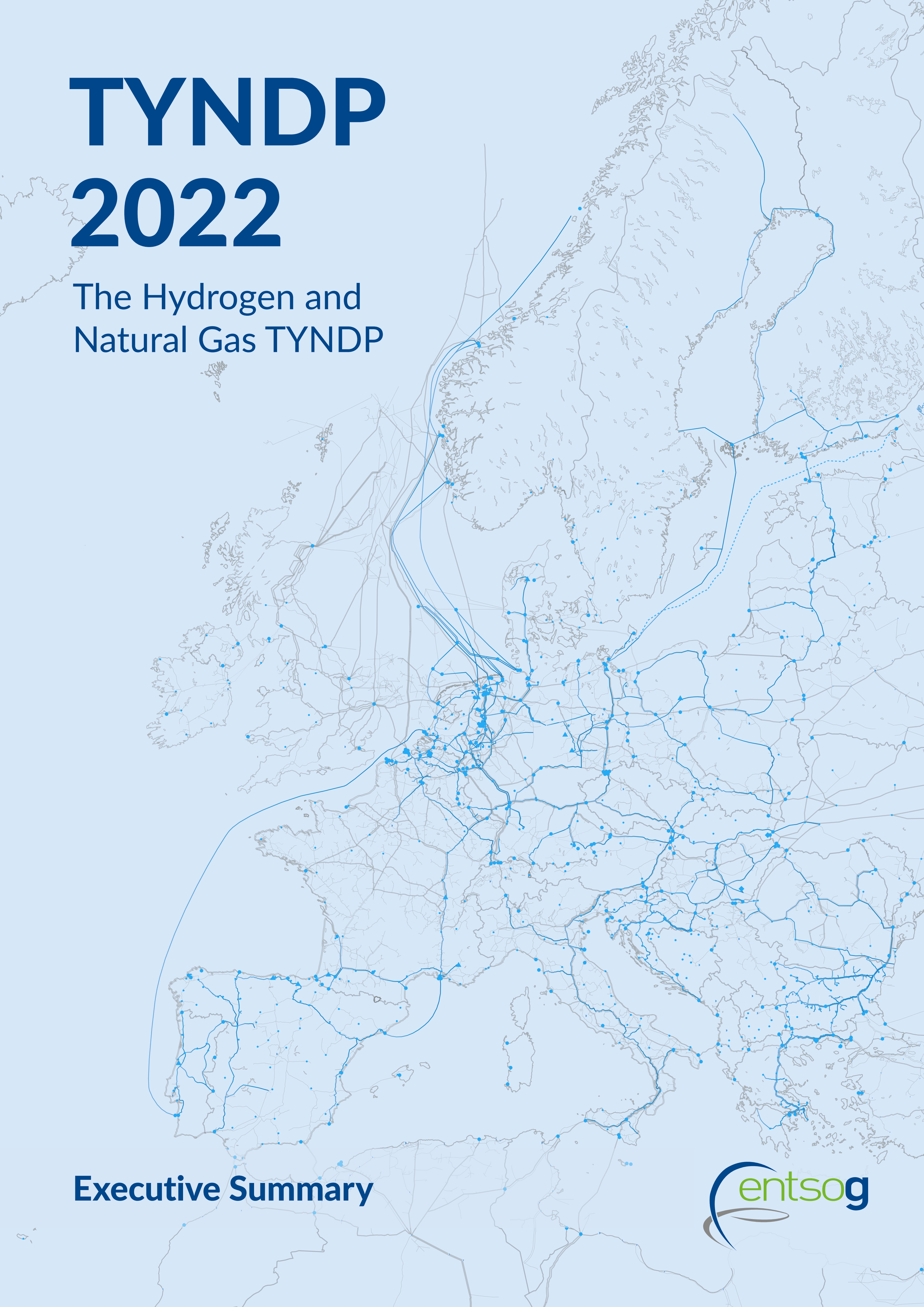
TYNDP 2022

The Hydrogen and Natural Gas TYNDP



Executive Summary

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PRESIDENT'S FOREWORD

This Hydrogen and Natural Gas Ten-Year Network Development Plan – ENTSOG's TYNDP 2022 – provides a unique opportunity to visualise the possibilities for the EU's decarbonised gas grid. It also reflects the dramatic changes we saw in the energy market last year, and the quickly commissioned projects to support stability and security of energy supply in a time of crisis. This report maps the way forward as the most efficient way to achieve Europe's energy and climate goals.

