CEE Energy Outlook

Where do national commitments lead?

Warsaw, January 2024

The CEE Energy Outlook examines the region's energy transition path and identifies key challenges and opportunities

As a leading energy company operating in Central and Eastern Europe, we decided to aggregate the policy and legislative goals of 13 CEE countries in order to deliver a comprehensive regional Energy Outlook.

The focus countries are:

- 11 CEE countries that joined the EU in or after 2004: Poland, Latvia, Lithuania, Estonia, Czechia, Hungary, Slovakia, Slovenia, Bulgaria, Romania, Croatia (further referred to as CEE11)
- Germany and Austria – included in the analysis to serve as a useful benchmark, since they are more advanced e.g. in EV adoption, and ORLEN operates/will operate in the two countries (further referred to as DE+AT)

At ORLEN, we firmly believe that transition towards sustainable energy is not only a challenge, but also a chance to develop new, sustainable paths for the region to prosper in the coming decades.

In order to assess the full potential of the CEE region, it is crucial to first identify CEE's current position on the transition map and assess where national energy and climate policies are heading.

In this assessment, we analyse national energy and climate plans, delve into how countries within the region have strategically diversified their supply routes, encompassing both fossil fuels and electricity. Furthermore, we scrutinise their forward-looking plans for interconnecting energy systems, providing a glimpse into the future of energy infrastructure. This comprehensive Outlook addresses two critical facets of the energy trilemma – sustainability and security.

It is important to note that this work does not include the third aspect - examination of costs. The decision to omit cost considerations stems from our reliance on the national plans that, unfortunately, do not furnish comprehensive cost estimates. Nevertheless, we hope this Outlook will serve as a valuable resource for understanding the current trajectories and future aspirations of the CEE region in the realms of sustainability and security.

It is crucial to emphasise that this publication is not ORLEN's forecast or official view. Instead, it serves as a complex aggregation and, where necessary, an extrapolation of existing plans and energy policies of CEE countries. Any assumptions made regarding e.g. decarbonisation pathways are presented on page 16. By adhering to this approach, we aim to provide an objective and data-driven overview of the region's energy landscape, allowing stakeholders to make informed decisions based on the current trajectories and aspirations of the countries within the CEE region.

An overview of the regulatory framework affecting the CEE region

Broad regulatory conditions:
Climate targets and agreements

The EU signed the Paris Agreement in 2016, acknowledging the importance of global warming and pledging to “hold the increase in the global average temperature to well below 2 °C above preindustrial levels and pursue efforts to limit the temperature increase to 1.5 °C”.

In 2021 the EU launched the Fit for 55 package, a set of regulations with the aim of reducing net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. Among its key targets are: sourcing 42.5% of total energy supply from renewables, reducing emissions from ETS sectors by 62% (compared to 2005 levels), and 14.5% reduction of greenhouse gas intensity in transport (or achieving an overall share of 29% of renewable energy in final energy consumption across all transport sectors).

There are also national commitments – under Germany’s Climate Change Act, the country should become carbon-neutral by 2045. A number of countries have also set coal phase-out dates.

Key climate targets

temperature rise well below
2°C

2030 emissions reduction target
-55% CO_2

2030 total energy supply
42.5% RES

net zero by
2050

Key findings

1. A move away from hydrocarbons towards variable renewables in the energy supply mix

The energy system emerging from national plans is a much more electrified one. It is characterised by a high share of renewables (including wind, solar, hydropower and modern bioenergy). Their share is projected to surge from 15% in 2021 to 45% under the Current Plans (CP) scenario and 62% under the Higher Ambitions (HA) scenario in 2050. Nuclear is set to rise in prominence, growing from 7% to 11% and 20% of the total supply under CP and HA, respectively. Energy provided by oil is more than halved under CP and reduced sevenfold under HA.

2. Decrease in total final consumption

Total final consumption is projected to decrease by 23% in CP and 35% in HA scenario driven by electrification across the board, especially in transport and energy efficiency growth in buildings and industry.

3. Significant increase in electricity generation

Widespread electrification will lead to growth in electricity generation - 56% under CP and 120% under HA scenario between 2021 and 2050. It is identified as a strategic lever for achieving net zero targets, promising significant emissions reductions across the economy.

4. Three approaches to the future electricity mix

Three distinct approaches to shaping the 2050 electricity mix are evident: scenarios with no nuclear capacities (Germany, Austria, Baltic States, Croatia), renewables supported by nuclear (Poland, Romania, Slovenia) and the reverse (Czechia, Slovakia, Bulgaria, Hungary).

5. Electrification of passenger cars, hydrogen, electricity and biofuels for heavy-duty transport

The transport sector is set to undergo a dual transformation. Light vehicles will witness decarbonisation driven by electrification, while heavy-duty vehicles will be decarbonised by a plethora of solutions, depending on a use-case – some will go electric, some will run on hydrogen and the remaining will continue to use liquid but decarbonised fuels – both bio and synthetic.

6. Decline in fossil fuel consumption in transport

The share of energy from fossil fuels in total energy supply for transport is expected to decline significantly, from over 90% to 52% under CP and 12% under HA.

7. Biofuels consumption will grow, but only until 2040

If decarbonisation goals are to be met without faster than anticipated adoption of electric vehicles, biofuels consumption in transport would need to grow significantly, especially in CEE11 (2-4x between 2021 and 2040). The demand is anticipated to peak in 2040 and subsequently decline with further progress in electrification. Germany and Austria would see 1.2-2x growth over the same period since they can rely on wider EV adoption.

8. Region (almost) free from Russian hydrocarbons

Before the outbreak of the full-scale war, Russia supplied over a third of oil and over two-thirds of natural gas consumed in the region. This dependence has been greatly reduced in the two years following the Russian invasion of Ukraine.

Key Outlook insights

GDP growth (2021-2050 average):

DE+AT 1.1%

CEE11 2.1%

RES capacity growth (2020-2050):

DE+AT 3-4x

CEE11 5-8x

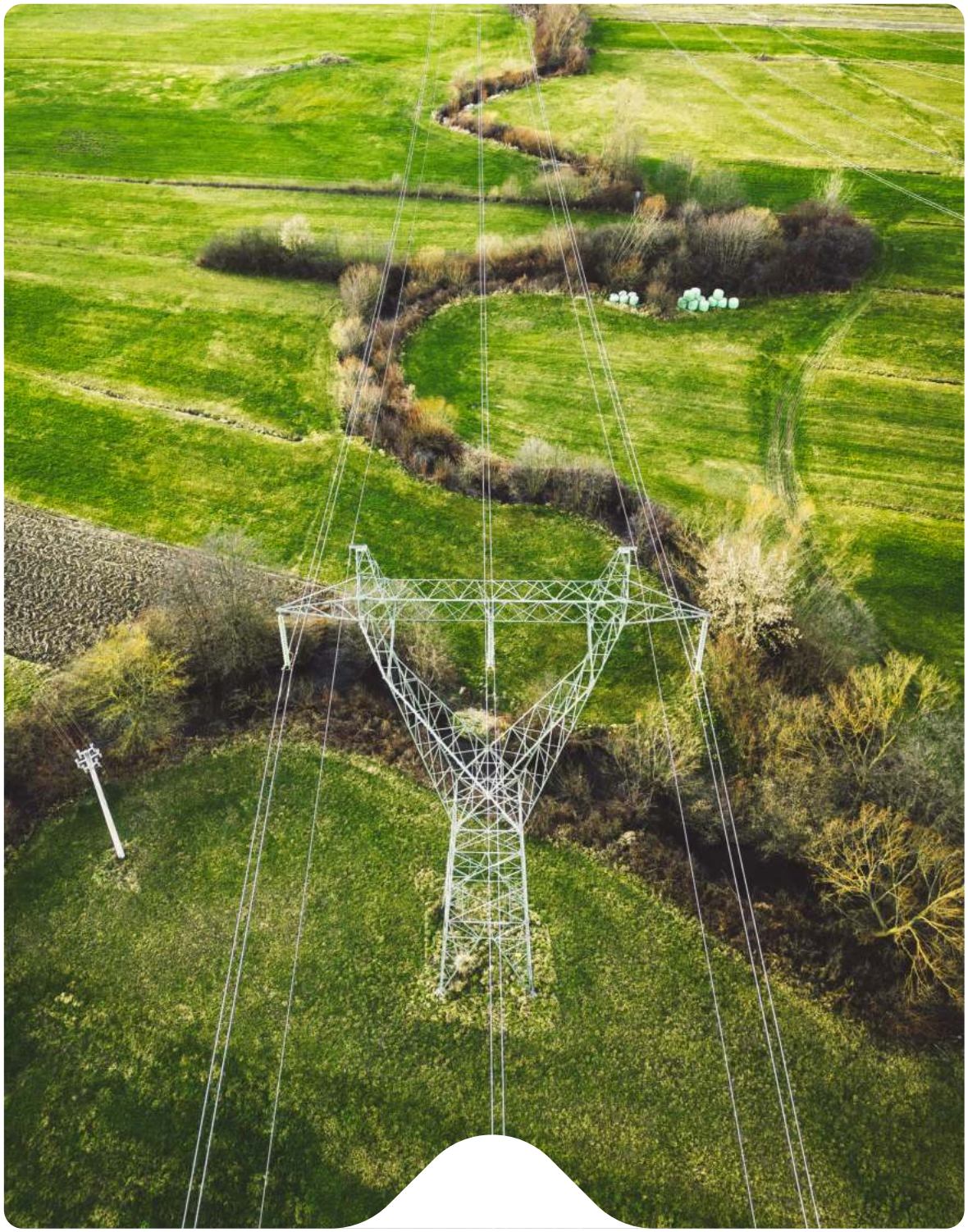
Biofuels in transport growth (2020-2040):

DE+AT 1.2-2x

CEE11 2-4x

Key data

Share in total energy supply	2021	Current Plans (2050)	Higher Ambition (2050)
Fossil fuels	74%	41%	14%
Renewables	15%	45%	62%
Nuclear	7%	11%	20%



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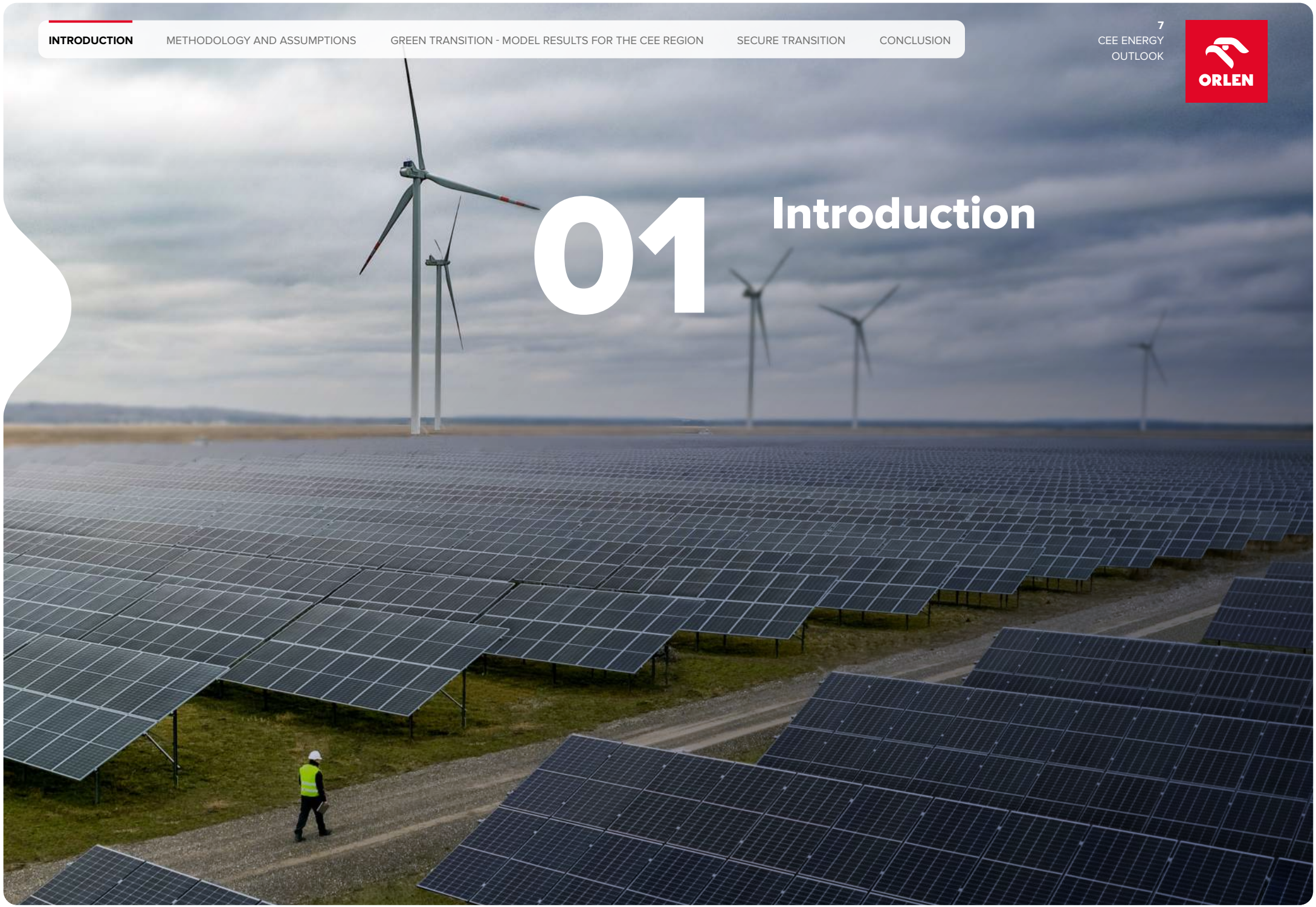


01 Introduction

Introduction

The fight against climate change presents both challenges and opportunities for companies and countries. Yet, to reap the benefits of this transition, it is necessary to put in considerable effort, make thoughtful investment, and implement well-designed policies.

In 2015, almost 200 signatories to the Paris Agreement, responsible for 98% of global GHG emissions, pledged to do their utmost to keep the global temperature rise this century well below 2 degrees Celsius above pre-industrial levels, and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.

The Paris Agreement was a culmination of a decades--long process of mainstreaming the notion that climate change is one of the biggest threats to humanity. Experts, scientists and politicians were calling for a concerted global effort to reduce greenhouse gas emissions and a change of attitude towards the environment and the world has listened.

Pace of decarbonisation varies across the globe, but it is safe to say the European Union has been at the forefront throughout the years. It has managed to decouple GDP growth from emissions growth, introduced the world's first major and biggest emissions trading system and has been willing to deploy new solutions, like offshore wind and electric vehicles at scale.

Until February 2022, the "secure" and "reliable" aspects of the energy trilemma received less spotlight than reducing the cost of energy through greener alternatives. However, the war in Ukraine brought energy security to the forefront of the agenda.

CEE11 countries have historically been slower to adopt many of the decarbonisation technologies, as governments and consumers were unwilling to pay a premium over the cost of existing, established solutions. This is beginning to change as the economics of new technologies become more favourable: the cost of energy generation from new renewables is lower than from new thermal plants, electric vehicles are about to reach parity with traditional internal combustion engine vehicles (on the total cost of ownership basis), the countries are becoming richer and climate goals are getting increasingly more stringent.

However, while they might have lagged behind on greening their grids and transport systems, they have been very much ahead of the curve on supply diversification and trying to wean themselves off Russian hydrocarbons.

Russia's full-scale invasion of Ukraine in February 2022 proved they were right to invest in resilience – and this time it was other countries playing catch-up e.g. on LNG terminals.

The war led to fuel supply issues in the European market and caused a shift in short-term priorities of many countries, bringing energy security into focus. The present state of energy security is, in part, a result of investment decisions made over the past few decades. Thus, it is essential to highlight that effective management of the energy transition now is crucial for ensuring energy secu-

rity in the upcoming years. There is no long-term tension between energy security and energy transition as the move away from imported fossil fuels induced by the transition enhances the countries' energy security.

CHIEF ECONOMIST'S COMMENTS

Dr. Adam B. Czyżewski

The energy transition will not succeed based solely on scaling up and modifying existing techno- logies. What is needed is revolutionary innovation, i.e. investment in new early-stage technologies. It will be necessary not only to meet the growing demand for available energy as the world's population expands, but also to displace CO_2-emitting fossil fuels from the energy mix. Moreover, this will have to be done within a relatively short period of time.

