapidly work to change it. The current crisis gives us an opportunity to have a more realistic conversation about the role of energy in our lives and the need for change. The European Union’s (EU) failure to integrate climate policy and energy security/affordability in the past calls for reflection on ways to address both simultaneously. The US so far emphasizes these objectives separately (and often in ways that make them appear in conflict with each other), although there are early indications that this approach may be changing. In order to set the stage for a successful energy transition, it is crucial that our leaders acknowledge the need for a framework that drives a rapid transition while also providing the secure, affordable energy society needs today.

Introduction

The dramatic increase in global energy prices seems to present policymakers with a stark choice:

1. Double down on aggressive climate policies to reduce dependence on fossil fuels; or
2. Put climate policy on the back-burner and admit that we need greater fossil energy investment.

Which road should the world take? Recent events prove that neither will lead to a satisfactory outcome. The world needs affordable, reliable and secure fossil fuels today and to dramatically reduce emissions (or more precisely, stop the growth of atmospheric concentrations of greenhouse gases).

How do we thread the needle? While both roads have vocal constituencies, policymakers should consider blazing their own trail to foster increased fossil fuel investment and accelerated energy transition policies. These two objectives are not mutually exclusive.

Indeed, economic and political realities – as demonstrated by recent developments – indicate that climate policy cannot succeed without simultaneously ensuring adequate energy availability.

The challenge of higher energy prices

In most countries, and for most energy forms, prices have risen sharply since the end of 2020. Recovery of energy demand – as activity rebounded from COVID-related lockdowns – and a sharp decline in investment in energy supply have been the key drivers. For oil (and fuels priced off it, like much of the world's contracted natural gas), the price recovery was assisted by unprecedented production cuts from the so-called OPEC+ group of countries.[1] Since February 2022, the disruption of supplies (both real and feared) resulting from the Russian invasion of Ukraine has pushed energy prices still higher.[2] While spending on energy as a share of gross domestic product (GDP) remains below previous peaks in most industrialized countries, it could reach a record share this year globally.[3] Moreover, even in wealthier countries, the absolute increase in spending on energy has been substantial, with implications for households and businesses – and therefore political leaders. In the EU especially, both extremely high prices and likely shortages have already led to the shutdown of some industrial uses.

Global prices for oil – the world's leading energy form – in 2021 saw one of the largest increases on record. The global benchmark of Brent crude increased by USD 29 per barrel (USD/bbl), the second largest nominal increase ever and the fourth largest real increase (behind 2011, 1974, and 1979). In the US, retail gasoline prices increased by nearly 85 cents per gallon, the largest (real and nominal) increase ever, and the nearly 75 cent increase in diesel prices was the third largest real increase on record.[4]

European regional prices increased even more rapidly in 2022, pushed by the disruption of energy flows from Russia, the continent's largest supplier.

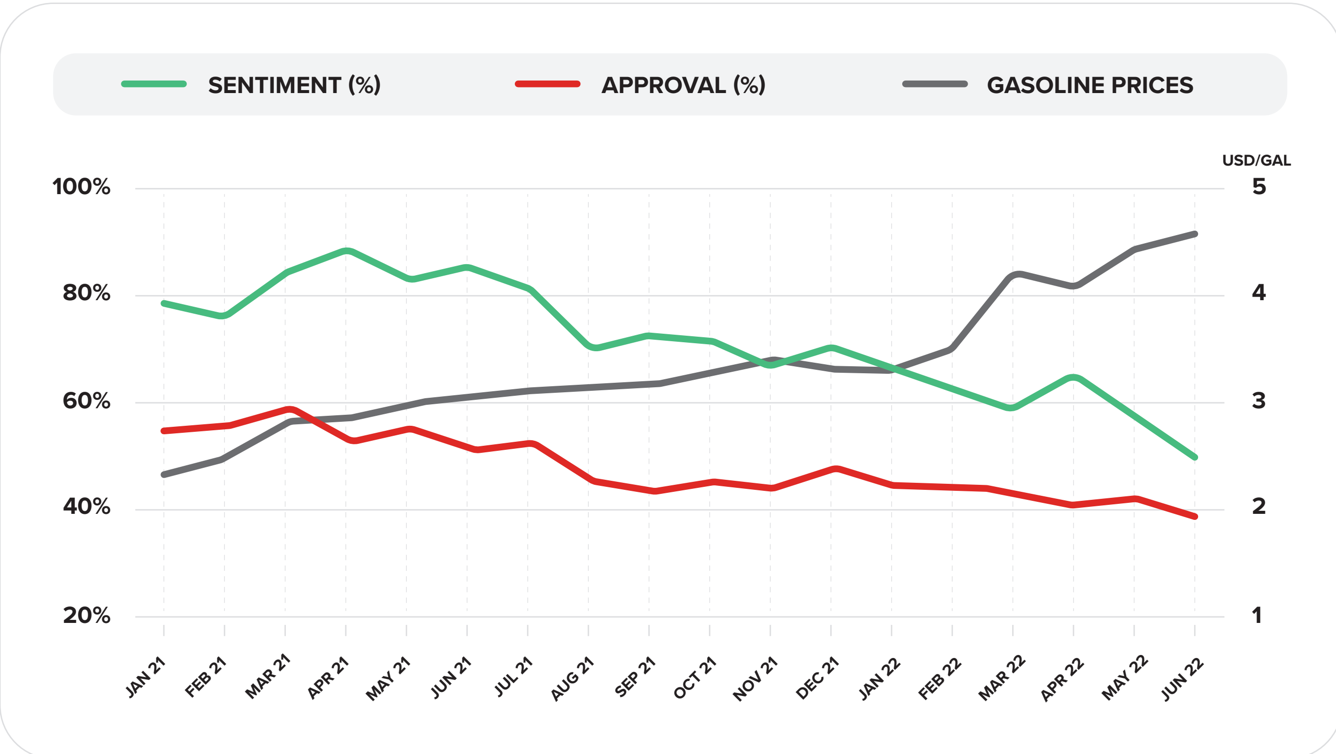
Natural gas prices at TTF, the EU's most liquid hub, were five times higher than they had been exactly a year earlier. API2 Rotterdam coal futures almost quadrupled between January 3rd and July 11th 2022,[5] contributing to the rise in electricity wholesale prices.