The TYNDP 2022 development process was adjusted and modified to include REPowerEU ambitions with respect to the infrastructure development and its assessment. **The REPowerEU Plan is addressing the European Commission's response to the hardships and global energy market disruptions caused by Russia's invasion of Ukraine.** It sets out a series of measures to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition, while increasing the resilience of the EU-wide energy system. On this basis, the TYNDP 2022 scenarios for 2030 were adjusted by ENTSOG and ENTSOG exceptionally reopened its project collection for TYNDP.

In this TYNDP, ENTSOG collected projects under four new categories to reveal development trends. These projects comprise new or repurposed infrastructure to carry hydrogen, projects for retrofitting infrastructure to further integrate hydrogen, biomethane development projects and other infrastructure-related projects that facilitate decarbonisation. Most significantly, of the total TYNDP 358 investments, 215 of these (in 26 countries) fall within the four categories, highlighting the progression of energy transition projects since the last TYNDP edition.

For the first time, ENTSOG has introduced "hydrogen infrastructure levels" and includes hydrogen infrastructure projects submitted to the first PCI selection process under the revised TEN-E Regulation. The results of TYNDP 2022 for Projects of Common Interest and Projects of Mutual Interest candidate projects should be complemented by the latest energy strategies of the Member States, for further and complete analyses.

On behalf of ENTSOG, **I would like to thank all parties involved in the TYNDP 2022 process. We welcome stakeholder feedback, together with the ACER Opinion**, allowing us to continue to develop and improve our processes, capturing the interconnectivity of a well-integrated gas system. I hope you enjoy reading the report and we look forward to your further contributions!

BART JAN HOEVERS
President, ENTSOG

GENERAL DIRECTOR'S FOREWORD

The ENTSOG team have delivered a very special edition of the Ten-Year Network Development Plan for gas (TYNDP), recognising the importance of hydrogen and biomethane in the current European energy system, and its critical role in the coming years.

Starting with the TYNDP scenarios, assessing hydrogen together with natural gas and biomethane, the report also evaluates the benefit of relevant decarbonised gas projects. In fact, approximately two thirds of the total investments analysed in the report represent these kinds of projects. For the first time, the assessment includes import and production capacities of renewable and decarbonised gases, including hydrogen, as well as demand for hydrogen. **Numerous stakeholders have contributed along the way, from many parts of the energy value chain.**

Indeed, a holistic approach was first and foremost applied when modelling the European energy system, to ensure consistency across all sectors beyond interactions solely between gas and electricity. **ENTSOG developed a dual gas system modelling approach considering hydrogen and methane networks simultaneously**, including the evaluation of the TYNDP projects to capture their ability to consider the identified infrastructure needs. The project-based assessment considers hydrogen projects submitted by project promoters, as well as hydrogen projects submitted to the first PCI selection process under the revised TEN-E Regulation. The parallel policy-based infrastructure assessment was developed by ENTSOG together with the TSOs to incorporate additional infrastructure needs required to comply with the relevant policy objectives, such as the 2030 hydrogen imports targets defined by the REPowerEU Plan. **These combined views provide a solid basis on which the necessary project investment, planning and development can proceed.**

In line with the provisions of the new TEN-E Regulation ENTSOG is working on a new CBA methodology to allow for more complete assessments, including costs and benefits triggered by the projects for the overall energy system as well as the impact of projects on CO_2 emissions reduction. For this TYNDP 2022, the scenarios were already established by a modelling of gas and electricity assets on a pan-European scale.