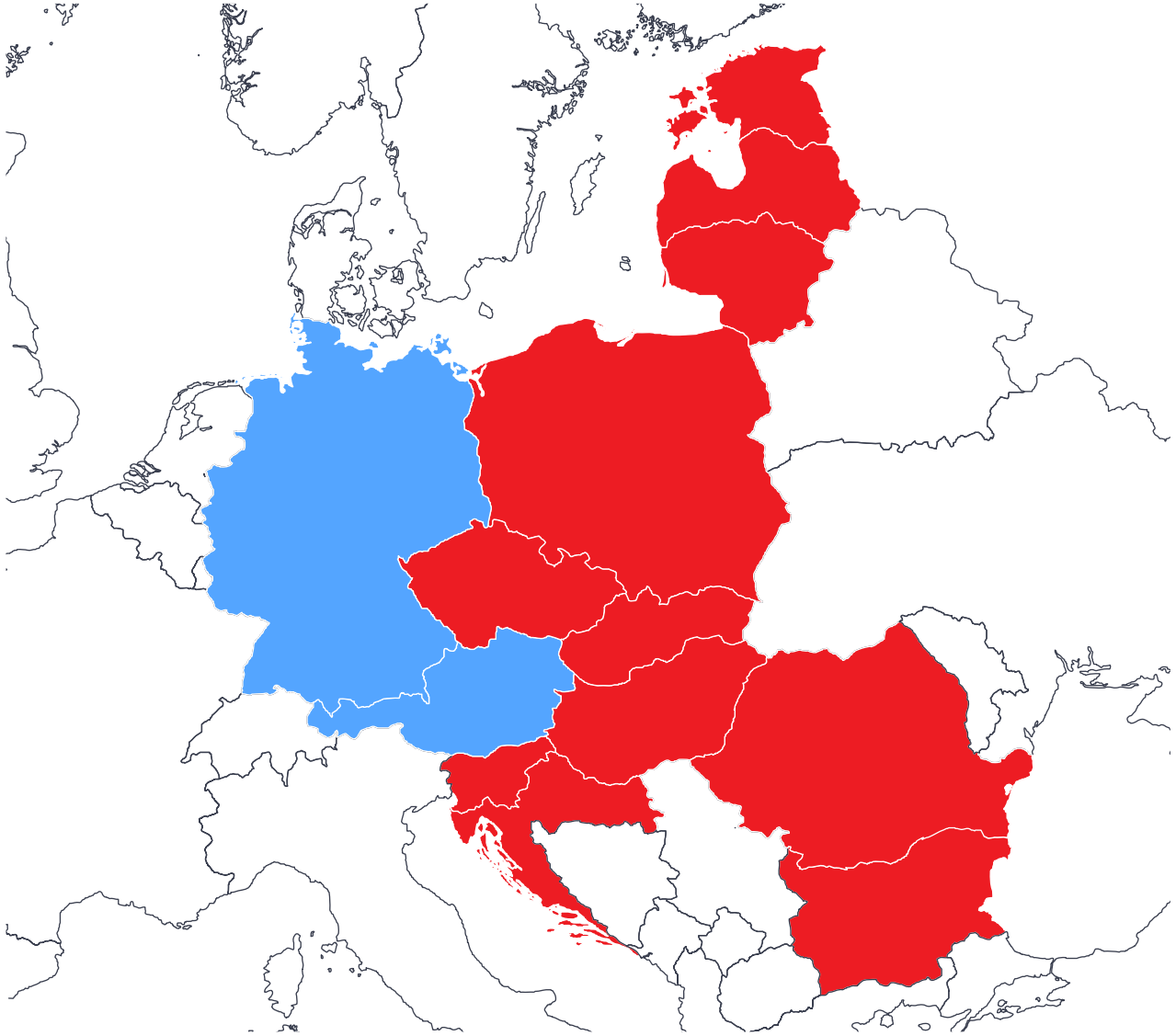
According to the Paris Agreement, there is only a quarter of a century left to develop and deploy entirely new technologies to drastically reduce the share of fossil fuels in the energy mix from the current 80%. For the transition to succeed, it is not enough to develop such new technologies in isolation. To achieve the ultimate goal of energy transformation, new technologies must form a new economic and social ecosystem, a new eco-puzzle in which our needs will be met in a sustainable way.

The challenge of energy transition is particularly daunting for developing and emerging economies that, until now, have relied on proven and commercially available technologies. The region of Central and Eastern Europe has not been at the forefront of technological breakthrough. However, we belie- ve that after a period of integration with the EU and the intertwined, constant growth of their economic potential, the time has come for the CEE countries to enhance their capabilities in the energy sector and to join the ranks of countries that have built their development on technological advantage.

The CEE region is unique in terms of its history, but also in terms of its assets and resources, which in the face of the energy transition can bring both challenges and exceptional opportunities for the region's development. ORLEN, as a player aware of the existing factors, anticipates growth opportunities in CEE and will seek to encourage the region's considerable potential.

With our strong asset base we have the opportunity to take a comprehensive view and an outlook for our region to see upcoming opportunities that may benefit CEE as a whole.

At ORLEN, we have modelled the Energy Outlook for CEE11, Germany and Austria to provide a holistic view of our region



Key data:

Population
~194 million
DE+AT ~92 MILLION
CEE11 ~102 MILLION

GDP per capita
~26k EUR[1]
DE+AT ~40K EUR
CEE11 ~14K EUR

Annual electricity generation
~1,100 TWh
DE+AT ~660 TWH
CEE11 ~490 TWH

Passenger car fleet
105 million
DE+AT 54 MILLION
CEE11 51 MILLION

Source: Eurostat.
1) 2015 real prices, not in PPP

A Tale of Two Transitions: Navigating the green and security shifts in the CEE region

The CEE region now finds itself at the crossroads of two transformative forces – the Green Transition and the Secure Transition. Each of these transitions entails unique challenges and opportunities, shaping the region's energy landscape and defining its trajectory for years to come.

Green Transition

The Green Transition is a response to the urgent need for decarbonising the economy to combat climate change. In the energy sector, this transition involves a fundamental shift towards renewable and other clean energy sources, reducing the role of fossil fuels. The deployment of technologies such as wind, solar, and hydroelectric power is paramount in this endeavour. Fossil fuel solutions will either be phased out or equipped with carbon capture technologies.

In transport, the Green Transition is evident in the widespread adoption of electric motors (used by both battery and fuel cell electric vehicles), reducing dependence on traditional combustion engines. Additionally, the wider usage of biofuels and synthetic fuels offers pathways to a cleaner and more sustainable future for some hard-to-abate industries. In the industry sector, electrification, recycling and a shift towards less environmentally damaging feedstock are key elements of the Green Transition: reducing the carbon footprint of industrial production and making it more environmentally friendly.

Secure Transition

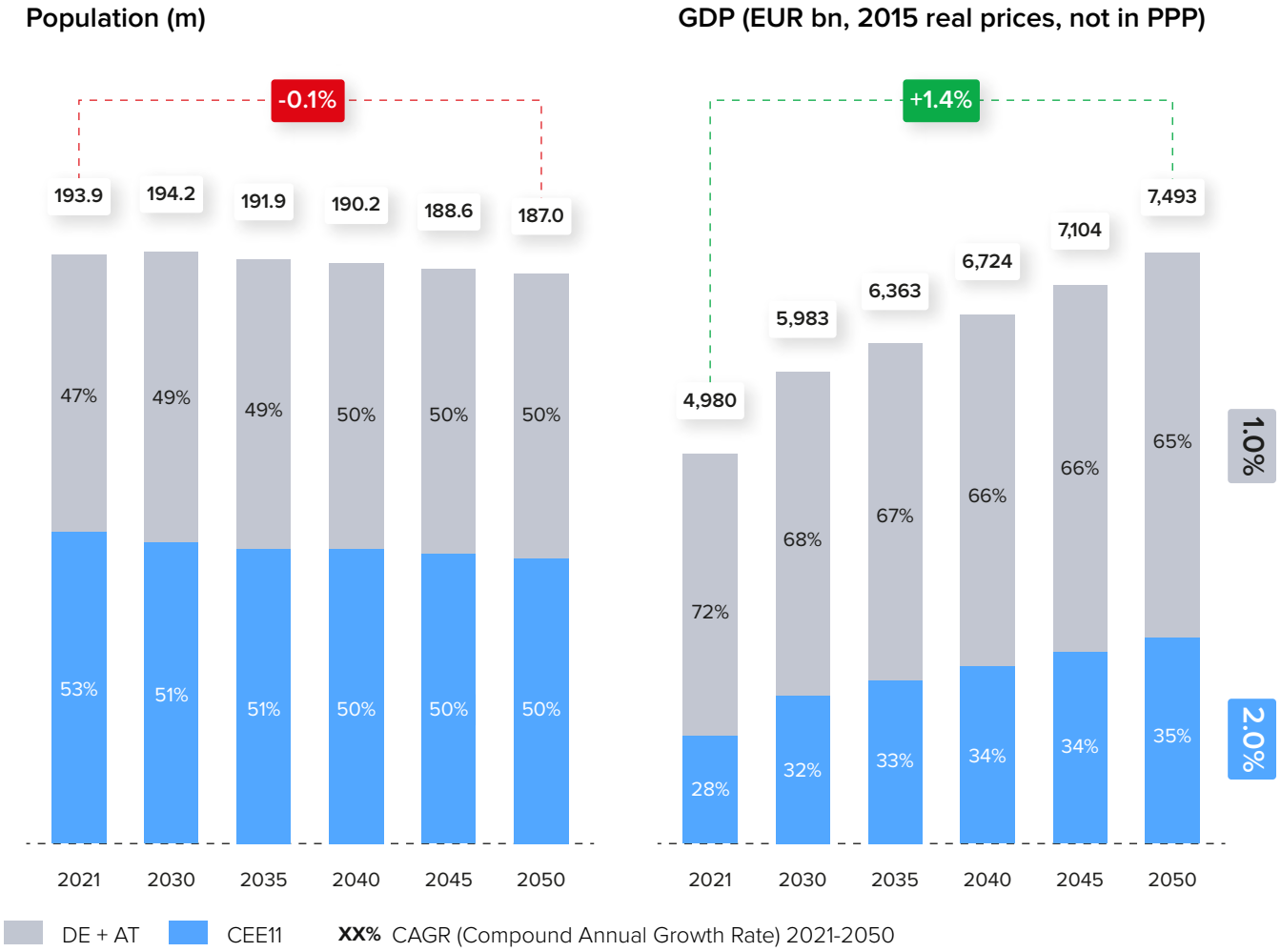
Energy security is a perennial concern in the CEE region due to its geopolitical positioning. The landscape, however, has evolved significantly, particularly in the wake of the full-scale Russian invasion of Ukraine in 2022. The war has elevated the importance of energy security to unprecedented levels, necessitating a reevaluation of supply routes and strategic partnerships.

Post-February 2022 changes in the supply directions have been both visible and significant, reflecting the region's swift and bold response to geopolitical shifts. The ongoing decisions to establish new routes underscore the region's commitment to shaping future security dynamics. Beyond resource supply, the Secure Transition involves fostering increased cooperation within the region. Notably, the development of interconnectors and transmission infrastructure for gas, electricity and oil (in the case of landlocked countries) emerges as a critical aspect in fortifying the region's energy security. Additionally, the role of storage, which contributes to mitigating supply risks and enhancing overall resilience, is being revaluated.

To successfully manage these transitions, a holistic approach is required that integrates sustainable practices with strategic security considerations. The region's response to these transitions will not only define its energy future but will also position it in the global landscape.

An overview of macroeconomic forecasts shows growing GDP levels, but also increasing demographic challenges that could in the future lead to a slowdown in the GDP growth rate in some CEE11 countries

Macroeconomic forecasts for CEE countries



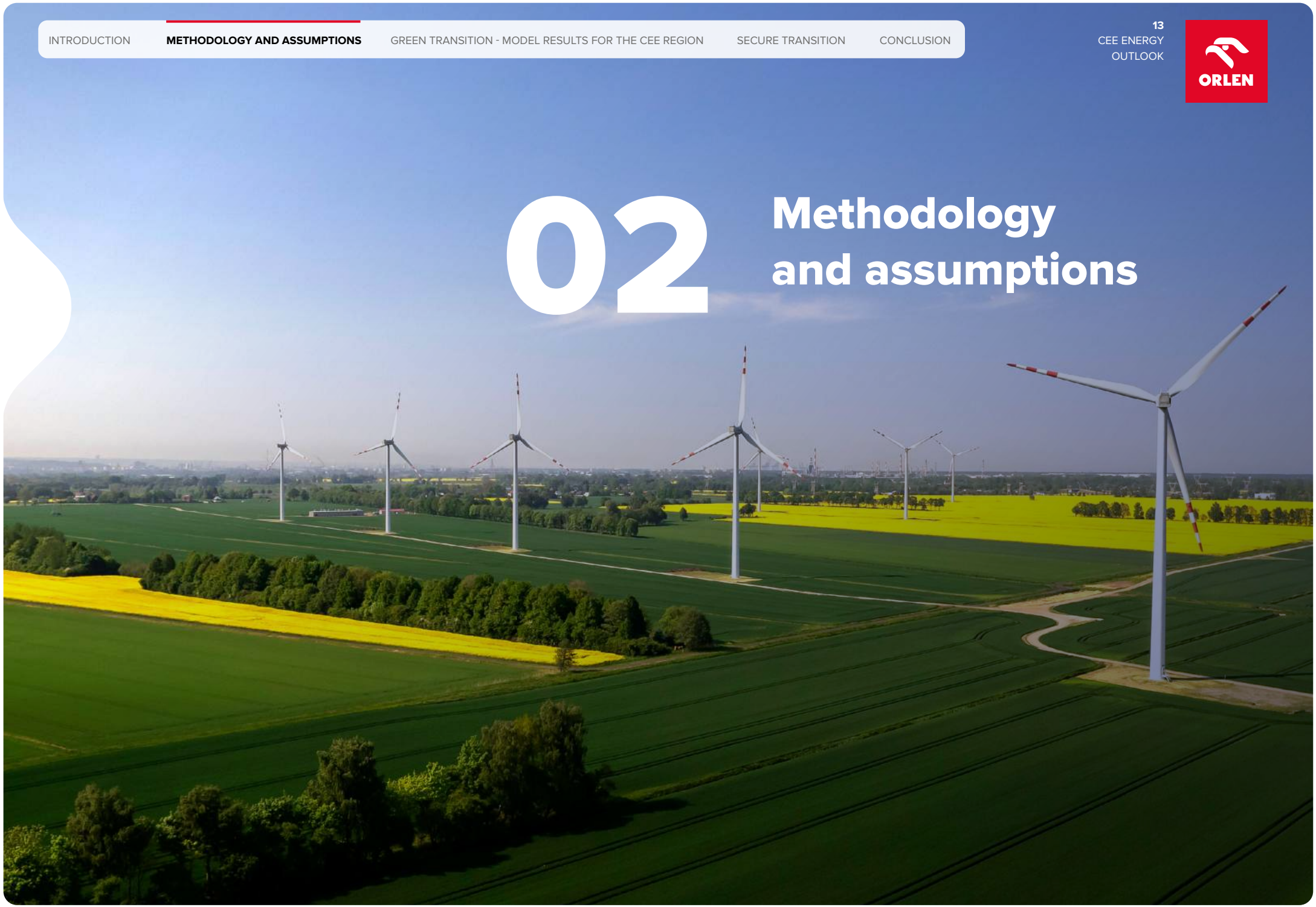
In order to understand the context of the energy transition and the energy sector as a whole, it is useful to start by looking at the underlying macroeconomic data that provides a broader overview of the region.

Key macroeconomic considerations:

- **Germany and Austria** are more developed economies, with ca.72% share in overall GDP, 47% share in population and 58% share in final energy consumption
- Moreover, **Germany and Austria** are expected to remain **stable economies** with relatively constant population and GDP **growth** of ca. **1% p.a.**
- **CEE11** countries in focus are expected to enjoy higher **GDP growth (2% p.a. on average)** but decelerating over time due to **declining population,** which is one of the greatest **socio-economic challenges** in Europe
- We expect that In the medium-term **population change** will become the **differentiating factor** for CEE countries' economic growth

Source: Eurostat data (population forecast);
GDP growth rates, derived from IEA GECM 2022 model

02 Methodology and assumptions



The Outlook examines two scenarios – Current Plans and Higher Ambitions

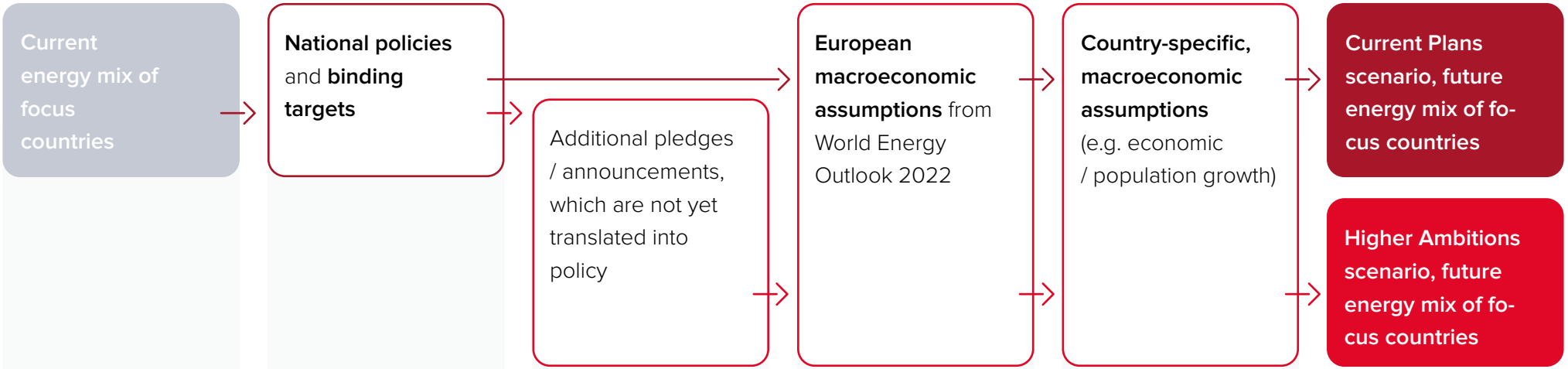
Scenario comparison

	Current Plans	Higher Ambitions
Scope	The scope of the model is the energy outlook until 2050 for 13 EU countries separately: Germany, Poland, Austria, Czech Republic, Slovakia, Hungary, Slovenia, Croatia, Romania, Bulgaria, Lithuania, Latvia, Estonia. The model is based on Eurostat historical data (2010-2021), national energy and climate plans of the respective countries, as well as International Energy Agency's assumptions on trends under STEPS and APS scenarios until 2050 with particular focus on the EU	
Definition	Based on IEA STEPS „A scenario that reflects current policy settings, based on a sectoral and country-by-country assessment of the specific policies in place and those announced by governments in the countries analysed"	Based on IEA APS „A scenario that assumes that all national and EU climate commitments and longer-term net zero targets1 are met in full and on time"
Methodology	EU appears as a single, uniform region in the IEA analysis. Therefore, country-specific data and supporting forecasts were used to extract 13 CEE countries from the EU scenarios	

1) As in IEA APS scenario, in this scenario we arrive at extremely reduced, but not zero emission levels - the remaining part has to be captured, offset or handled in any other way to achieve net zero.