The latter skyrocketed with the largest year-over-year (yoy) increases in the first quarter of 2022 in Spain and Portugal (+411%), and the European benchmark rising 281% higher than in the first quarter of 2021. Gasoline and diesel prices increased significantly in all EU countries as well. The EU average in January of 2021 for gasoline (E-95) was at EUR 1.32 and for diesel at almost EUR 1.2 per litre (or USD 5 and USD 4.54 per gallon, respectively). In July of 2022 these prices rose to an average of EUR 1.88 and EUR 1.9 per litre (or USD 7.12 and USD 7.19 per gallon), respectively. And in many EU countries prices for both gasoline and diesel rose above EUR 2 per litre (USD 7.57 per gallon), and diesel reached a record price in Sweden of EUR 2.37 per litre in July (nearly USD 9 per gallon).[6]

Soaring energy prices had a significant impact on macroeconomic indicators including inflation. In the US, gasoline alone accounted for roughly 20% of the increase in the Consumer Price Index from June 2021 to June 2022, even though it is less than 5% of the consumer basket used for inflation calculation.[7] Rising energy prices (and in particular gasoline) also caused a sharp drop in consumer confidence, with the University of Michigan consumer sentiment index in June hitting the lowest reading on record. High prices at the pump also correlated adversely with President Biden's approval ratings.[8]

Similarly, energy is behind much of the inflation in the Eurozone, with nearly half the countries registering double-digit inflation.[9] The loss of President Emmanuel Macron's party in the June 2022 parliamentary elections in France, attributed to the nation's difficult economic situation and high energy prices amid the Russia-Ukraine war,[10] is also a sign that European political leaders need to be prepared for an electoral backlash and lower approval ratings. Economic forecasters, including the International Monetary Fund, are revising their GDP outlooks to be lower, in part because of sharp energy price increases, as well as rising concerns over how such increases could impact lower-income countries and households.[11]

Chart 1 | Gasoline, consumer sentiment and approval for the US president



The policy response: initial context and reactions

Even as energy prices began to spike, the global focus was still on climate policy, in particular leveraging COVID-related stimulus funding to follow through on commitments such as those made at the 2021 United Nations Climate Change Conference, more commonly known as COP26. The following discussion is not meant to be a full examination of climate and energy security policies of the US and EU, but rather an illustration of how focus has shifted since the Russia-Ukraine crisis.

There were also renewed commitments to keep global temperatures from rising above 1.5 C. Importantly, the actions designed to achieve these goals were not only inward looking, but were also designed to motivate other countries to adopt more stringent decarbonization goals, or at least to prevent them from adopting carbon-intensive technologies. Hence, the EU carbon border adjustment mechanism and several initiatives to end fossil fuel investments – including the European Investment Bank's 2019 move to end fossil fuel funding – were implemented.

A similar pledge was made at COP26 by 34 countries and five development institutions, representing both the developed and developing worlds, with the notable exception of major Asian investing economies such as China and Japan.[12]

In general, COP26 has experienced significant push back from the developing world on the scope and speed of the energy transition.[13] As such, the rift between the developed and developing worlds has grown. The rhetoric, policies enacted, and funds dedicated toward development of energy markets differ drastically, with the former being more concerned

The early energy transition plans for post-COVID recovery were particularly ambitious in the developed world. The effort was led by the EU and the US in the aftermath of the 2020 election and the installment of the new, more environmentally conscious Biden administration. The idea was not only to build back the economy affected by the COVID slump, but to simultaneously move away from fossil fuels and toward a more sustainable world.

about climate action and the latter with access to energy and energy security, which would allow billions of people to move out of poverty. COP27 further accentuated these differences, although Russia's invasion of Ukraine shifted the spotlight to energy security (note added by the authors as part of an update in the current publication).

However, in 2021, when recovery efforts were underway, and in early 2022 after the start of the Russia-Ukraine war, spiking energy prices significantly changed the focus for policymakers and voters. A much sharper focus on energy security and economic growth joined – and to some observers' minds, replaced – the attention given to the energy transition.

Whether the change will be conducive to developing a better understanding of the challenges ahead and building more common ground – both within the US and EU, as well as between the developed and developing worlds – depends on the path taken.
We argue that, if managed properly, a policy framework that acknowledges the centrality of fossil fuels and the need for secure, affordable energy in today's world can co-exist with aggressive transition efforts. Indeed, these factors must be addressed if a successful transition is to be pursued.