Continuing a tradition of high transparency, all methodologies, input data, technical data and results are available for download on the ENTSOG website: **www.entsog.eu/tyndp**

I am honoured and proud of the work undertaken by the ENTSOG team and the extraordinary level of stakeholder engagement involved to produce a high quality and valuable report, reflecting the current realities and future ambitions for the integrated gas network.

PIOTR KUŚ
General Director, ENTSOG

HYDROGEN AND NATURAL GAS TYNDP 2022

The European gas system is one of the keys to achieve the European energy and climate targets. The gas infrastructure offers unique opportunities – in energy storage, transmission, and integration of renewables – to support the decarbonisation of the overall energy system in a cost effective, secure, and achievable way.

The European gas infrastructure has seen decades of investments and development. The gas system connects most European countries, as the most efficient solution for transporting and storing large amounts of energy over long periods and distances. Now, hydrogen emerges to complement the role of natural gas, contributing to ensure affordable, secure and sustainable energy for Europe. Therefore, this TYNDP is the first one to assess hydrogen together with natural gas and biomethane, covering scenarios, projects, and the system assessment.

An evolution of the energy infrastructure is necessary to allow significant import and production capacities of renewable and decarbonised gas, and to provide for the demand for new gases like hydrogen and biomethane.

Today, hydrogen is mainly used as a feedstock for the industry. However, the demand for clean gaseous energy increases to meet the COP 21 and EU climate and energy targets for carbon neutrality by 2050. In a net-zero future, hydrogen and biomethane play a key role as confirmed by the respective ambitious targets defined by the REPowerEU Plan. The future gas infrastructure evolutions must allow for this uptake while also reducing Russian gas supply dependence, ensuring wider energy sources diversification.

Hydrogen and biomethane projects will drive the decarbonisation of the energy system towards the net-zero 2050 goal.

The current gas infrastructure can already support the phase out of more carbon intensive fuels in energy intensive sectors such as industry and transport, but also in the power sector. However, additional investments in renewables and decarbonisation technologies and assets as well as infrastructure conversion are needed. Following the EU Green Deal and the revision process of the TEN-E Regulation, ENTSOG decided to further evolve its TYNDP by collecting projects in four new categories allowing for a differentiation between hydrogen and biomethane and displaying development trends. Indeed, the TYNDP 2022 includes 215 investments in 26 countries that were submitted as new or repurposed infrastructure to carry hydrogen, projects for retrofitting infrastructure to further integrate hydrogen, biomethane development projects or other infrastructure-related projects.[1] The evaluation of these projects is performed with a dual gas-hydrogen model to capture all relevant aspects of their ability to cover the identified infrastructure needs.

1 Among these projects, some are submitted to the PCI selection process. Hydrogen projects that apply for the PCI status will undergo a thorough eligibility check by the European Commission. Since this eligibility check was not completed during the preparation of this document, no project that fulfilled the formal submission criteria to the TYNDP was rejected by ENTSOG. The inclusion of a project in the TYNDP is neither an endorsement by ENTSOG nor by an EU body.

TYNDP 2022 addresses recent developments

The invasion of Ukraine by Russia on 24 February 2022 has led to a major overhaul of energy policy objectives in terms of energy security and diversification of supply. **ENTSOG has amended the TYNDP COP 21 scenarios – Distributed Energy and Global Ambition – for the year 2030 according to the REPowerEU Plan announced by the European Commission and to address its objectives of 10 mt domestic green hydrogen production and 10 mt hydrogen import.** Although multiple major and known developments of 2022 could be considered and have been included, it should still be noted that this TYNDP report cannot reflect all latest developments even at its publication date. Thus, the results of this TYNDP for PCI/PMI candidate projects should be complemented by the latest energy strategies of the Member States, for further and complete analyses.