To model energy transition in the CEE region we analysed countries' pledges, used IEA assumptions and conducted a technology review for key sectors

Approach to derive scenarios



Example values (simplified)

2022 energy mix

- Wind: 10 PJ
- Coal: 90 PJ

Binding policies / targets

- 2030: 50% RES
- 2040: 70% RES
- 2050: 80% RES

Additional pledges

- 2030: 500 thousand EVs in the country

European macroeconomic assumptions

- Industry productivity growth: 1% p.a.

Country macroeconomic assumptions

- Population growth: -0.2% CAGR 2021-30
- Economic growth: 1.7% p.a. CAGR 2035 -40

Calculated Current Plans scenario

Calculated Higher Ambitions scenario

Outlook assumptions focused on 4 major segments: electricity generation, industry, transport and buildings – applied to 13 countries separately

Key assumptions for CEE Outlook scenarios

Electricity generation

- Assumptions on generation and storage capacities by source until 2030 or 2040 based on recent national strategies/energy and climate plans
- Higher Ambitions scenario – upward extrapolation of Current Plans scenario in order to achieve 2050 climate neutrality goals
- Main sources of renewable electricity capacity expansion: wind (onshore and offshore) and solar, battery strorage capacities required for up to 10% of solar and wind generation capacities
- Nuclear capacities built up in Poland and expanded in 6 CEE countries that already run nuclear power plants
- Renewable expansion requires additional investments in system flexibility, e.g. battery storage, pumped hydro, low-emissions hydrogen in converted natural gas plants, as well as potentially limited retrofits of existing power plants with CCS

Industry

- Required energy volumes in the future are based on three input parametres:
  - industrial output growth
  - average annual energy efficiency gains of 1-2% (similar as in the period 2010-21)
  - decarbonisation pace (annual rate of exchanging fossil fuels for green hydrogen, electricty and heat) assumed at 1.0% under Current Plans and 2.5% under Higher Ambitions scenario

Transport

- Germany as the benchmark market
- Transition path for Higher Ambitions scenario transformed into other markets but with delay, gradually diminishing over time
- Overall substantial decarbonisation under Higher Ambitions scenario by 2050 assumed:
  - full (DE+AT) or substantial (CEE11) electrification of passenger cars
  - iin the duty vehicle segment: use of FCEVs for long-haul and EVs for short and medium haul
- Current Plans scenario assumes slower pace of decarbonisation, particularly in the duty vehicle segment
- Bio and synthetic fuels in the aviation sector

Buildings

- Required energy volumes in the future are based on two input parametres:
  - average annual energy efficiency gain of 0.6% (Current Plans scenario) or 1.2% (Higher Ambitions scenario), range as in the period 2010-21
  - decarbonisation pace (annual rate of exchanging fossil fuels for heat pumps energy) assumed at 1.0% under Current Plans and 1.8% under Higher Ambitions scenario

03

Green Transition model results for the CEE region

Green transition is a manifestation of the fight against climate change in the energy sector. In order to reduce the amount of greenhouse gas emissions that contribute to global warming, the economy must decarbonise.

This involves lowering the usage of fossil fuels in energy, transport, and industry and simultaneously developing new capacity in renewable energy sources. The green transition presents a significant challenge, but also a remarkable opportunity. New, innovative technologies can offer cheaper energy, increased resource effiiciency, and enhanced security.

Energy

The energy sector emerged as a major target for the transition, since it accounts for a sizeable part of global emissions. It became clear that conventional energy sources, predominantly relying on fossil fuels, would not be environmentally and/or economically feasible in the future.

Starting from the broadest measure, i.e. total energy supply, we observe that coal (which has long been a major component of the energy mix of a number of countries, including Germany, Czechia and Poland) is about to go into a sharp decline under both scenarios. Current coal exit dates span from 2023 in Slovakia to 2049 in Poland.

There will be no need to replace every joule of energy, as wide rollout of more efficient technologies will allow total energy supply and total final consumption to decrease. This is because renewables generate much smaller losses during the process of electricity production, electric motors are much more efficient than internal combustion engines and finally, with a wave of building thermal retrofits we will also see a decrease in energy demand from that sector.

Analysis clearly shows that electrification is the obvious direction for many sectors and it will be enabled by modern renewable energy sources, with more ambitious policies coming into force. This is driven by the businesses' need for decarbonisation stemming from the cost of the ETS and commitments made in accordance with the Paris Agreement, etc. The growth of renewable energy capacity will be significant in the whole region of 13 countries analysed, but will be particularly visible in CEE11 countries, which still have geographical, financial and technological advantages to be unlocked.

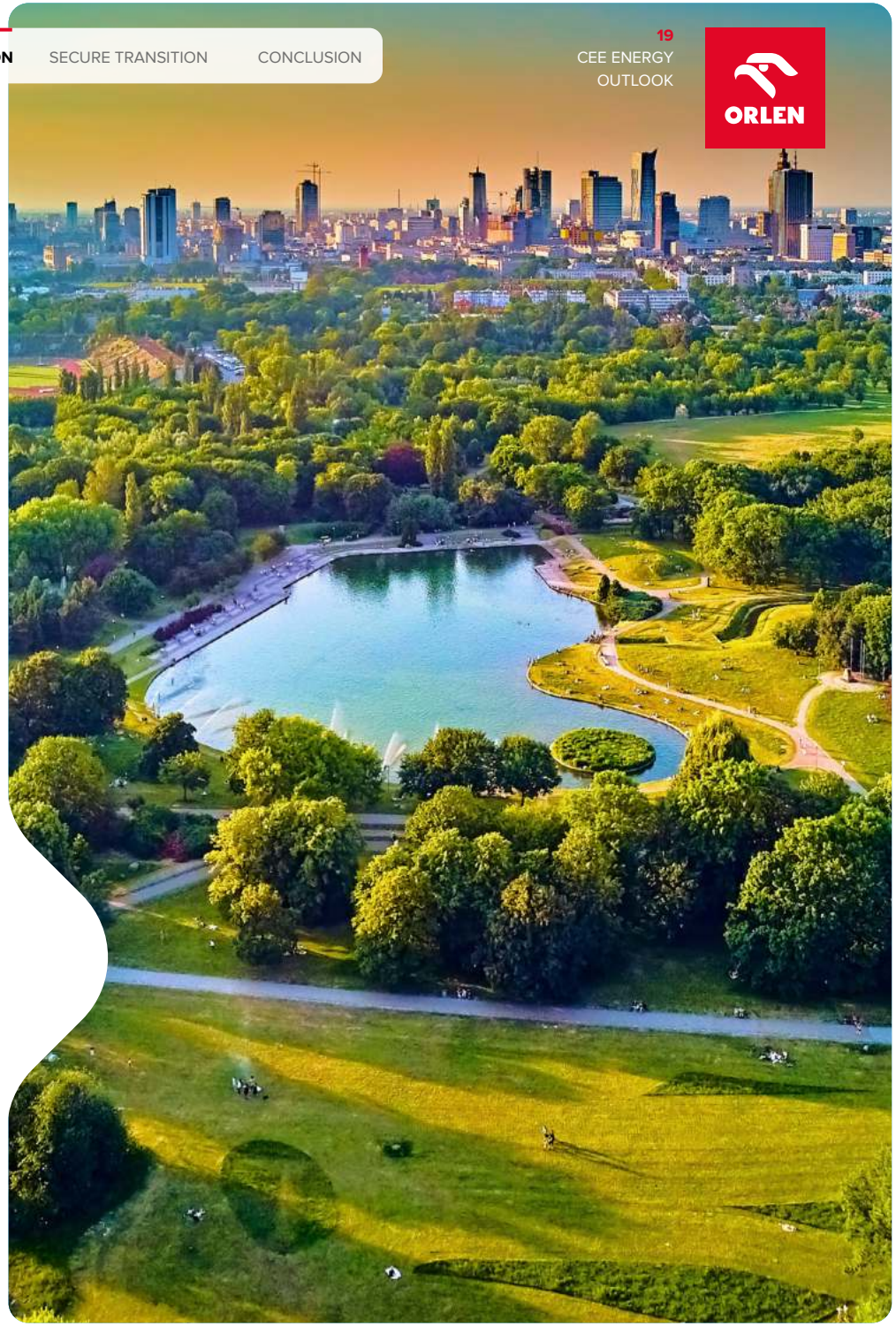
Although wind and solar sources seem to be a perfect solution for generating clean and cheap electricity, it needs to be stressed that they have a discontinuous, intermittent nature. Renewables need to be backed up by flexible sources and this role at the current stage of the energy transition is filled by natural gas. It is easy to store and gas-fuelled power plants are very flexible, able to ramp up or down very quickly. However, it is a fossil fuel that will eventually need to be removed

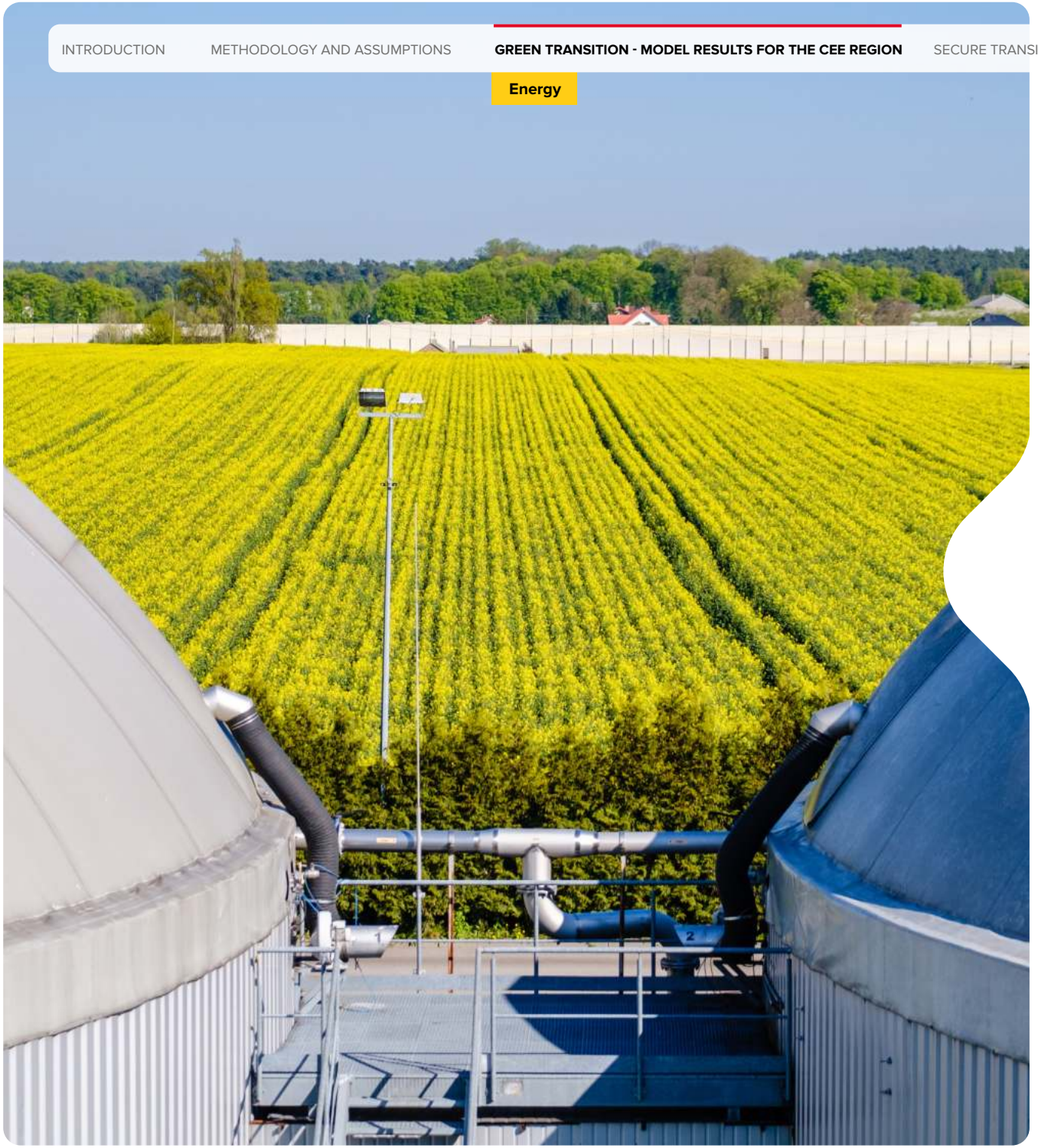
(or used in plants equipped with carbon capture systems) if the EU is to reach its climate neutrality goals. Batteries are already beginning to play a role in stabi- lising the system over the course of hours, allowing e.g. the excess energy gene- rated during sunshine hours to be used after sunset. Longer-term storage is a much more challenging quest though – biomethane and green hydrogen can be used in the same/reconverted turbines. Countries that have favourable geo- graphic conditions turn to hydropower as a long-term storage solution.

Furthermore, with growing digitalisation it becomes possible to use DSR (Demand Side Response) to stabilise the grid through the demand side. It is not just big industry that can play a role – so can individual customers – e.g. smart homes can shift energy-demanding activities to a time when it's good for the energy system.

More than half of the countries in the region have announced plans to develop nuclear power plants. They are not inter- mittent – on the contrary, they generate at very steady rates and high capacity factors. In theory, the generation can be reduced, but given high upfront capital costs and low operating expenditures they tend to run at baseload. Countries in the region plan to develop both traditio- nal, large-scale nuclear projects as well as Small Modular Reactors (SMRs).

SMRs are also proposed as a solution to one of the major emission sources – heat generation – both for industrial and district uses. The popularity of the latter is one of the distinct features of the region.