EU response: energy security concerns escalate both long-term climate goals and current emissions

The organization and its members have been relying mostly on regulation for setting goals and targets for decarbonization. The European Green Deal proposed in 2019 became officially enshrined in the European Climate Law in 2021 (EU 2021/1119). The law legally binds all EU members to become climate neutral by 2050 with an intermediate step to limit emissions by a minimum of 55% in 2030 (vis-à-vis 1990 levels).[14] This is consistent with the policy direction from before and during the COVID-19 pandemic with nearly EUR 25 billion in the 2021–2027 budget directly intended for environment and climate action[15], and 30% of the budget devoted to fight climate change in general.[16] In addition to the general rules introduced by the Climate Law, in July and December 2021, the European Commission introduced two packages with more specific regulations, known as "Fit for 55". Among other stipulations, the two packages focus on reforming the EU emission system, promoting energy efficiency, reforming the EU's law on renewable energy, reducing barriers to fossil fuel phaseout, and lowering emissions from fossil fuels.

These regulations, which will require a lengthy legislative process to be implemented, are yet to be enacted by the EU. Hence, the final wording of "Fit for 55" is likely to be influenced by the current energy crises facing Europe.

The rise in energy prices at the heels of post-COVID recovery combined with Russia's deliberate reductions in energy exports in the second half of 2021 made Europeans increasingly uneasy about the feasibility of their post-COVID development plans. This was exacerbated by Russia's invasion of Ukraine on February 24th 2022. Following the invasion, Russia became an unwelcome source of energy – as well as a risky and unreliable source. Given Russia's dominant position as an energy supplier to Europe, it has also been impossible to replace Russian energy in the short term.

As a result of the Russian-Ukraine war, energy security concerns have become of paramount importance for the EU. In direct response, the EU has reframed its goals for decarbonization included in the European Climate Law to achieve two aims: 1) a significant, longer-term trend away from carbon-intensive fuels, and 2) a short-term move to cut dependence on Russian energy, which Russia has used as a geoeconomic and geopolitical weapon and to finance its military and war efforts.

The REPowerEU framework has been proposed by the European Commission to guide the EU and its member countries to achieve these goals by building on the "Fit for 55" proposal. It has not only reaffirmed the decarbonization goals included in the European Climate Law, it has supercharged them.[17] It has announced a rollout of wind and solar projects designed to help in both the short and long terms with secure energy sources.

It has also designated medium-term measures (to be completed before 2027) to support stronger decarbonization efforts like increasing renewables targets from 40% to 45% in 2030 and accelerating the development of the hydrogen economy. Meanwhile, the European Commission is pouring money into investments in industrial decarbonization under the Innovation Fund.[18]

However, if Russian energy imports were to be cut further in a significant manner, these actions would not be enough to keep all the lights on and houses warm. Accordingly, the EU has envisaged additional goals, such as increasing levels of energy efficiency. A proposal by the European Commission calls for raising the current binding energy efficiency target from 9% to 13%, and the four largest parties in the European parliament that have united behind that call have even suggested that a higher, 14.5% benchmark could be set.[19] As the uncertainty over gas supplies escalates, on July 20th 2022, the European Commission also proposed a law that would put the economy on a war footing by requiring EU member states to ration natural gas. The move would enable EU countries to fill gas storage to higher levels during the summer and avoid – or at least soften – a potential gas crisis in the winter months. Besides energy-saving measures, to ensure energy security, the EU has been seeking short-term fossil fuel alternatives to coal, gas, and oil that, until now, were imported from Russia. This has been especially challenging in the current environment of high prices and strained global supply, especially in the case of natural gas where the infrastructure is insufficient to move available supply into and within the EU.[20]

In addition, relatively mono-dimensional policies toward an energy supply and decarbonization path that were in place before the Russian invasion (such as Germany's policy of Energiewende coupled with its overreliance on Russian natural gas and new supply routes via Nord Stream 1 and Nord Stream 2) have impeded Europe's ability to effectively respond to cuts in Russian exports, perversely reinforcing continuing energy security vulnerability. The latter has been surely underappreciated in Western Europe where there is a persistent acquiescence toward Russian dominance as well as hesitancy toward investment in fossil fuels. Meanwhile, energy security has often been one of the major objectives in much of the post-Soviet EU, in particular in Lithuania and Poland, but also in Romania and Croatia. This has resulted in the buildup of gas infrastructure to back up Russian gas with imports of piped gas from Norway and LNG from the US, Africa, and the Middle East, in addition to the continued use of coal over the last decade. This buildup allowed Poland and Lithuania to completely give up Russian gas imports almost effortlessly as early as in mid-2022, a feat than no Western European country has been able to achieve so far.

In the context of the short-term shift in the European market, the reality of power generation in 2021 and especially in 2022 means the EU has been far from reaching its climate action goals. Two interrelated factors are to blame:
1) the pricing deferential between skyrocketing natural gas and expensive, but still more affordable, coal (despite high EU carbon prices); and 2) the need to save gas in storage for the upcoming winter, including the need to comply with national and EU legal requirements that set obligatory gas storage levels at 80% for November 1st 2022, (and 90% in subsequent years), which in turn drives up demand for natural gas over the summer and increases its prices.[21]

As a result, gas-to-coal switching intensified in the second part of 2021. For example, Germany, known for its extremely ambitious policy of decarbonization, already replaced some of its gas usage with hard coal and lignite in 2021. Other countries that already have sizable coal generation, including Bulgaria, the Netherlands, and Poland, also increased their reliance on coal in the second part of 2021.[22]

What next?
Potential ways forward

Potential responses to spiking energy prices span a range of possible outcomes. Will major energy consumers adopt policies to accelerate the transition to a low-carbon energy system? Will they pursue development of fossil fuels with renewed vigour?

We argue that the only successful way forward is to answer "yes" to both questions.

Today's economy is heavily anchored in fossil fuels, which account for over 80% of energy use globally (with the US and EU at 81% and 70%, respectively).