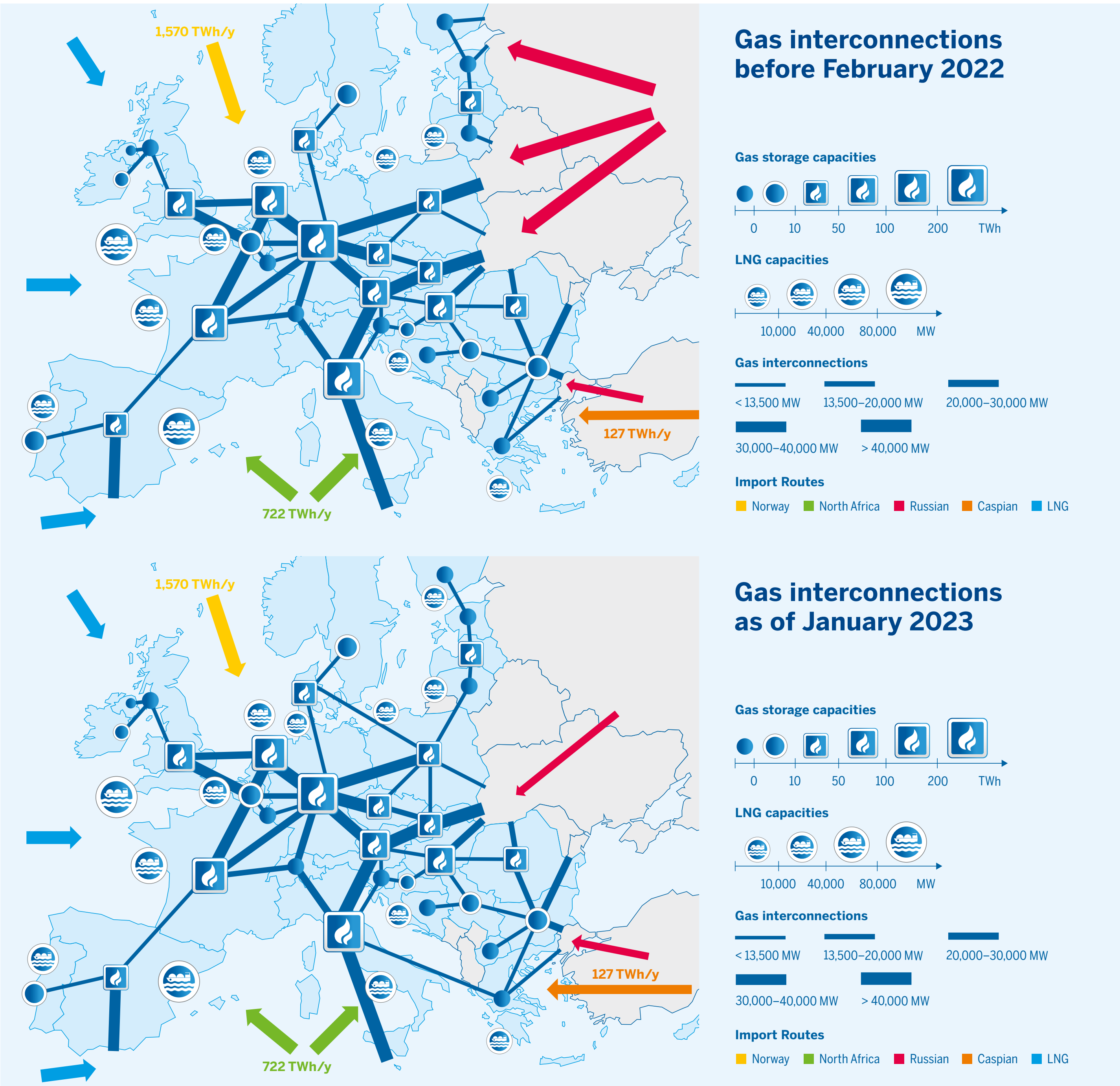


Figure 1: A glance at the European gas infrastructure before the Russian invasion of Ukraine (above) and infrastructure as of January 2023 used in the System Assessment (below).