Key data

6-21%
Natural gas share in total energy supply in 2050

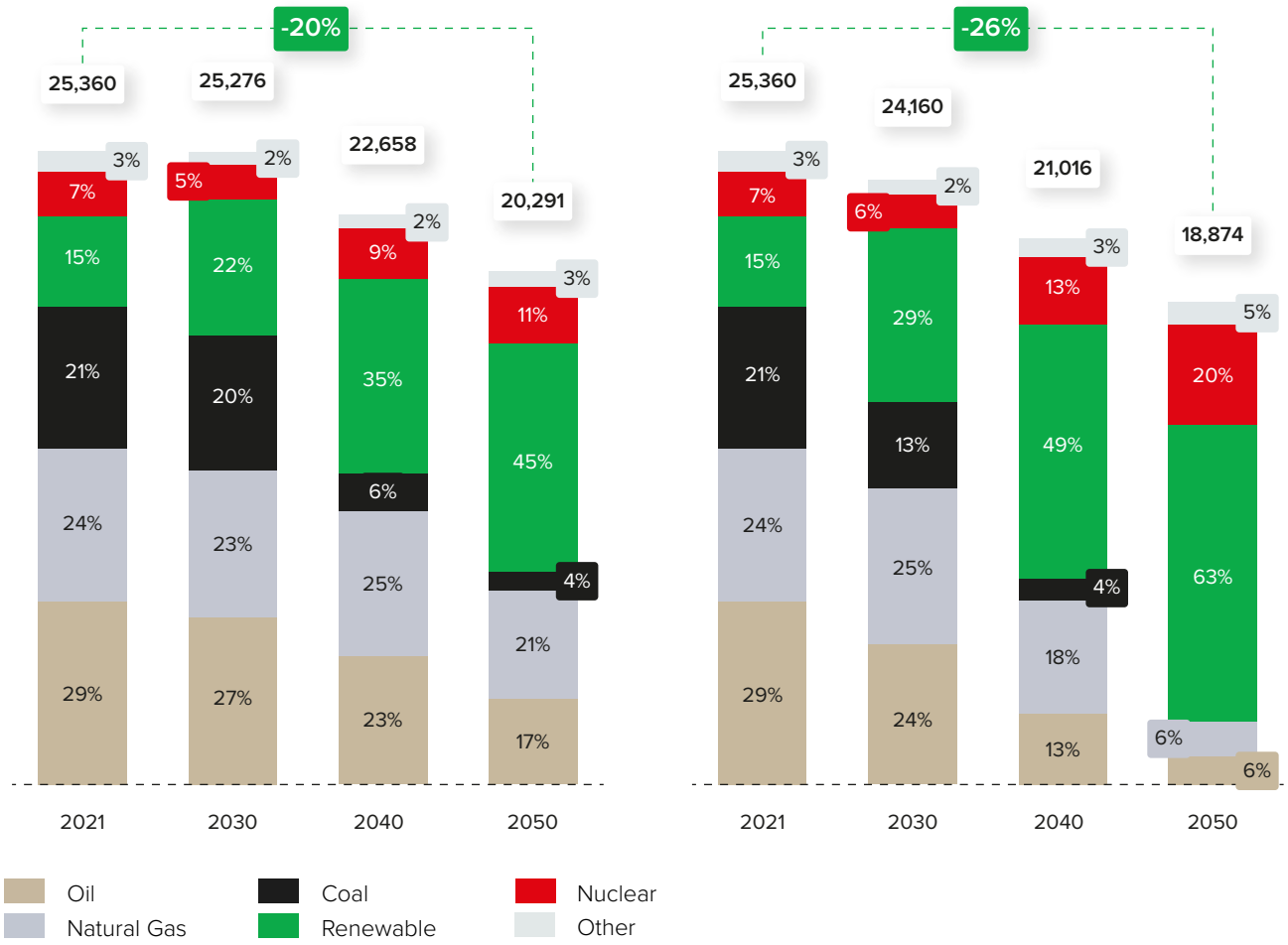
23-37%
Reduction in total final consumption by 2050

5-8x
Growth in renewable installed capacity in CEE11 by 2050

7 Countries
Planning to develop nuclear power

As total energy supply declines, renewables will play a key role under both Current Plans and Higher Ambitions scenarios reaching 45-63% by 2050, while the share of fossil fuels will decrease to 42-12%

Total energy supply [PJ]



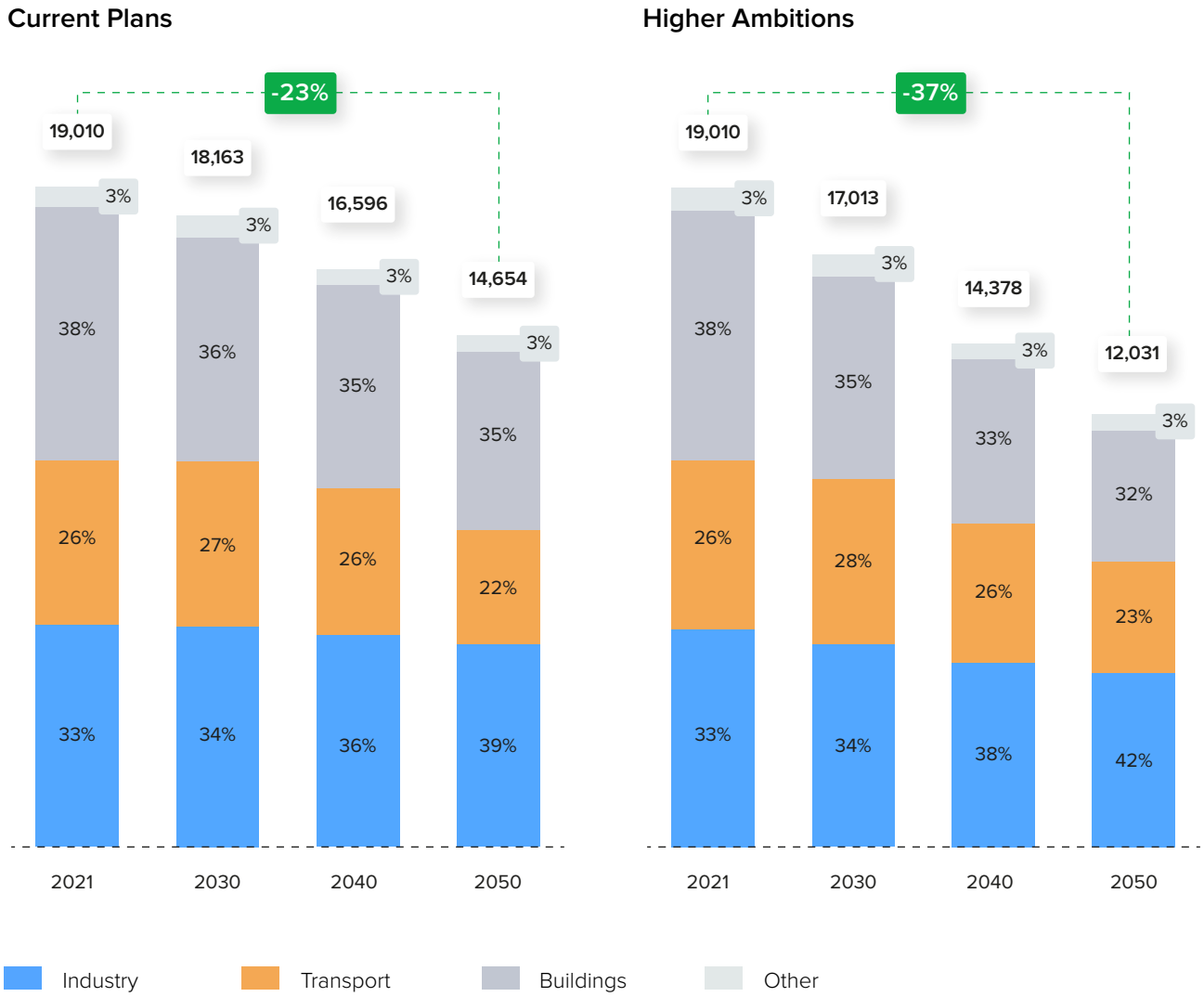
According to our estimates, we will observe a decline of total energy supply until 2050, by 20% under Current Plans and 26% under Higher Ambitions. This can be explained by a move towards more efficient technologies.

- Renewables (wind, solar, hydro, bioenergy) will provide the lion's share of energy in the future – between 45% and 63% of the total supply
- Under Current Plans, nuclear provides a steady amount of energy throughout the next three decades. Under the Higher Ambitions scenario, nuclear generation grows significantly, but only after 2030
- Natural gas remains an important part of the mix under both scenarios for the next two decades. Under Higher Ambitions, it goes into rapid decline after 2040
- Under both scenarios the role of coal and, to a lesser extent, oil is significantly reduced

Source: ORLEN model based on IEA (World Economic Outlook 2022); National Energy and Climate Plans of the countries analysed; Eurostat

Total final energy consumption declines due to technology advances, especially in buildings and transport

Total final consumption by sector [PJ]



Total final energy consumption decreases under both scenarios, due to technology advances and a shift in public attitudes towards the use of energy. In buildings, heat pumps promise coefficients of performance of three or more, drastically reducing demand. In transport, a move away from liquid fuels and internal combustion engines brings significant efficiency gains.

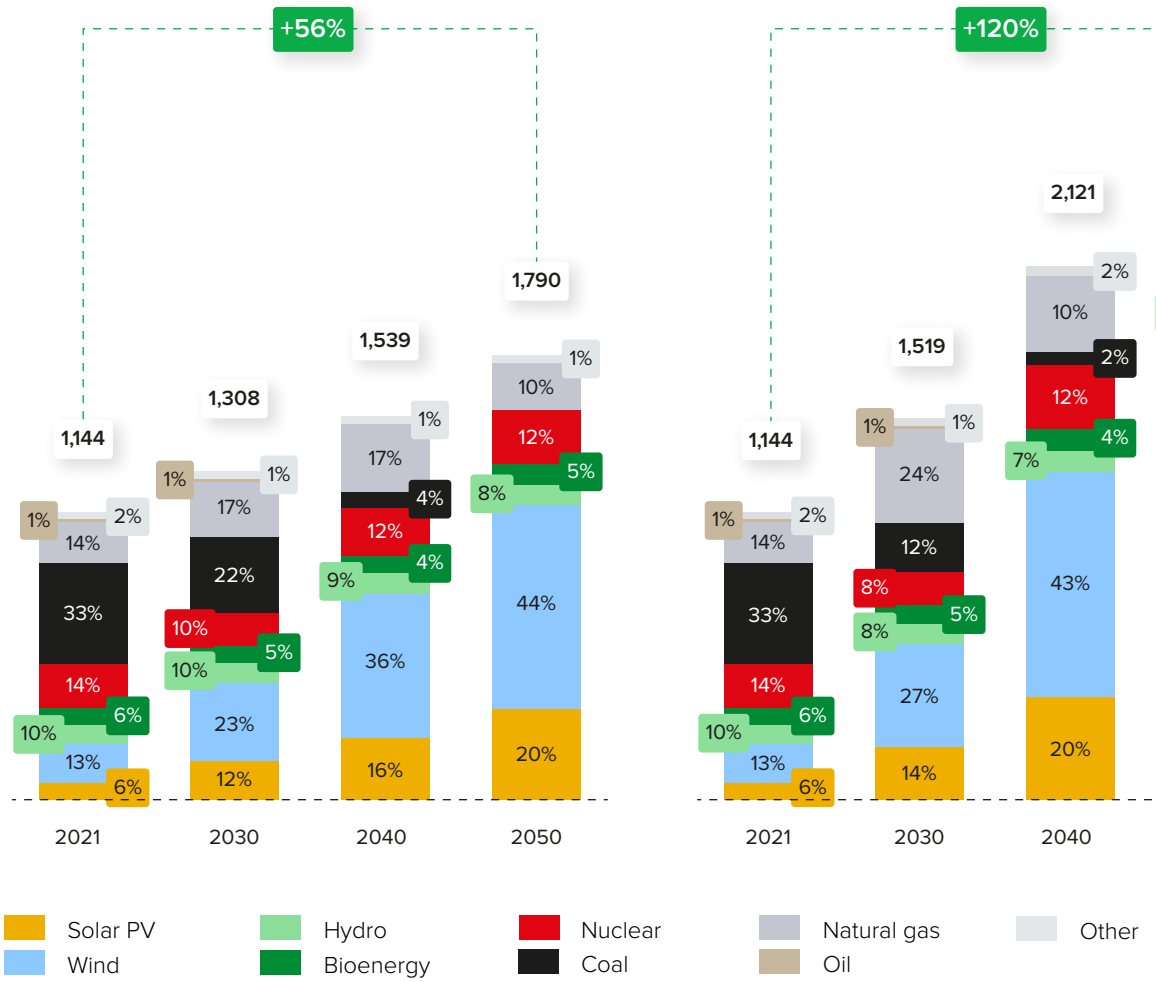
No efficiency breakthrough of similar size is anticipated in industry, but gradual improvements lead to a decrease in consumption too.

- The decrease in buildings ranges from 29% to 48%
- The decrease in transport ranges from 33% to 42%
- The decrease in industry ranges from 8% to 19%

Source: ORLEN model based on IEA (World Economic Outlook 2022); National Energy and Climate Plans of the countries analysed; Eurostat

Electricity generation to grow by 56% under Current Plans and 120% under Higher Ambitions – wind, solar and nuclear expected to dominate in 2050

Electricity generation [TWh]



Widespread electrification is one of the most important trends revealed by the energy sector forecasts. The new demand will be met by a mix of variable renewables (wind and solar) as well as nuclear in some countries.

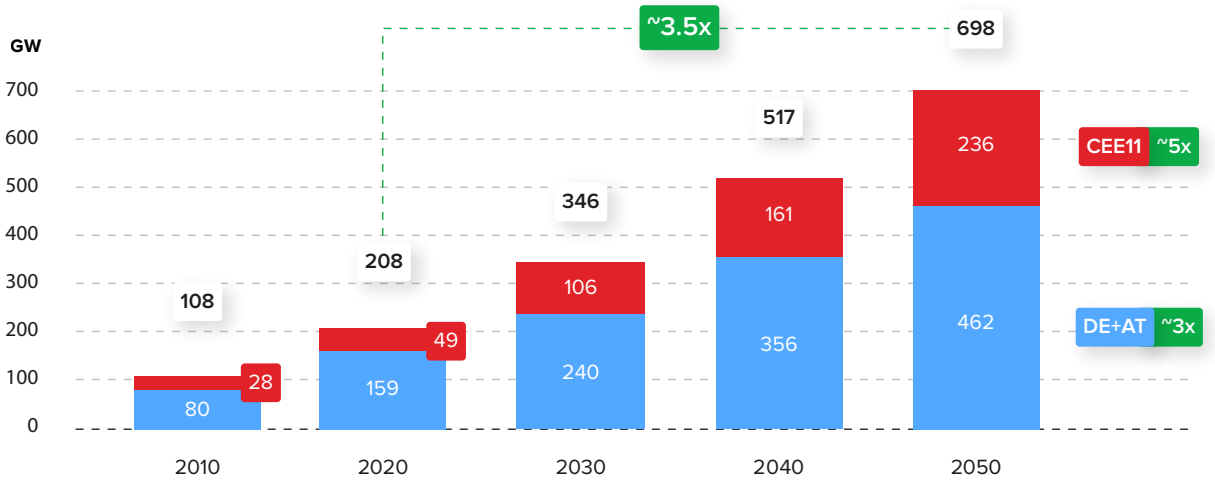
- The projections show that much higher electricity volumes will be needed in 2050 (56% growth under CP and 120% under HA). The increase in demand is driven by electrification of transport, heating in buildings, low-temperature industry heat as well as green hydrogen production
- The expected main sources of electricity in 2050 will be wind and solar. 7 countries (Poland, Czechia, Slovakia, Slovenia, Hungary, Romania and Bulgaria) will also have nuclear in their electricity mix
- Electrification to such a large extent will bring with it technological constraints and challenges. Due to the increasing share of intermittent energy sources and the need to balance the electricity system, an integral part of the electrification process will have to consist in the development of energy storage – batteries, hydrogen, pumped hydro or other solutions

Source: ORLEN model based on IEA (World Economic Outlook 2022); National Energy and Climate Plans of the countries analysed; Eurostat

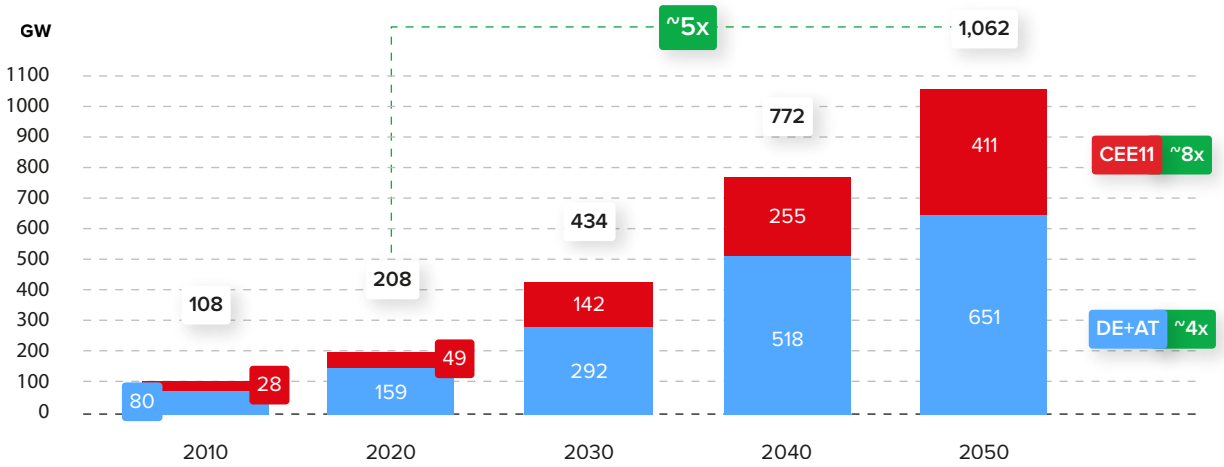
13 countries in focus will see their renewable capacity grow between 3.5-5x depending on the scenario – the growth will be even faster in CEE11

Renewable capacity installed

Current Plans



Higher Ambitions



Renewable capacity installed is projected to grow steadily. This trend is in line with the energy transition and correlates with the widespread electrification.