As we have seen, the critical importance of energy to modern life means that affordable, secure, and reliable energy today must remain a priority for political leaders – or at least for those who seek to remain in office. Thus, policies cannot divert investment away from fossil fuel supply more quickly than demand and the underlying capital stock can be turned over. Importantly, the natural rate of decline in existing oil and natural gas wells means that continued global investment in fossil energy supply is needed, even in the International Energy Agency's (IEA) successful transition scenario (the "Sustainable Development Scenario").

The imperative to rapidly reduce emissions of greenhouse gasses (or, more accurately, to stabilize atmospheric concentrations) remains unchallenged. It is also increasingly a priority for voters around the world.

The key question is, can the current crisis help us learn to walk and chew gum at the same time? That is, can society learn to simultaneously acknowledge the need for affordable (fossil) energy today, while also pursuing a rapid transition to a more sustainable energy system in the future? A “drill baby, drill” approach will fail at reducing emissions. A “no fossil fuels soon” approach will fail at supplying sufficient affordable energy in the short term and at running factories and providing electricity, mobility, and air conditioning and/or heating for consumers in the medium term.

The policy responses seen to date in the US and EU have differed significantly. In the past few months, the EU has sought to adopt policies that accelerate and integrate climate and economic/energy security objectives. The adjustment period is likely to be a difficult one with high energy prices across the board. It remains to be seen whether the ambitious climate goals in the EU remain, become adjusted, or are coupled with new measures to ensure the security of supply of traditional fuels. But at least for now, the two concepts have become linked in the minds of policymakers and in the practice of making policy.

But the approach of the EU countries and the United States has been quite different, at least so far. EU member countries have tangible obligations to reduce emissions on a set timetable. In contrast, the United States relies more on incentives, such as numerous tax credits, provided for example in its Inflation Reduction Act. Moreover, the EU is much more dependent on energy imports, including on Russian energy supplies. Low domestic fossil fuel reserves make renewable energy more attractive, not only in the face of energy transition and decarbonization efforts, but also in terms of pricing.
After all, the EU has seen much larger spikes in natural gas and electricity prices than the US, which can rely on abundant – and more affordable – domestic natural gas.

This is not to say that the EU’s policies have or are likely to succeed. Most analysts believe that the EU was not on track to meet its climate commitments before the Russian invasion of Ukraine.[23] Early indications of growing coal use throughout Europe highlight that, if forced to choose, future climate objectives will be a lower priority than immediate access to affordable energy, even in the most developed and most climate-friendly regimes around the globe.

Importantly, even a good start will require constant follow-through. A successful energy transition is one that will continuously meet the requirements for affordable energy throughout the transition period. This balance must be continuously assessed and addressed over time. Unfortunately, successful policies are not "one and done."

For example, there are concerns about the growing dependency on countries not aligned with the EU and US – like China and Russia – for minerals and supply chains that are needed for the development of renewables, batteries, and EVs. This is an issue that will need more careful consideration if the energy transition is to succeed. In the meantime, it is important to underscore that the United States' status as a natural gas and oil producer and exporter has provided significant benefits by reducing the geopolitical influence of energy producers like Russia. One can only imagine the extent of leverage Russia would have over Europe and even the US if both were dependent on oil and gas supplies from abroad.

In other words, energy security/ availability and climate must continually remain linked in the policy framework, as the energy system transitions.

But if the current crisis is to serve a useful purpose, it will be to remind us that society must pursue both policy objectives at the same time – affordable, secure energy today and a rapid energy transition. By forcing us to acknowledge the former, we are guardedly optimistic that the crisis can push political leaders – and the voters who elect them – to choose the middle path that will make all the difference.

What would this middle path look like in practice? Fossil energy companies and their advocates would need to acknowledge the reality of climate change and the need for policies to address it. Climate policy advocates in turn need to acknowledge the need for continued oil and gas investment. In the US, moreover, we must admit that a robust domestic oil and gas industry is vital to achieving economic and strategic security for ourselves and our allies, and that this can be consistent with a rapid energy transition – if managed properly.

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One goal but many paths to get there

– technological dilemmas in the energy transition

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The goal sought by countries which together account for more than 90% of the world's GDP and nearly 70% of the global population has been clearly defined, they all want to achieve climate neutrality. However, the time frames set for achieving that goal vary – the European Union, United States, United Kingdom, Japan, Australia or Korea have taken the lead, targeting climate neutrality by 2050. China and India, on the other hand, expect to reach the net zero target by 2060 and 2070, respectively.

Also the paths leading towards that ambitious goal are far from settled. The pioneering role entails a lack of available models to emulate and need to deal with considerable technological uncertainty. In its 'Energy Technology Perspectives' report released in January 2023, the International Energy Agency (IEA) indicates that a half of the emissions reductions in 2050 will come from technologies that are still at the prototype or demonstration stages[1]. Which specific solutions, and in what order, will make it to the commercial uptake and large-scale deployment stage will depend not only on technological issues, but also on the prevailing regulatory framework and investment decisions concerning public infrastructure projects.

Moreover we can see that, faced with technological uncertainty, the European Union is generally trying to mitigate the related risks through regulatory frameworks designed to support preferred technologies in various sectors of the economy (such as power generation and passenger transport), and by helping investors and the financial markets understand which economic activities are environmentally sustainable (the EU Taxonomy). However, as there is no such thing as a free lunch in the economy, the outcome is either a heightened regulatory risk or divestments in areas that are currently generating growth. For this reason, the regulatory approach is not the only conceivable one. For example, the US has not introduced as extensive a regulatory regime for green technologies as the European Union, nor has it designed penalties for non-compliance or environmental charges similar to those imposed by the EU. Instead of a stick, the US has chosen to offer a carrot: in particular, the adoption of a USD 369 billion-worth package of subsidies, tax credits and other support measures for investing in green technologies as well as incentives for consumers to switch to green alternatives under the Inflation Reduction Act is expected to entice entire green technology value chains to move to the US, at the expense of Europe and China.