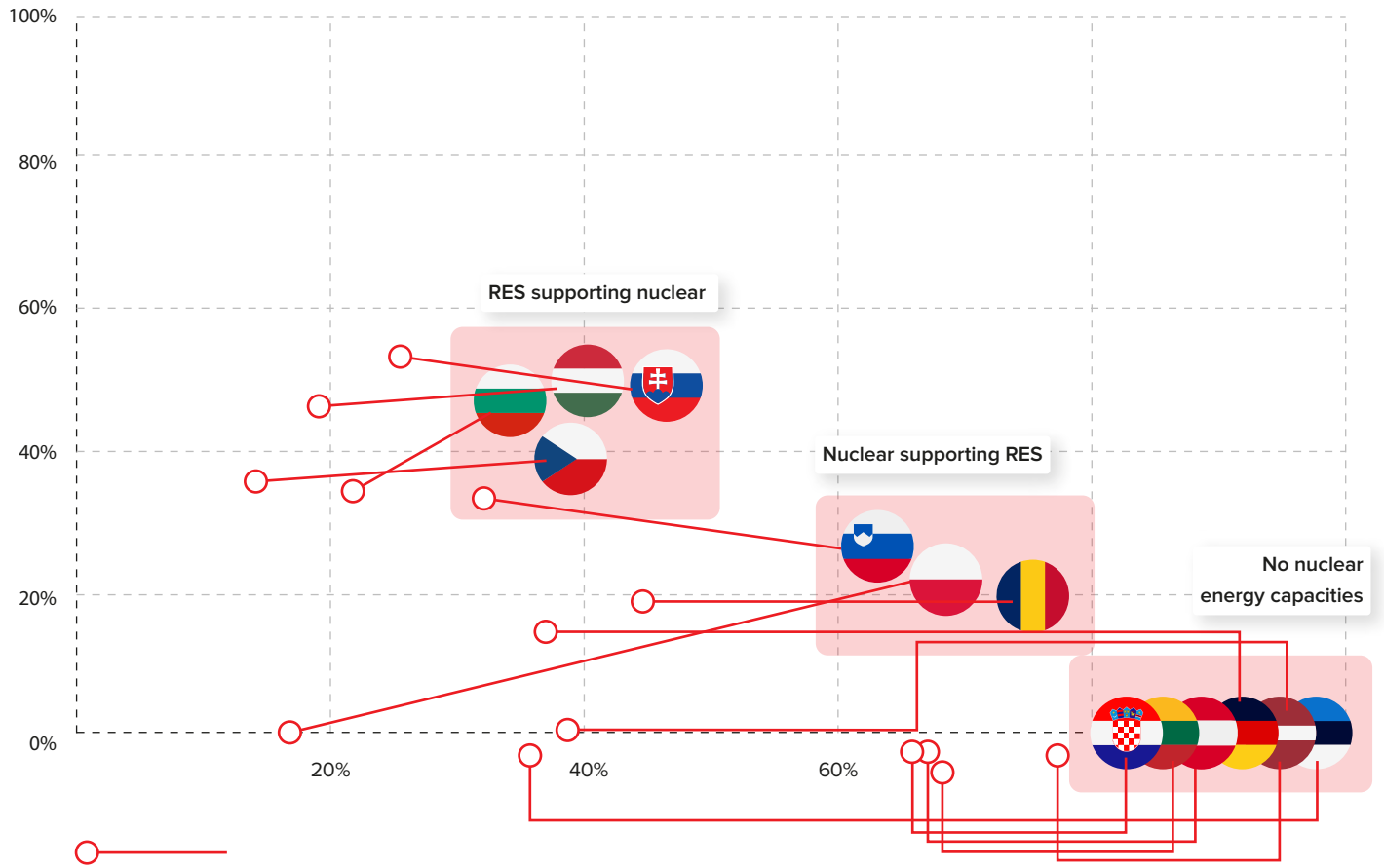
- Depending on the scenario, the overall renewable capacity, including wind and solar in the analysed region, will grow 3.5 to 5x between 2020 and 2050
- The growth rate is even higher in the CEE11, a region that has historically been slower to adopt renewables – the forecast growth in capacity is **5 to 8x**
- The rise is mostly driven by solar (8x capacity growth under the Higher Ambitions scenario) and wind (5x under the same scenario)
- To enable the growth of renewable energy sources and to ensure energy security in the region, deeper cooperation is needed, for instance on the development of interconnectors. Interconnectors allow the transmission of larger volumes of electricity between countries, which can support each other in balancing their systems

Total growth 2020-2050
CEE11
DE+AT

Source: ORLEN model based on IEA (World Economic Outlook 2022); National Energy and Climate Plans of the countries analysed; Eurostat

Three approaches towards 2050 electricity mix can be observed: no nuclear capacities, nuclear supporting RES and RES supporting nuclear

Share of nuclear in electricity generation in 2050



Transition path for electricity generation between 2021 and 2050 (Current Plans)

Share of RES in electricity generation in 2050

- All countries in focus are expected to increase the share of renewable electricity by 2050 from 35% in 2021 to 77% in 2050 under the Current Plans scenario
- The differentiating aspect, however, is the approach to nuclear energy – with three models:
  - No nuclear capacities – 6 countries (Germany, Austria, Baltic States and Croatia)
  - Nuclear supporting RES electricity – 3 countries (Poland, Romania, Slovenia)
  - RES supporting nuclear electricity – 4 countries (Czechia, Slovakia, Hungary, Bulgaria)
- All the V4 countries plan to build nuclear capacities
- Further development of the SMR technology may influence the trajectories of the countries analysed

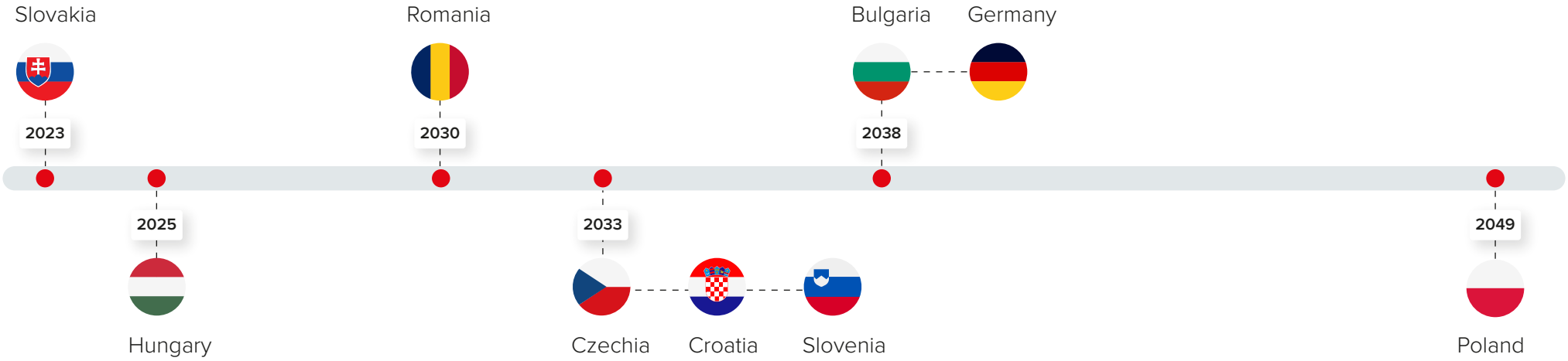
Note: Krško Nuclear Power Plant is based in Slovenia and started operations in 1983, before the breakdown of Yugoslavia. It is now co-owned by Slovenia and Croatia and set to operate until 2043 – while the former is considering expansion (decision to be made by 2027), the latter does not include generation from nuclear in its plans until 2050 and, from the technical standpoint, it is power import.

Source: ORLEN model based on IEA (World Economic Outlook 2022); National Energy and Climate Plans of the countries analysed; Eurostat

Coal phase-out timelines in the CEE countries under analysis

Coal has played different roles in energy systems across the region – and the varying coal phase-out dates prove that. Given the sector's importance, moving away from mining and using coal must be thoroughly planned and must happen in a just way, to avoid dire social consequences.If executed rightly, the coal phase-out can bring not only environmental but also long-term economic benefits by diversifying regional economies.

Phased-out Lithuania, Latvia, Estonia, Austria

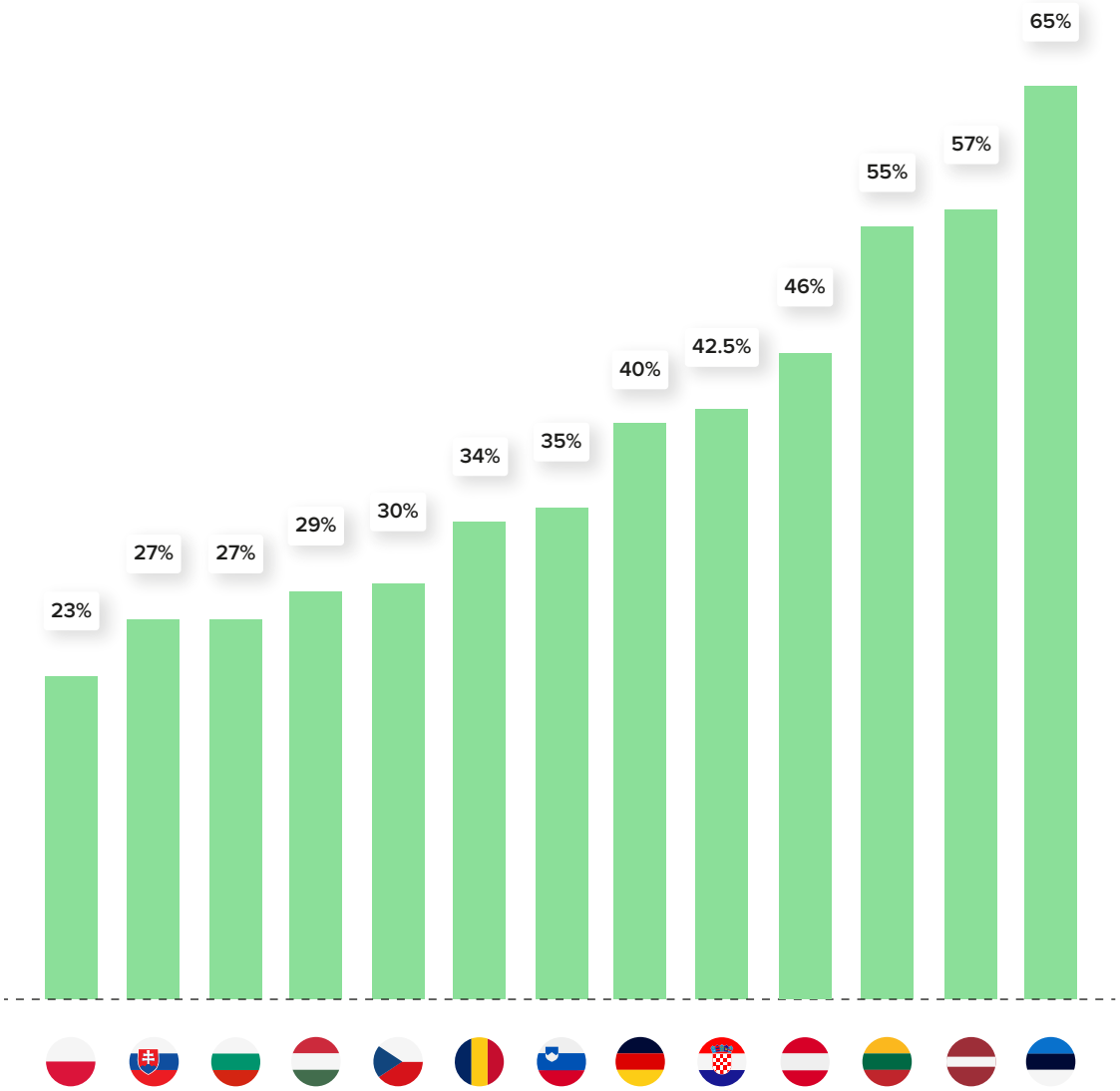


Following phase-out , Austria reactivated its last coal-fired power plant in 2022.
Hungary in December 2023 announced the coal phase-out might be postponed until 2027.

Source: Recent announcements by the countries analysed

Energy

Target share of renewables in gross final energy consumption by country in 2030



Source: Most recent updates of the National Energy and Climate Plans of the countries analysed

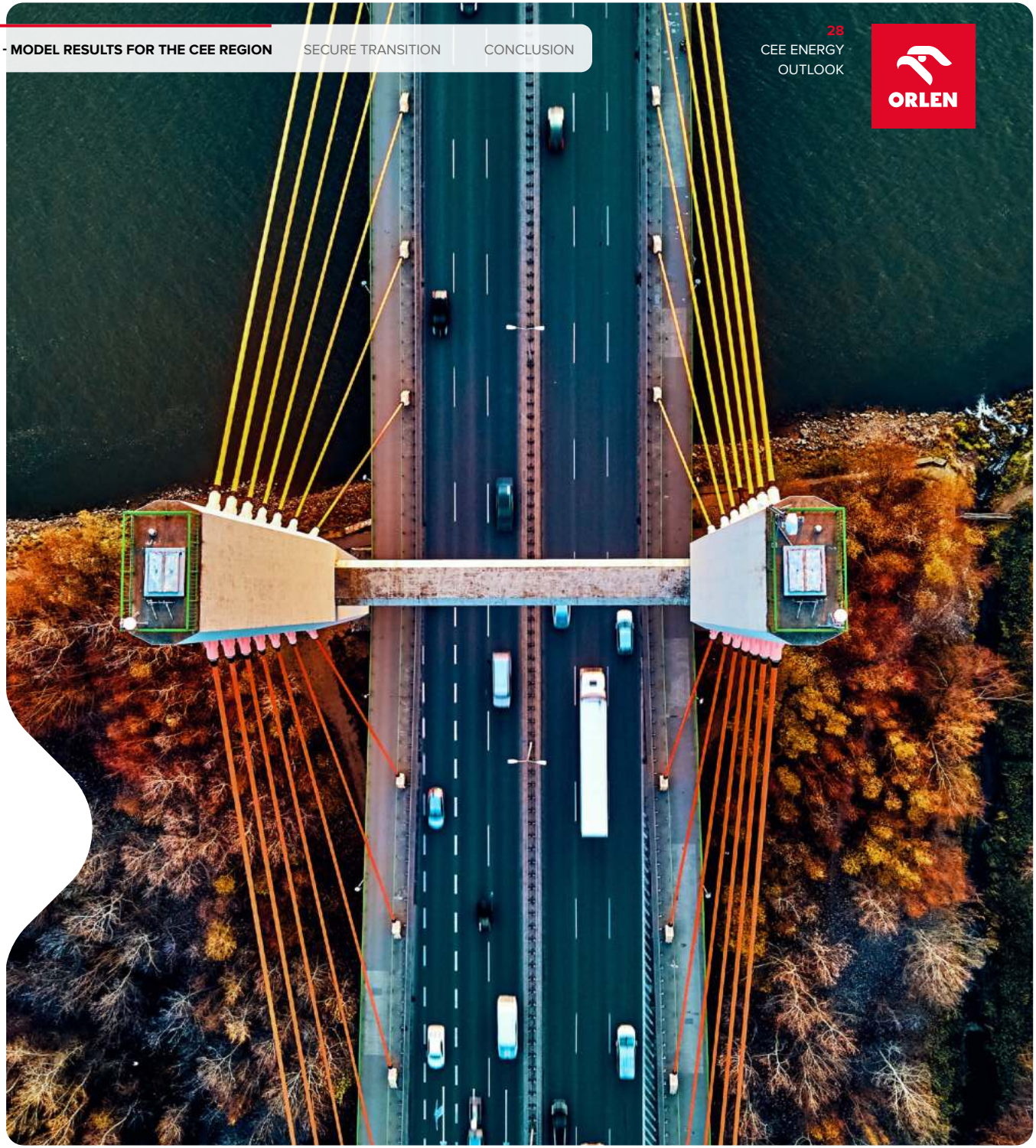
Transport

The broad transport sector, which includes the movement of both people and goods by road, rail, sea, inland waterways and air, is one of the largest contributors of CO_2 emissions in the EU. Achieving net-zero emissions requires the decarbonisation of all transport modes.

Battery electric vehicles (BEVs) are the most promising so- lution for private transport. Although they are approaching cost parity with internal combustion engines in terms of total cost of ownership (TCO) as they are less expensive to operate and maintain, achieving sticker price parity is unlikely in the near future. This presents a challenge for uptake in CEE11 countries, where customers are highly price-sensitive.

As a result, our modelling indicates a significant increase in demand for biofuels. If the decarbonisation objectives of transport are to be met with insufficient uptake of BEVs (because only a limited number of consumers can afford them), biofuels could aid in their achievement. However, the increase in biofuels demand might be reduced if we see steep price reductions for EVs and/or increase of popularity and availability of schemes reducing the upfront cost (long-term rentals, subsidies, etc.).

New regulations on heavy duty transport have put the sec- tor in the spotlight. As such vehicles are much more energy consuming and are utilised in a number of ways, they are harder to abate. A mix of solutions, including battery electric vehicles, fuel cell electric vehicles and - to some extent - bio and synthetic fuels, is envisaged.



The pace of moving away from fossil fuels is slower here, since trucks are often used for a longer time and cost parity with ICEs is further away.

Maritime and aviation sectors are among the hardest to abate, with high energy demand and limited options to access electricity en route. Methanol and ammonia are among the pathways suggested for the former, while sustainable aviation fuels are viable alternatives for the latter. These sectors have not been analysed in detail here.

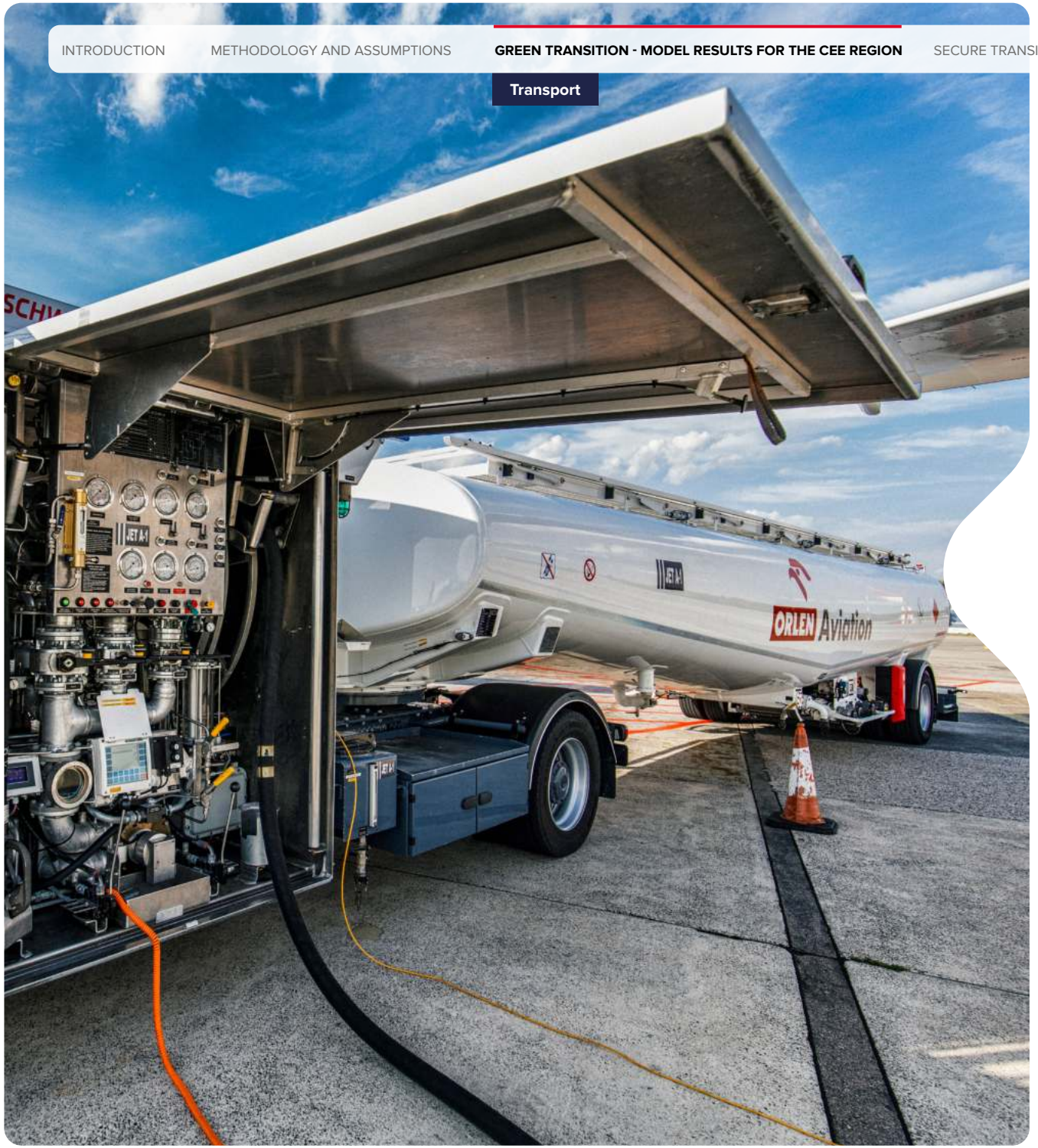
CHIEF ECONOMIST'S COMMENTS

Dr. Adam B. Czyżewski

There are two dimensions to decarbonising transport. The first one focuses on a change of the engine type. This means switching from internal combustion engines to electric motors.

Another crucial aspect for this sector is demand. Decarbonising transport starts with the demand for transport. What matters is the weight transported (vehicle and cargo, number of people transported) and the distance covered by a vehicle, which in turn determines the amount of energy consumed. The lower the mass per kilometre, the lower the energy consumption. The shorter the distance travelled, the lower the energy requirement. The more efficient the engines, the lower the energy consumption. This short calculation leads to a conclusion that, besides new technologies in transport, a shift in social perception concerning transport is needed.

Reducing the complex issue of transport decarbonisation to zero-emission fuels is an oversimplification. An important role is also played by the structure of demand for transport services, which should change to reduce weight per kilometre and distance travelled. It determines the form of infrastructure and the energy required to build it, which in turn is a factor behind Industrial emissions.



Key data

34-49%
Share of electricity in total final energy consumption in transport in 2050

2-13%
Share of hydrogen in total final energy consumption in transport in 2050

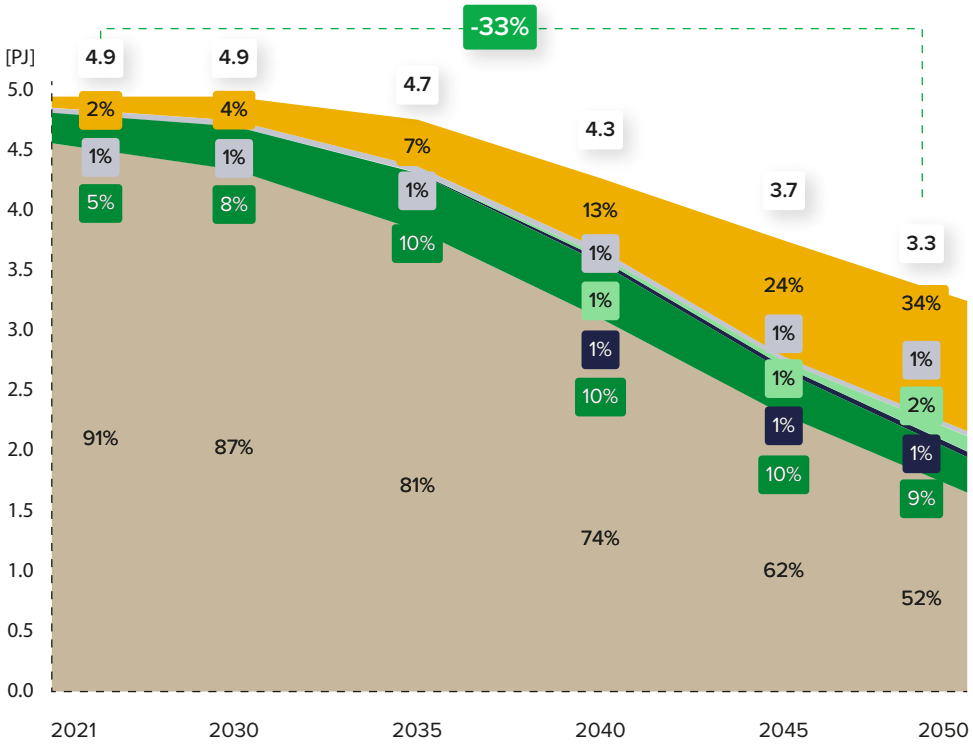
9-19%
Share of biofuels in total final energy consumption in transport in 2050

100%
Electrification of passenger car fleet in Germany under both scenarios in 2050

A reduction in fossil oil consumption will be driven by electrification of passenger cars and batteries, hydrogen and decarbonised liquid fuels in other types of transport

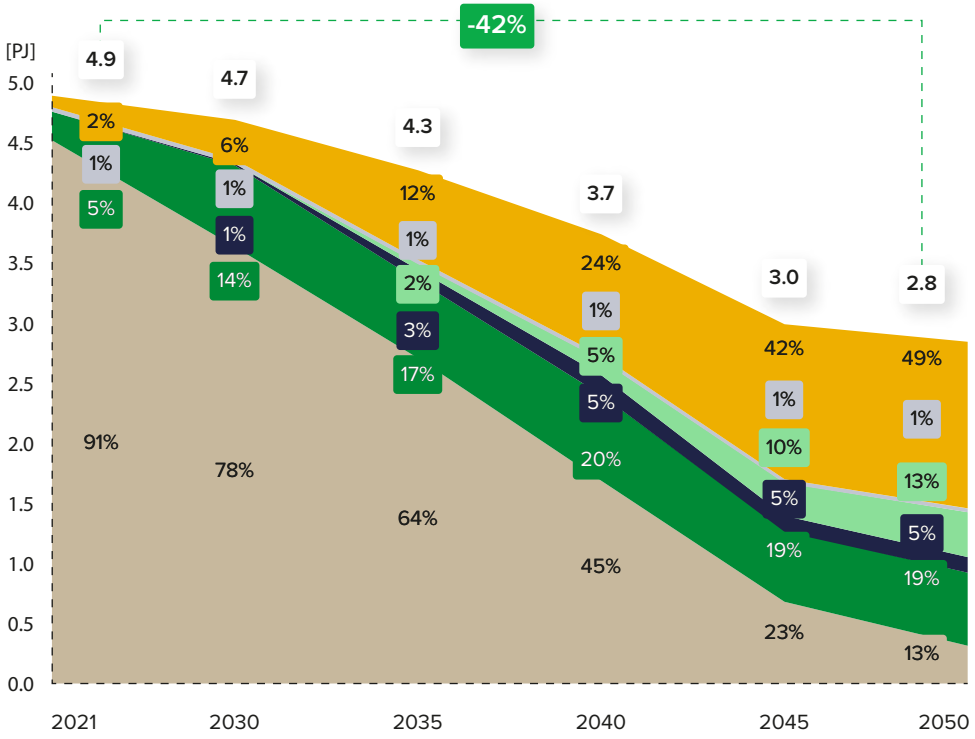
Final energy consumption in transport [EJ]

Current Plans



- Transport electrification contributing to energy efficiency gains
- Substantial electrification of passenger cars – ranging from 33% to 100% of the fleet depending on the country
- Limited decarbonisation of heavy-duty transport – from 9% to 26% of the fleet depending on the country

Higher Ambitions



- Much higher fleet electrification rates for both passenger cars and HDVs – but still short of full decarbonisation of the truck fleet
- Biofuels playing a significant role, reaching almost 20% in 2040
- Oil's share declines by a factor of 7.5
- Synthetic fuels used in aviation and edge cases in transport

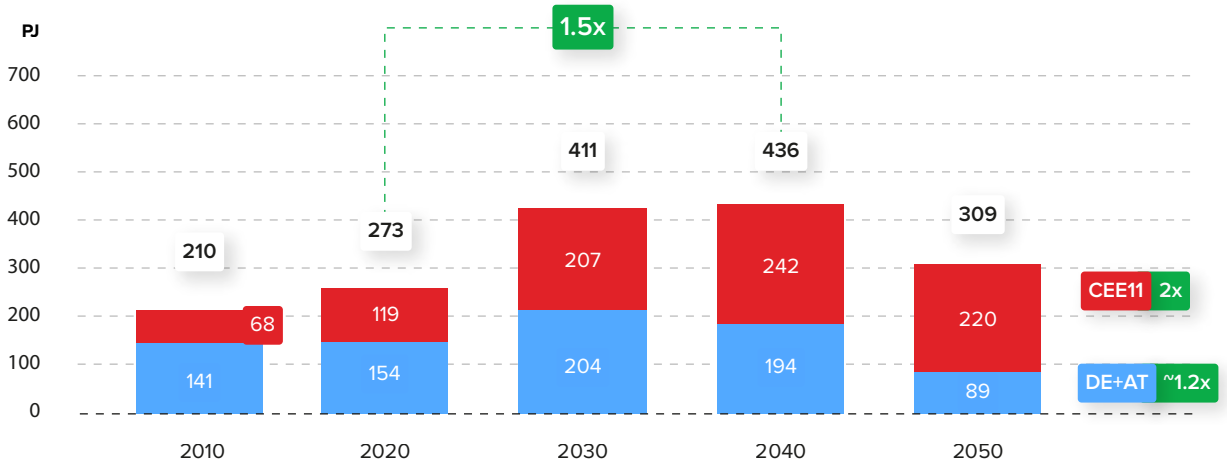
Fossil oil e-Fuels Natural gas Biofuels Hydrogen Electricity Other

Source: ORLEN model based on IEA (World Economic Outlook 2022); National Energy and Climate Plans of the countries analysed; Eurostat

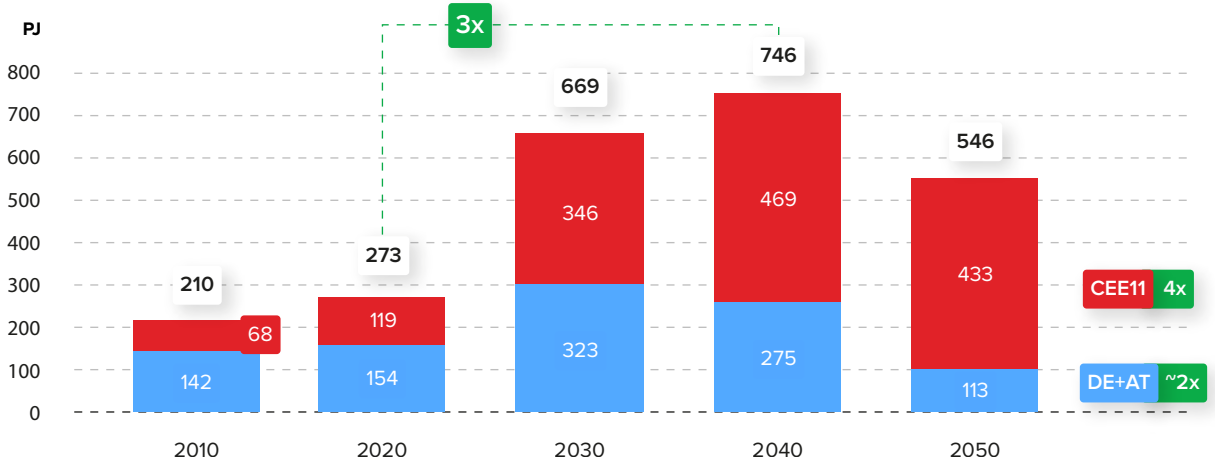
Biofuels consumption in transport will peak in 2040 and decline as electrification in transport continues

Biofuels in transport

Current Plans



Higher Ambitions



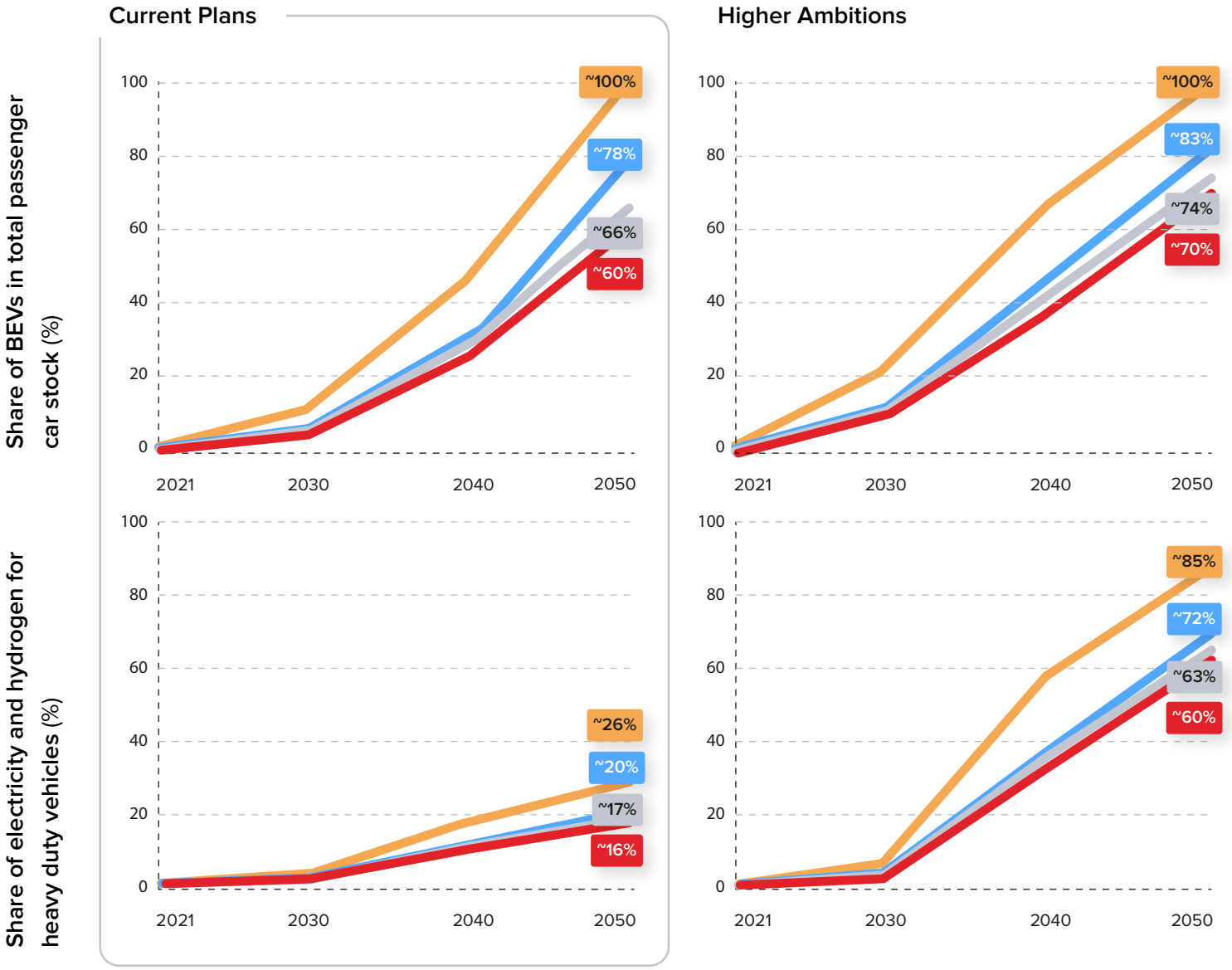
Biofuels in transport present a more nuanced picture. While Germany and Austria are currently responsible for over half of the biofuels consumption in transport, this is likely to dramatically change over the next two decades as the two countries rapidly move away from ICEs.