Whether the Global North opts for the carrot or for the stick, the Global South seems to have taken an entirely different approach. Especially countries sitting on abundant deposits of fossil fuels, mainly crude oil, are advocating a completely different way of thinking about the technological future of hydrocarbons. Saudi Arabia, for one, is promoting the concept of a Circular Carbon Economy[2], which – in the absence of technological capabilities enabling quick departure from petroleum on the global scale – proposes to develop a closed-loop system for carbon dioxide and hydrocarbons involving, among other things, improved management and recycling of carbon, as well as widespread adoption of carbon capture and storage (CCUS) systems, capturing CO_2 directly from the air and from exhaust pipes.

These diverse approaches to the technological transition do not call into question our overarching goal. On the contrary, we expect that the varying approaches and viewpoints will make investment and development in these times of huge uncertainty (involving more than just technological issues) at least slightly easier.

Trying to figure out how to confront the technological uncertainty, we can assume that, depending on the sector, some zero-carbon technologies are now ready for deployment (for instance, in power generation), with uncertainty surrounding only the pace of the transition. By contrast, in other sectors, such as industrial manufacturing, a lot still remains to be done.

Power generation

In power generation, we are dealing with moderate technological uncertainty over the time horizon until 2030. A significant reduction of power generation costs has made renewables cost-competitive relative to conventional counterparts without any subsidies, even before the recent surge in the prices of energy carriers such as coal and natural gas. In some countries, renewable energy sources are being or will be complemented by large nuclear power plants.

This concerns both onshore wind assets (with the average global LCOE down 68%, from USD 0.102/kWh to USD 0.033/kWh between 2010 and 2021) and offshore farms (with the metric down 60% over the same period, from USD 0.188/kWh to USD 0.075/kWh). For large-scale solar PV systems, the cost reduction has been even more pronounced, coming to 88% (USD 0.417/ kWh, to USD 0.048/kWh)[3].

Variability is an inherent feature of renewable energy generation – when conditions are favourable, renewable assets can produce more energy than is needed, but when they are not, the energy output may be insufficient to meet demand.

Thus, it should be noted that while LCOE is a widely used and helpful, albeit imperfect, measure to capture all generation costs from a unit, it fails to take account of the system costs and how the unit's presence affects the entire grid. Another measure used by IEA is VALCOE (value-adjusted LCOE), which additionally reflects the value of services generated for the system. All this considered, renewables are still a cheaper option than new-build gas- or coal-fired sources, but the gap is narrowing down. As pointed out by IEA, a rising share of renewables in the energy mix will entail a higher VALCOE for renewable sources and a lower VALCOE for dispatchable sources (which can be switched on whenever needed)[4] – not necessarily based on fossil fuels.

As argued by Professor Dieter Helm of Oxford University, we cannot advance the energy transition without addressing the systemic consequences of intermittency or, to put it simply, the problem of where to derive energy from when the wind is not blowing and the sun is not shining. The answer in theory was to increase the output from gas-fired plants, which are flexible (can be fairly quickly switched on or off). While this is not an argument against wind, or even against speeding up the development of offshore wind power, it does have its implications.

Some of them have to do with the fact that the operation of gas-fired plants becomes intermittent, too (gas-fired generation is intermittent because it is driven by temporary unavailability of renewable wind or solar power, which disrupts revenue streams from gas-fired plants), as well as increased system costs (the issue of system balancing, management of power grids or need for more capacity within the system).

One solution to the problem can be found in battery-based energy storage. As the share of renewable sources in the energy mix is rising, so is demand for services to optimise their operation and ensure system flexibility. Energy storage can also play a role in stabilising the system, whether through the capacity market, or through the provision of system services encompassing frequency, voltage or 'black start', i.e. the process of restoring a power plant or section of a power grid to operation after a blackout.

A challenge associated with batteries, regardless of the sector in which they are applied, is the availability of critical minerals. The energy efficiency-driven appeal of decarbonisation based on the use of batteries is pushing up demand for key materials needed to manufacture them. According to the cited technology report by IEA, these include lithium, nickel, cobalt, copper, graphite, silicon, and manganese sulfate. For most of them, a gap oscillating around 20% is projected until 2030 between production capacities announced by mining or processing companies and demand under the climate neutrality (NZE) scenario[5].

Batteries can be helpful in balancing demand and supply over short timespans – such as between day and night. Stability of the system over prolonged periods with low wind and dense cloud cover (Dunkelflaute) can be ensured by gas-fired power or combined heat and power plants adapted to burning hydrogen, which can be stored, e.g. within salt caverns.

SMR

For the most part, the technologies discussed above are mature and being deployed around the world. But the growing demand for electricity (in Poland, the projected growth until 2040 is about 20%)[6] is prompting continued development of new, cost-effective, zero-carbon generation technologies. These include, for example, small nuclear reactors (SMRs). Their generation patterns are not unpredictable and their smaller scale allows private entities, not just state-owned ones, to bear the investment costs, unlike in the case of classic nuclear reactors. The Orlen Group, as a partner in the ORLEN Synthos Green Energy joint venture, is collaborating with GE Hitachi to build a fleet of BWRX-300 reactors in Poland (consisting of 300 MWe units based on the boiling water reactor (BWR) technology). The first project of this kind, currently at the site preparation stage, is to be delivered in the Canadian province of Ontario. The technology is being evaluated by the Canadian Nuclear Safety Commission, the world's first governmental agency to undertake its formal certification. As both GE Hitachi and Ontario Power Generation have assured, the construction is due to begin in 2025, and the completed reactor is expected to be placed in service by the end of this decade. The BWRX-300 fleet in Poland will be modelled on the Canadian project.