- The growth rate for biofuels in transport is particularly significant in CEE11, where the projected increase in total energy supply is 2x to 4x[1]
- Both scenarios emphasise a heavy decrease in the use of biofuels in transport after 2040 – ca. 35% under the Current Plans and Higher Ambitions scenarios
- The drop in the use of biofuels correlates with the development of BEVs and FCEVs in both groups of countries

Total growth 2020-2040
CEE11
DE+AT

Source: Orlen analysis based on IEA (World Economic Outlook 2022); National Energy and Climate Plans of the countries analysed; Eurostat.
1) base year: 2020

Decarbonisation of passenger transport likely to be much faster and more widespread than duty vehicles



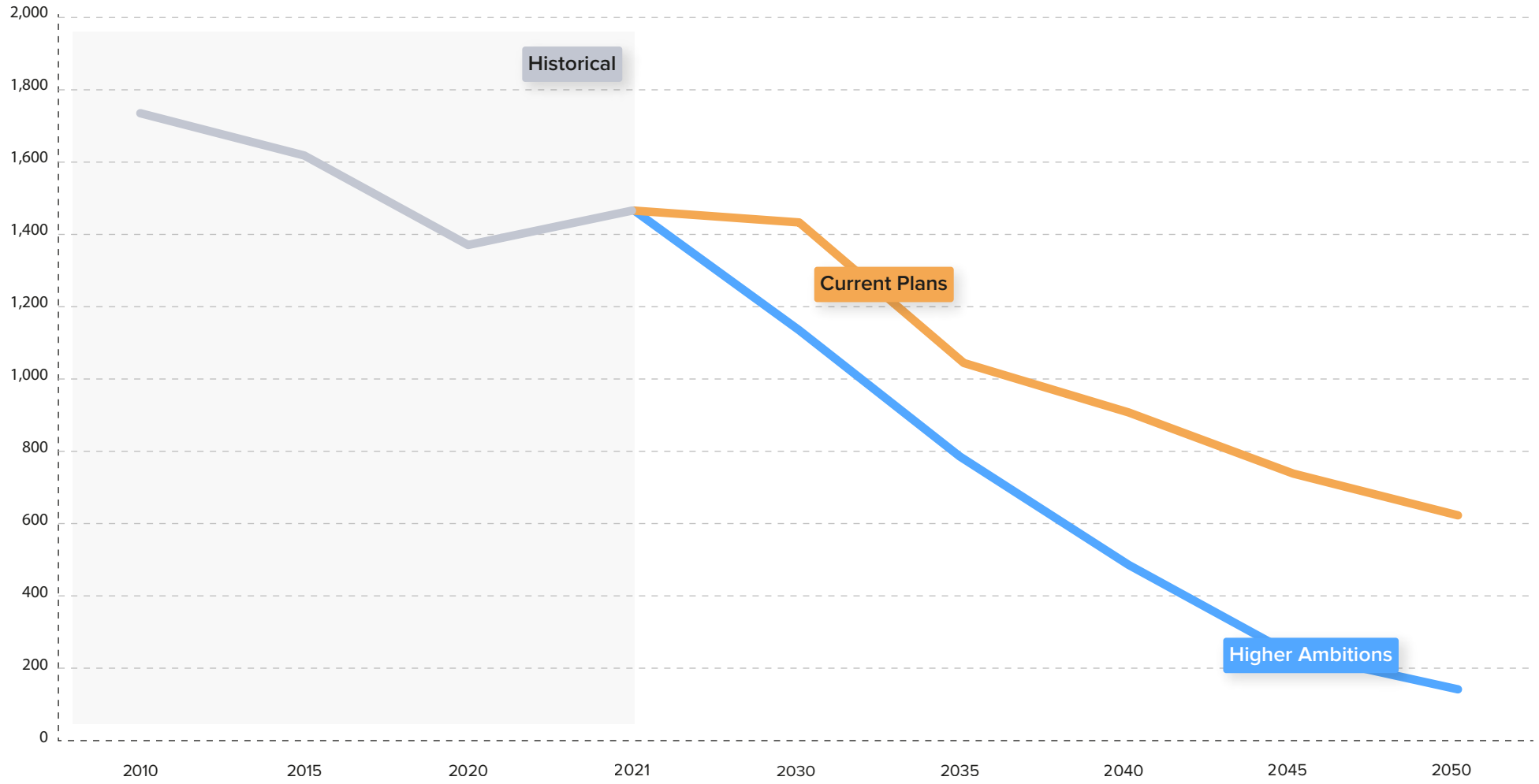
Decarbonisation of transport is driven by:

- Battery Electric Vehicles (BEVs) in the passenger car fleet
- Electricity and hydrogen in heavy transport
- Under both scenarios, Germany leads the way in decarbonising passenger transport with 100% BEVs in the total car stock in 2050
- With regard to electricity and hydrogen fuels for heavy transport, Germany also leads the focus countries, increasing the share to 26% in 2050 under Current Plans and to 85% under Higher Ambitions

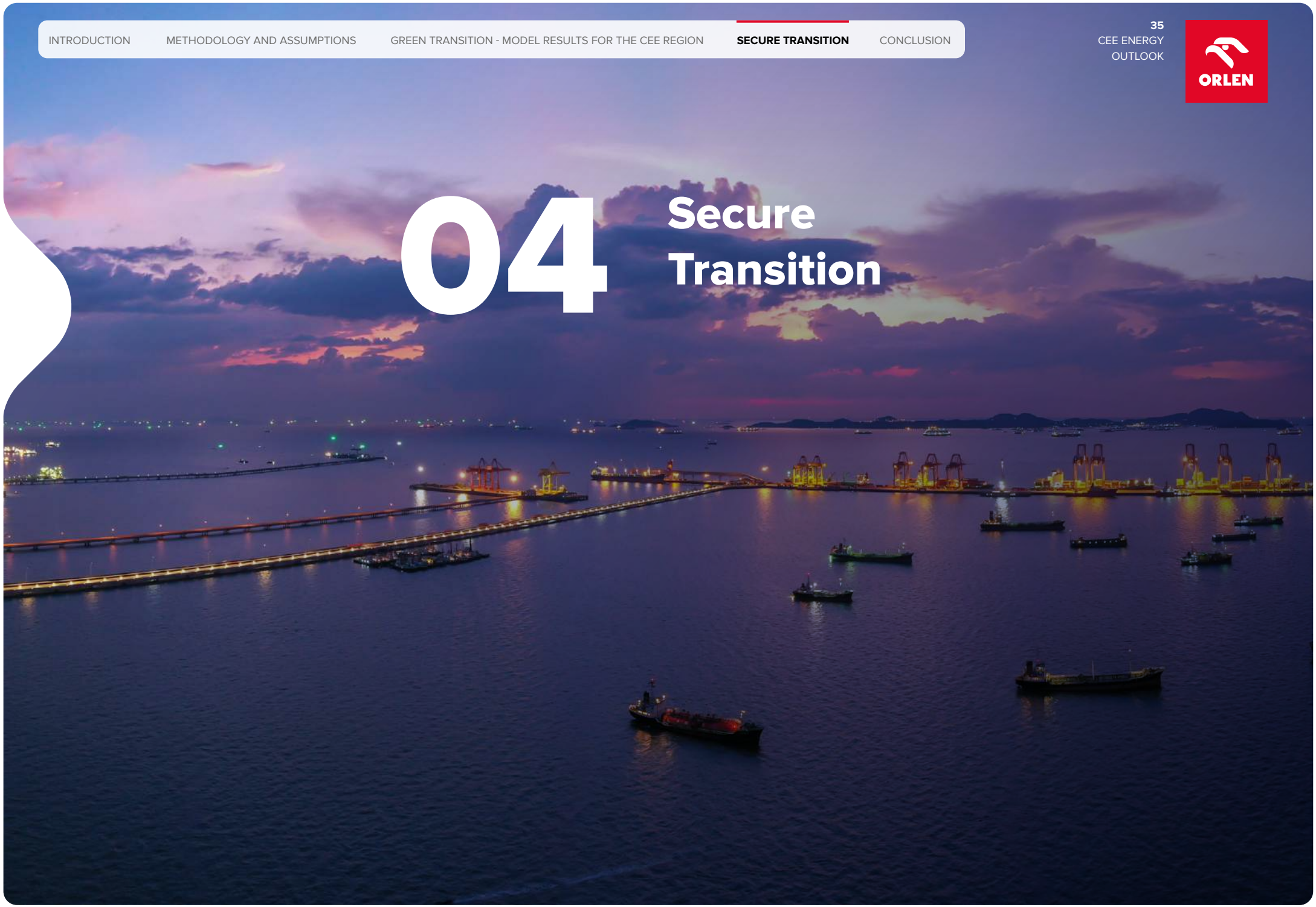
Source: Orlen analysis based on IEA (World Economic Outlook 2022); National Energy and Climate Plans of the countries analysed; Eurostat.

CO_2 emissions in the CEE region decline under both scenarios, but the pace is varied

CO_2 emissions (Mt)



Source: Orlen analysis based on IEA (World Economic Outlook 2022); National Energy and Climate Plans of the countries analysed; Eurostat.



04 Secure Transition

Secure transition

The conflict in Ukraine has exposed Europe to the stark reality that energy security is not a given. The impact of rapid and unplanned major rerouting of natural gas and oil supply away from Russia has been severe for energy-intensive industries, which were forced to reduce production, as well as for national budgets as many countries shielded individual customers from drastic price increases.

Geopolitically, the CEE region has been particularly exposed to energy security risks due to its close proximity to Russia and historically determined infrastructure links. Aware of this threat, many countries of the region have been investing in resilience, diversifying import options and creating spare capacity. Recently developed pipelines from non-eastern directions and LNG terminals allowed them to prevent the worst scenarios (like blackouts or running out of supplies) from materialising. However, further diversification of energy sources, especially by developing renewables and nuclear, is needed to build more resilience into the system.

In terms of security, it is equally important to have energy production decentralised among numerous small units, such as wind, solar or SMRs. The current dominance of large generation units puts countries in a vulnerable position, prone to serious disruptions caused by attacks or natural disasters. The dispersal of energy production enhances the system's resilience to such threats, which is a vital factor in ensuring the continuity of supply.

While electrification is a great way to increase security in some aspects, it brings about a number of concerns that have to be addressed.

The new, electrified system will need not only an expanded, but also more digitalised grid – which will entail a number of benefits but also threats, like bigger exposure to cyberattacks.

Another concern is storage – strategic reserves in an electrified, zero-emission world are harder to maintain. Batteries can balance the grid over the course of hours, but not days. To provide resilience and avoid blackouts, sizeable reserves of energy carriers have to be stored. While natural gas and oil lend themselves easily to storage, electricity does not.

Large-scale long-term storage solu- tions, other than pumped hydro, are yet to be developed at scale, not just for the sake of the electricity system but also for e.g. emergency services.

But storage is not the only solution. Inter- connections can also enhance the stabili- ty of future renewable and nuclear-based systems, making it crucial to develop them. This is why there is an increasingly urgent need to revise our approach to energy security. The current approach, focused on constructing energy self-suf- ficiency systems heavily dependent on home- grown resources (like coal in some CEE countries) or on resources imported from abroad (gas and oil), must, in an organi- sed, planned and secure way, yield to a new paradigm of security based on do- mestic, dispersed production of electricity from renewables and nuclear, supported by a diversified set of intercon- nections.

It should be stressed that such appro- ach will not only improve security and reduce emissions but will also limit costs of importing fossil fuels. The transition will suport climate targets while bolstering the stability of the national economies.

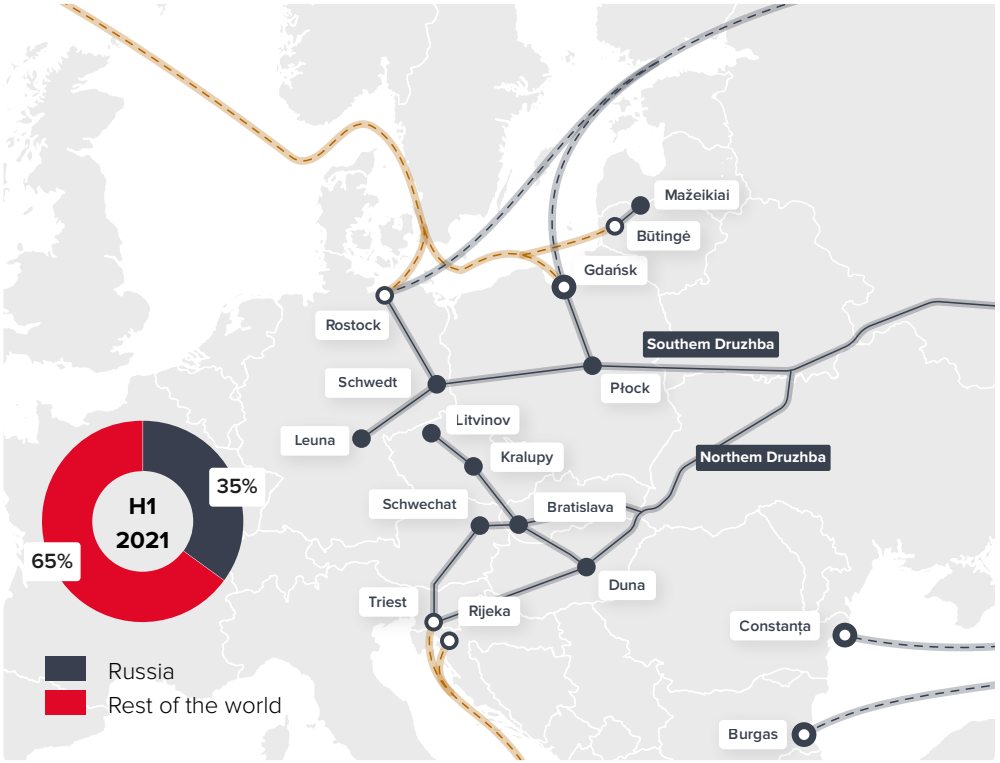
To make this transition a reality, renewa- bles must be deployed faster, permitting needs to be streamlined and long grid connection queues have to be resolved. This is a huge challenge for regulators as well as distribution and transmission system operators.

But in the course of the transition, depen- dence on a single supplier of hydrocarbons should not be replaced with another dependence – this time on a single technology and critical minerals provider. Selectively chosen parts of the supply chain of key technologies should be onshored or friendshored and diversi- fied to avoid repeating the past mistakes. It is also worth pursuing research into technologies that do not rely on rare minerals to limit demand for them.

Such revision of the approach to energy security presents challenges to the region but simultaneously opens up new development opportunities. Transitioning from traditional, fossil-based energy sour- ces to modern, sustainable technologies is not only a step towards meeting global climate objectives but is also a pivotal element in constructing a resilient energy system for future generations.