The SMR technology is also a solution to decarbonise a large and very important sector of the economy, namely that of heat generation. Heat pumps, which are gaining in popularity across Poland (with a 140% year-on-year increase in sales and a nearly 30% share in the total number of heating devices sold in Poland during 2022)[7] will help residents of single-family houses, but will not solve the problem of district heating, which is used by 42% of Polish households[8] and currently relies largely on coal and gas-fired sources. Small nuclear reactors co-generate electric power with heat, which can be used for district heating or (at higher temperatures) in industrial processes.

Source: GE Hitachi Canada

CCS for industry

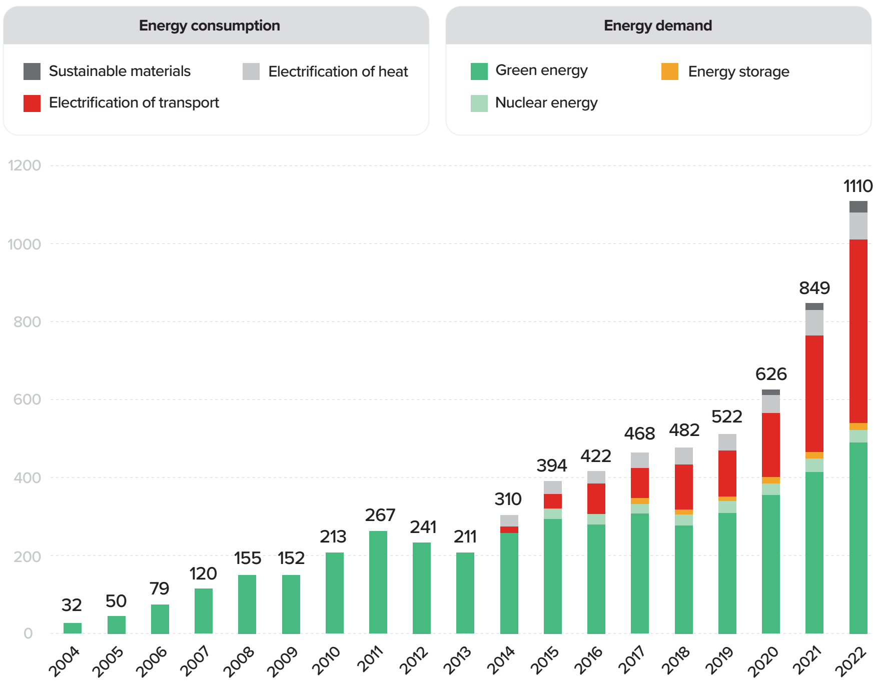
Given their maturity and wide applicability across various industries, the CCS technologies are coming to the forefront, especially over the time horizon until 2030, as a solution for reducing carbon emissions. At present, there are 109 CCUS units operating worldwide, with a commercial capacity to capture 47.5 million tonnes (MMt) of CO_2 per year.

However, in 2022, also Oil&Gas companies were actively involved in CCS development. Some 50 new projects were announced during that time, of which about 95% are to be delivered under strategic alliances formed to study, research and develop new, cost-effective technologies across the carbon capture value chain.

Companies regard carbon capture not only as a means of reducing emissions, but also as a new business opportunity. Interest from companies seeking to reduce industrial emissions has grown strongly, which is why upstream players in particular, holding licences to produce petroleum from increasingly depleted fields, are working on carbon capture-as-a-service (CCS) offerings.

Transport

According to the 'Energy Transition Investment Trends' report published by BloombergNEF in January 2023, electrification of transport (which also includes hydrogen vehicles and infrastructure) is the fastest growing (in absolute terms) category among energy transition projects. Only 0.1% out of USD 1.2 trillion spent in 2022 on transformation of the energy and transport sectors went to hydrogen projects (although this project category has seen the biggest spending increase in relative terms). Currently, funds are being allocated mainly to electric vehicles and EV charging stations, but given the pace of growth and the social importance of transport (being an evident aspect of decarbonisation), investments in heavy transport and long distance buses are bound to gather pace soon. It is thus worth paying closer attention to the available decarbonisation technologies and the consequences of choosing a particular one. With no decisive moves and prolonged deliberation, Europe can be left lagging behind other players. The report suggests that this trend might have already started, for instance in the case of hydrogen projects: while Europe is in the process of regulatory discussions, with 167 MW of electrolyser capacity installed in 2022, China managed to commission almost four times as much (724 MW) in that very same year[9]. As for investment projects, Europe is also facing competition from the United States. The IRA scheme referred to above grants a tax credit of USD 3 for every kilogram of hydrogen produced in the US.



Source: BloombergNEF Energy Transition Investment Trends 2023

Today, road, maritime and aviation transport rely largely on oil and its distillates. Also, both of these transport sectors have no option but to become zero carbon by 2050. The way to achieve this goal is by using four technologies: batteries, hydrogen, biofuels and synthetic fuels. Each comes with their own set of advantages and drawbacks.

	Batteries	Hydrogen	Sustainable fuels
Light duty vehicles (LDVs)	●●●	-	TBD
Short- and medium-distance cars and buses	●●○	●○○	●○○
Long-haul trucks	●○○	●●●	●●○
Off-road	●●○	●○○	●○○
Railway	●●○	●●○	●●○
Maritime transport	●○○	●●○	●●●
Aviation transport	●○○	●○○	●●●
Additional opportunities	• Stationary use of batteries (the car as energy) • Power grid support (EV charging management)	• Heavy industry • Grid support • Feedstock, raw material for other sectors	• Decarbonisation of plastics and chemicals • Bioproducts
Development priorities	• EVs • Recycling of spent batteries • Grid integration • Infrastructure development	• Costs of electrolysers • Costs of fuel cells • Development of green hydrogen infrastructure	• Scalability of bioenergy • Reducing ethanol emissions intensity • Cost efficiency improvement

●○○ Slim prospects in the long term
●●○ Good prospects in the long term
●●● Excellent prospects in the long term

Source: The U.S. National Blueprint for Transportation Decarbonization: A Joint Strategy to Transform Transportation

Road transport

Batteries

As regards energy efficiency, direct electrification of road transport through the use of batteries and electric motors reduces losses to a minimum. According to think tank Transport & Environment, an electric motor (with an efficiency of 95%, which is more than twice that for internal combustion engines) can use about 800 kWh out of 1 MWh[10].

An electric motor reduces the frequency and extent of maintenance work. Compared with an internal combustion engine, it has far fewer moving parts and needs less fluids – for instance, it operates without engine oil. An analysis on light-duty vehicles performed in 2021 by the US-based Argonne National Lab showed that maintenance costs are 65% higher for combustion-engine cars[11].

For many years, electromobility development has been severely hampered by high costs and weight of batteries, which significantly increased the weight of vehicles. Progress has been made in both of these areas in recent years – the price of car batteries has fallen by about 80% relative to 2013, while energy density has increased by 43%[12] for the same car model between 2011 and 2018. Technological success has been followed by a surge in sales: in November 2022, EVs and plug-in hybrids accounted for, respectively, 17.3% and 10.4% of all passenger cars in the EU[13].

As car batteries are subject to gradual wear and tear over time, after about eight years they may need to be replaced. It is possible, for instance, to use car batteries that have lost efficiency but still work to absorb energy and serve as energy storage. As the electrification of road transport is in its infancy, the whole ecosystem of applications for spent batteries is yet to take shape. EV batteries could also potentially be used as energy storage systems and export electricity back to the grid during peak demand.

Choosing this form of decarbonisation entails higher demand for electricity at many places[14] – research shows that users of electric cars charge them at homes, workplaces or shopping centres. Based on the study we refer to, the first two locations are the most popular. It should be noted, though, that the survey used in the study was carried out in California, where urban structure is much different from that in Europe. Further consumerisation of electric cars will require digital solutions – if all users were to start charging their EVs at home in the afternoon after returning from work, the spike in demand that is already seen today would become even sharper. Smart solutions make it possible to optimise energy demand – charging an EV could begin when demand for energy drops, allowing the curve to flatten out. While fast chargers are not the default option for charging

passenger EVs, they do play a key role: it would be far more difficult to cover longer distances without them at hand.

Driving range and charging speeds are even more crucial in freight and passenger transport. Trucks and buses consume much more energy than passenger cars and often travel longer distances. This requires a larger-size battery, which weighs more, increasing the overall weight of the vehicle.

Working hours for truck drivers in the European Union are limited by regulations, mandating a 45-minute break after every 4 hours and 30 minutes driven. Considering that the maximum speed limit for trucks on motorways in Europe is between 80 and 90 kilometres per hour, this means they can cover roughly 400 km without a break. The initial range should therefore be a safe 500 kilometres or so. Assuming energy consumption for a 40-tonne truck at about 1.72 kWh/km[15], a charger of about 800 kW would be required to fully recharge the range during a 45-minute break. The fastest commercially available vehicle chargers today are 300 kW[16]. Vehicles in the planning phases, such as the Tesla Semi, are expected to have a charging capacity of 1 MW, which would be more than enough to recharge the range during a 45-minute break. But massive investments in the transmission and distribution networks would be needed to turn this vision into reality. A group of trucks starting to recharge simultaneously would lead to a dramatic surge in power consumption – this demand could not be met without huge investments in the distribution network. One way to reduce the costs of this particular solution would be to build energy storage systems at service stations to enable peak shaving.

Commercially available models, such as the Mercedes eActros, currently offer ranges of around 400 kilometres – but this is in ideal test conditions. The manufacturer claims that cold weather and a full cargo load reduce the driving range to 60% of the maximum[17].

Hydrogen

Hydrogen vehicles rely on hydrogen that is fed into fuel cells to produce electricity, and they use that electricity to power an electric motor.

The efficiency of this process is lower than in the case of direct electrification[18]. Thus, more energy is needed initially to propel the vehicle, but storing energy in hydrogen is much easier (vehicles use compressed hydrogen), allowing even large vehicles to travel longer distances. Refuelling a hydrogen vehicle takes only a few minutes, while charging an electric car takes from less than twenty minutes (with ultra-fast chargers) to several hours (charging from a socket).

Using hydrogen does not in itself amount to decarbonisation – today hydrogen is obtained largely by steam methane reforming ('grey hydrogen'). Therefore, CCS or zero-emission energy-powered electrolysis need to be employed.