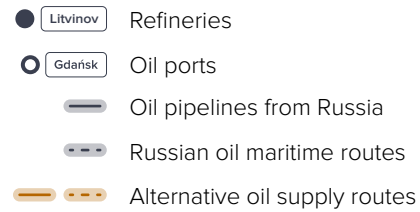
Before the outbreak of the war in Ukraine, crude oil supply to Europe and the CEE region was predominantly sourced from the eastern direction

Oil supply before the outbreak of full-scale war



Oil supply after the outbreak of full-scale war

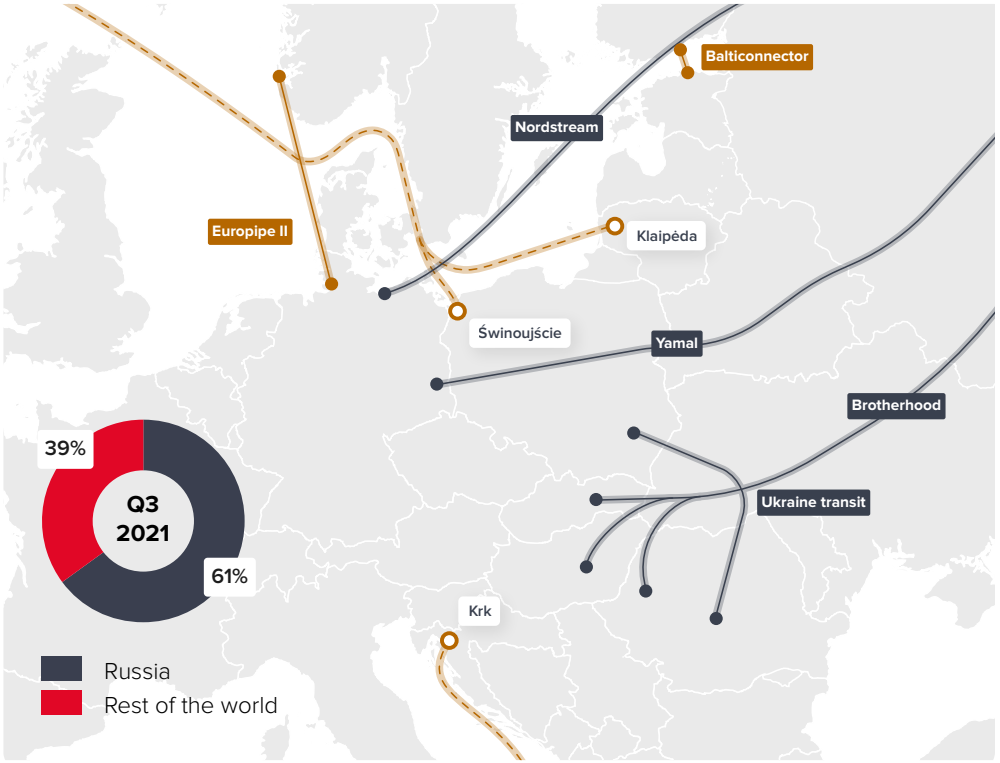
- Due to historical links between the CEE region and Russia, infrastructure connections for the transmission of crude oil were established. Historically, Russia, with its abundant oil reserves, transported crude oil by pipelines to refineries in CEE countries
- In addition, Russian oil was sent to CEE countries by sea to the ports of Rostock, Gdańsk, Būtingė, Constanza and Burgas. These ports were also able to receive oil supplies from alternative directions, which allowed the countries to react when the full-scale invasion of Ukraine started
- As a result of the strong reaction, the CEE region managed to significantly reduce its dependence on Russian oil, turning to seaborne supplies from the North Sea, West Africa, the Persian Gulf and the Gulf of Mexico, among other sources
- However, not all the countries have the option of rapid diversification. This problem affects mainly the landlocked countries, such as Hungary, Czechia and Austria. They can receive oil from the port of Trieste, but its capacity is limited, making it impossible to cut the dependence on Russian crude without infrastructure expansion



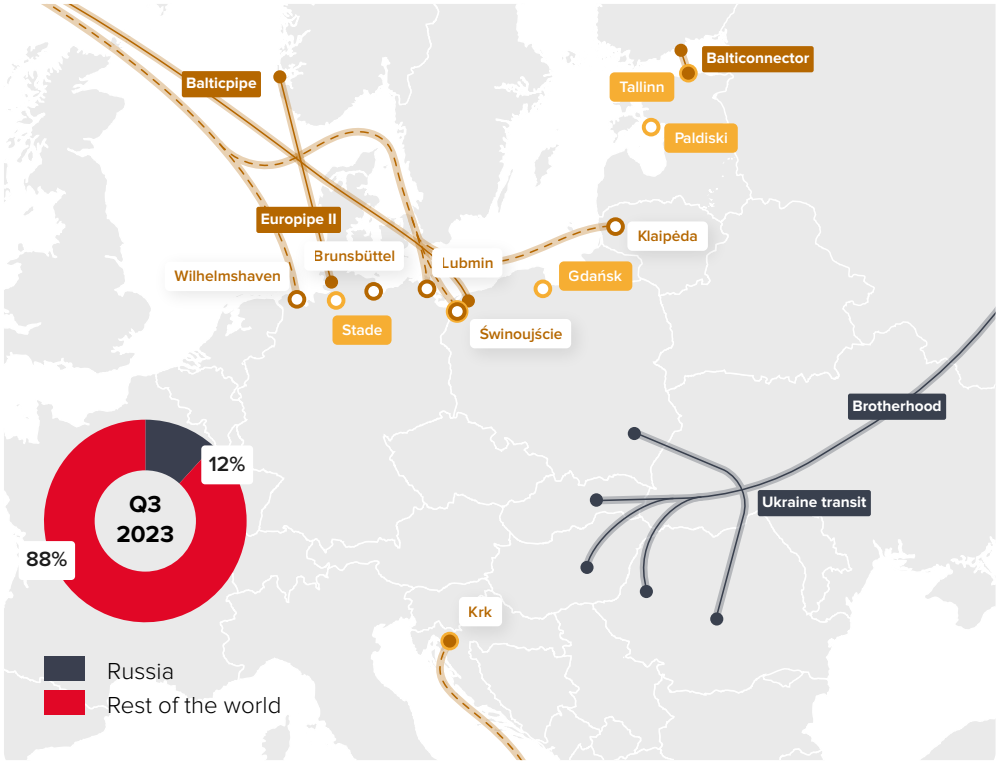
Source: ORLEN analysis Eurostat.
*This is a conceptual and exploratory illustration. It does not include all the links and delivery routes.

Following the outbreak of the full-scale war in Ukraine, natural gas supply routes have shifted towards LNG

Natural gas imports before the outbreak of full-scale war



Natural gas imports after the outbreak of full-scale war



- The war in Ukraine has clearly shown that dependence on a single natural gas supplier and lack of diversification is a very risky strategy. Limited interconnections and supply routes have exacerbated the energy crisis
- Efforts to alleviate these problems are now being undertaken at a record pace – a number of investments are under way and many more are being considered. To avoid stranded assets, a thoughtful approach needs to be worked out. Thorough discussions are necessary on how to maximise infrastructure utilisation to avoid overbuild (and associated high costs), while on the other hand ensuring resilience. It should be stressed that this is not just a question of import capacities but also e.g. storage
- It is crucial to align the increase in gas infrastructure capacity with demand to avoid unnecessary spending on stranded gas assets. Alternatively, an overly generous expansion of gas production and transport capabilities, surpassing forecast decreasing demand, could lead to renewed preference for gas as a transitional energy source in the long term, hampering efforts to curb emissions

Gdańsk Planned LNG terminals
Krk Existing LNG terminals
Gas pipeline from Russia
Non-Russian gas pipelines
LNG supply routes

Note: Import data for EU27 as a whole due to country-level data limitations

Source: ORLEN analysis, Eurostat.
*This is a conceptual and exploratory illustration. It does not include all the links and delivery routes.

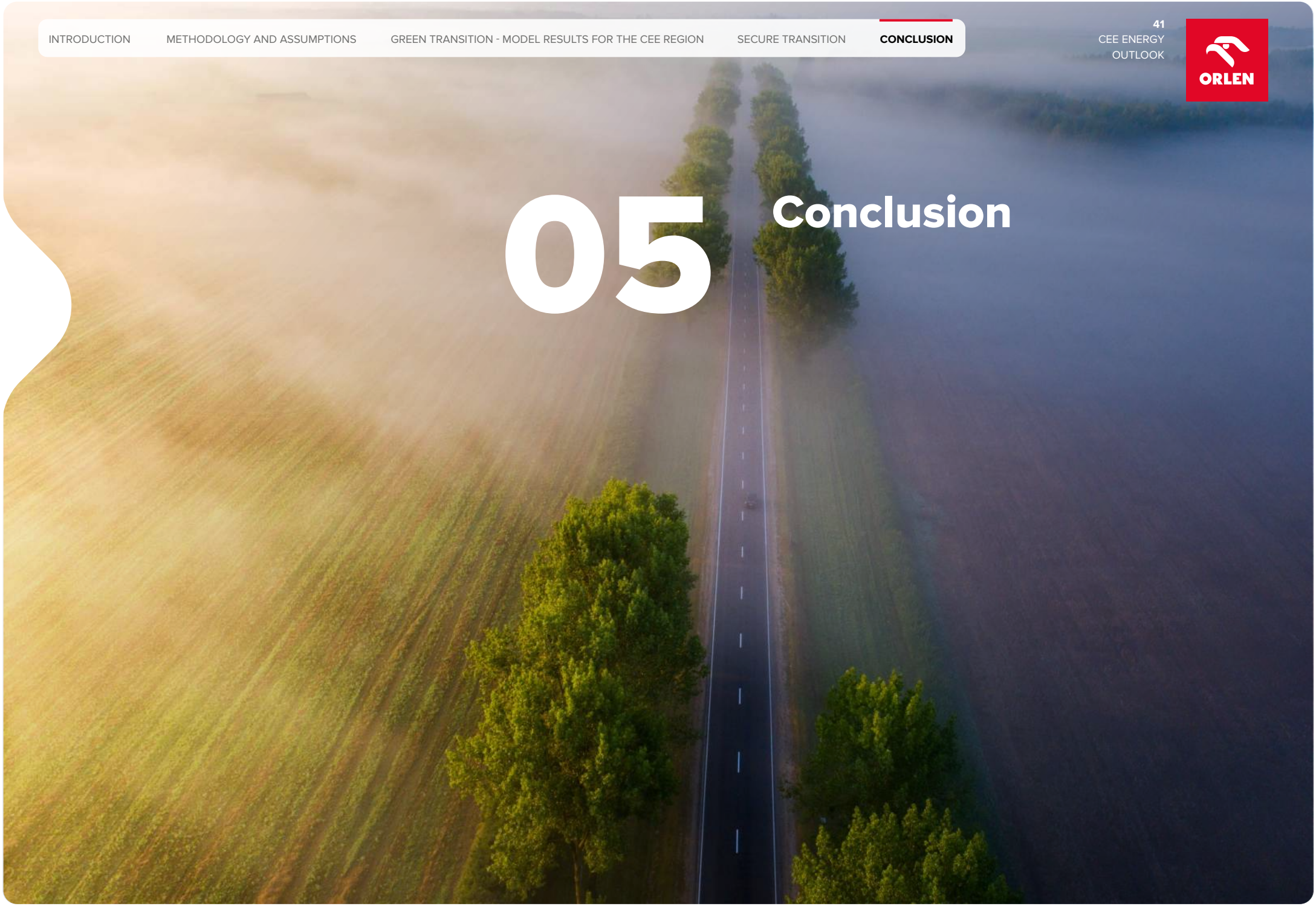
The Baltic Sea emerges as crucial for both a green and secure transition

The Baltic Sea emerges as a crucial basin for both green and secure transition, allowing us to source zero-emission electricity and providing an opportunity to develop interconnections.

Key areas include:

- Offshore Wind (Poland/Germany/Baltic States): The Baltic Sea has huge offshore potential – ranging from 83 GW (WindEurope) to 90 GW (European Comission). With capacity factors exceeding 40%, offshore wind can significantly contribute to the electricity mix
- Nuclear – Poland plans to develop its first large-scale nuclear power plant on the Baltic coast, following Oskarshamn and Finland's Loviisa and Olkiluoto
- The Baltic Sea hosts key infrastructure for oil, gas and electricity supply. It is home to two oil ports supplying refineries in Poland, Lithuania and Germany. New LNG/FSRU terminals are being planned to increase the capacity of existing three in Świnoujście, Klaipėda and Lubmin. Sub-sea cables connect countries across the basin. Work on Harmony Link connecting Lithuania and Poland has started, bringing the prospect of integration of Baltic States' grids with the European grid closer

Source: Orlen analysis based on Eurostat, IEFA. ENTSO-E.



05 Conclusion

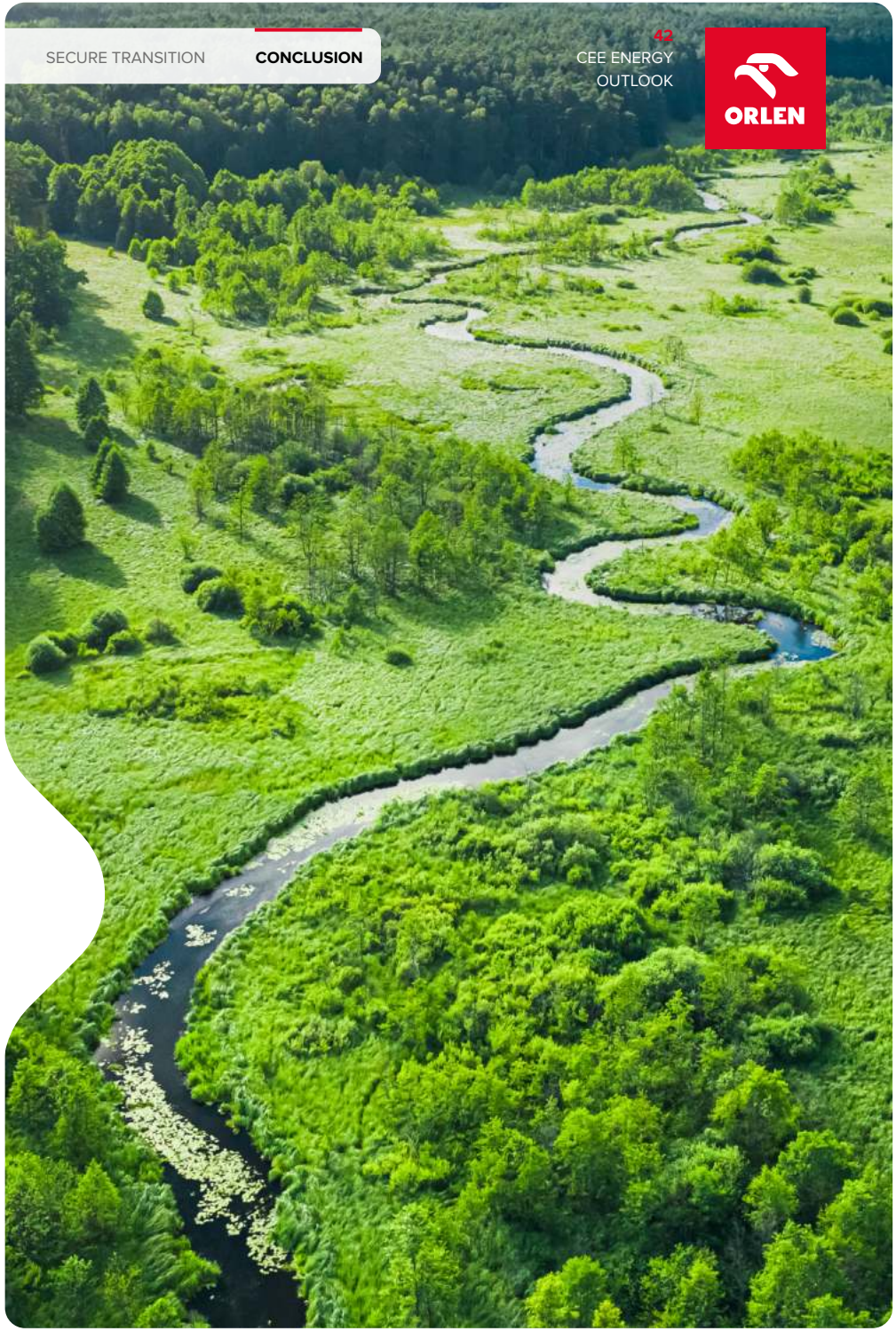
Conclusion

As the CEE11 region embarks on the dual transition towards a greener and more secure energy system we believe this overview of the energy landscape will provide a better insight into this region's very specific situation and plans.

Even though the CEE11 countries have enjoyed faster than EU average GDP growth, many of them already grapple with the significant socio-economic challenge of a declining population. To continue on a rapid development path, significant productivity increases are needed. The transition, if executed in a thoughtful and orderly way, offers vast opportunities. Diverse approaches to the future electricity mix, leading to a surge in all kinds of zero-emission energy sources including renewables and nuclear, are a chance for businesses from heavy industry to digital services to grow. Similarly, a comprehensive shift of the transport sector toward a diverse landscape of solutions: electrification, hy- drogen as well as bio and synthetic fuel, presents many companies with room to grow and innovate.

The SecureTransition, triggered by geopolitical shifts, has compelled the region to reassess its energy security landscape. After the Russian invasion of Ukraine, the visible changes in supply routes underscore the region's resilience and adaptability. The ongoing efforts to establish new routes and invest in storage facilities are a testament to a proactive approach aimed at mitigating supply risks and fortifying overall resilience.

Successfully navigating these dual transitions requires a holistic strategy that integrates sustainable practices with strategic security considerations.
CEE's response to the Green and Secure Transitions will not only define its energy future but also the region's position in the global energy landscape. Policymakers, industry players and stakeholders have an obligation to collectively address challenges, capitalise on opportunities, and shape a sustainable and secure energy future for the CEE region.



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