Hydrogen cars are currently much less popular than electric ones. Total global sales were less than 10,000 units in the first half of 2022 (with sales of electric cars, excluding hybrids, at over 3 million units in the same period[19]). This disparity may be due to the lack of available charging infrastructure (there were 685 refuelling stations worldwide at the end of 2021[20]) and high hydrogen prices at the pump – in California, the cost of driving a kilometre in a hydrogen car is higher than in a traditional car, with the car purchase price also higher. However, this may change as production volumes rise and hydrogen production costs fall.

The first hydrogen-powered trucks are being released on the market – Hyundai has unveiled its XCIENT model, which, according to the manufacturer, is expected to have a range of 400 kilometres in real-world conditions. Volvo is about to start testing models with a driving range of up to 1,000 km.

The challenge for this decarbonisation pathway is the costs associated with generating hydrogen and bringing it to fueling stations – this can be done by delivering compressed or liquefied hydrogen by truck, producing hydrogen on-site through electrolysis, or transporting the fuel via pipelines. The higher the pressure of the gas, the more hydrogen can be transported – but this entails higher requirements for the materials of hydrogen tanks and more energy and time needed for compression. Hydrogen liquefaction creates similar challenges. For electrolysis and pipeline supply, capital-intensive investments in the distribution or transmission network are necessary.

Aviation transport

Aviation transport is often considered one of the hardest sectors to decarbonise, because jet fuel has properties that are difficult to replace. Energy per unit mass is much higher than for batteries (44 MJ/kg vs under 1 MJ/kg for batteries)[21], but lower than for hydrogen (120 MJ/kg). With hydrogen, the challenge is energy per unit volume, at around 8 MJ/l[22] (vs 34 MJ/l for jet fuel)[23]. This could require a redesign of aircraft – those powered by hydrogen would have larger yet lighter fuel tanks. Airbus, an industry leader, has presented concept hydrogen-powered aircraft, saying it would achieve a mature technology readiness level by 2025[24]. In November 2022, Rolls-Royce and airline EasyJet unveiled a working green hydrogen-powered engine for use in aircraft[25].

The issue of specific jet fuel properties is solved by biofuels and synthetic fuels. They can be 'drop-in' alternatives fit for use in existing aircraft without any structural changes to the aircraft or airport logistics.

Work is well advanced on Sustainable Aviation Fuels (SAF), low-carbon biofuels derived from sources such as biomass, plant and animal fats or various types of waste. Depending on the raw material used, they could reduce emissions by a few dozen percent (80% in the case of the ORLEN Group's ongoing vegetable oil hydrogenation project) to 98% if algae are used (the process is at an earlier development stage and is yet to be commercialised)[26]. SAFs are already in use, but their market share is marginal (less than 0.05%[27]). Currently, the maximum blending ratio permitted under EU regulations is 50%, but full replacement of jet fuel is possible by 2030[28].

The problem with this solution is SAFs are more costly than standard jet fuel, which is largely down to feedstock prices and availability. This poses a major challenge given the anticipated increase in the number of flights[29]. That challenge is met by synthetic fuels, which are completely climate-neutral (assuming renewable energy is used for their production). Fischer-Tropsch synthesis produces hydrocarbons and desired fuels from a mixture of hydrogen and carbon oxides. However, its cost is currently high due to the energy intensity of the process.

Rail transport

The challenges of decarbonising rail transport may seem limited from the perspective of Poland, a country with a high degree of railway electrification (approximately 60% of the total line length[30]). But this is not the case – even in countries with large railway networks, such as the Czech Republic, the electrification rate is much lower than in Poland (around 33% for the Czech Republic)[31].

As in the case of other modes of transport, battery solutions (batteries would be charged from electrified parts of the overhead line) are competing with hydrogen solutions (locomotives). But a third option exists – electrifying the entire traction network. The latter technology is very well developed but capital-intensive and time-consuming, while the first two have the same advantages and disadvantages as is the case of road transport. High efficiency on the one hand and a longer range on the other.

Maritime transport

Maritime transport is another hard-to-abate sector where traditional fuels are difficult to replace due to the long distances that need to be covered and the massive weight of the cargo. Potential decarbonisation pathways are mostly based on hydrogen and its derivatives, from hydrogen and fuel cells, through green ammonia, to bio- and synthetic methanol. One of the largest industry players, Maersk, has opted for the latter pathway, having placed orders for 12 green methanol-powered container ships. The Danish-based company has also set itself an ambitious target to achieve net zero emissions by 2040.

For passenger ferries travelling short distances (up to twenty kilometres), electric propulsion and batteries may be a solution, in addition to hydrogen and its derivatives. Batteries are popular in the Nordic countries, especially in Norway.

Summary

Each of the sectors discussed in this article will have to fully transform over the next 27 years – at least in Europe and the United States. The transition to net zero is a combination of the industrial and information revolutions happening simultaneously and, in some cases, faster than its historical predecessors.

What the world will look like in 2050 is extremely difficult to predict – it will be a function of the pace of technological progress and decisions made by states and international organisations, From the development of infrastructure enabling the widespread adoption of some solutions and hindering the uptake of others, to direct regulatory decisions determining which paths are favoured and supported financially.

The multitude and diversity of challenges faced by companies in the various sectors that are mentioned above urge far-reaching caution before believing in the existence of a silver bullet. What is needed is an insightful analysis of the needs and capabilities of each area and the selection of an optimal solution meeting those particular needs. The 'picking winners' policy should be limited to the sectors where it is indispensable, while for other sectors a technologically neutral approach should be adopted, because the goal is one, but the various sectors of the economy will likely achieve it by following different paths.

Footnotes

1. Under the 2050 climate neutrality scenario.
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