1 **A NEW TYNDP 2022** TO SUPPORT THE EUROPEAN GREEN DEAL

1.1 **TYNDP 2022 SCENARIOS: NET-ZERO 2050** AND **COP 21** COMPLIANT

TYNDP 2022 scenarios support the European energy and climate ambitions

For the 2022 edition of their TYNDP, ENTSOG and ENTSO-E have developed **sustainability-oriented scenarios reaching net-zero carbon emissions in 2050**, considering either national policies as defined by the Member States' National Energy and Climate Policies (2019 **NECPs**, national long-term strategies, hydrogen strategies, etc.) published in the last years or the objectives as defined in the Paris Agreement **(COP 21)**. All scenarios therefore comply with European and national ambitions as displayed in Figure 2 and were consulted with stakeholders during the definitions of the scenarios' storylines.

Furthermore, building on the ever-improving interlinked model developed jointly by ENTSO-E and ENTSOG, the COP 21 scenarios – Distributed Energy and Global Ambition – are built on a **holistic approach to the European energy system** considering the total primary energy mix of Europe to ensure consistency across all sectors, beyond considering the sole interactions between gas and electricity. It is also the first time that the **scenarios have modelled hydrogen and electrolysis at pan-European scale**.

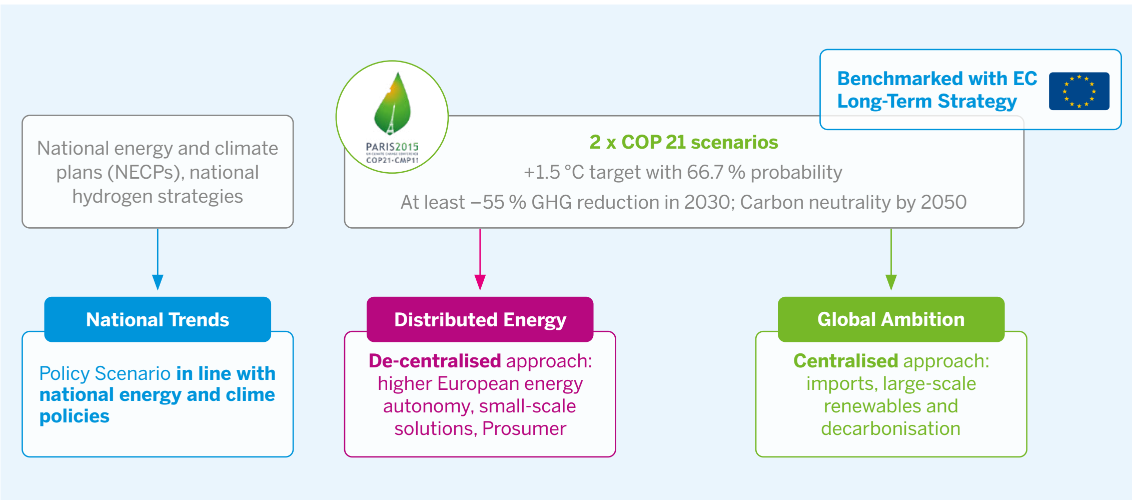


Figure 2: TYNDP 2022: scenario storylines

1.2 THE GAS SYSTEM IS A KEY ASSET TO REACH NET-ZERO 2050

An evolution of the energy infrastructure is necessary to allow significant import and production capacities of renewable and decarbonised gas, and to provide for the demand for new gases like hydrogen and biomethane.

Natural gas demand decreases and its supply decarbonises over time with biomethane

Aggregated on EU level, national policies show a large role for natural gas as a gas energy carrier with very limited evolution of the demand until 2030. After 2030 however, the natural gas demand decreases with the implementation of the strategy of some Member States which at the same time see the uptake of renewable gases and hydrogen demand.

The development of the final natural gas demand differs from region to region. Due to a high dependence on coal and coal-to-methane switch policies, methane demand for heating rather increases in Central and Eastern Europe, whereas other regions head towards more electrification in the private heating sector. Following the evolution of the hydrogen and methane production capacities, the **methane demand decreases as renewable gases and hydrogen develop already at 2030**. In all scenarios the natural gas consumption needs to be abated by 2050, either by direct replacement with non-emitting gases or by combination with CC(U)S. The demand for methane is generally sustained by the final demand including non-energy use and the indirect demand of abated natural gas for hydrogen production.

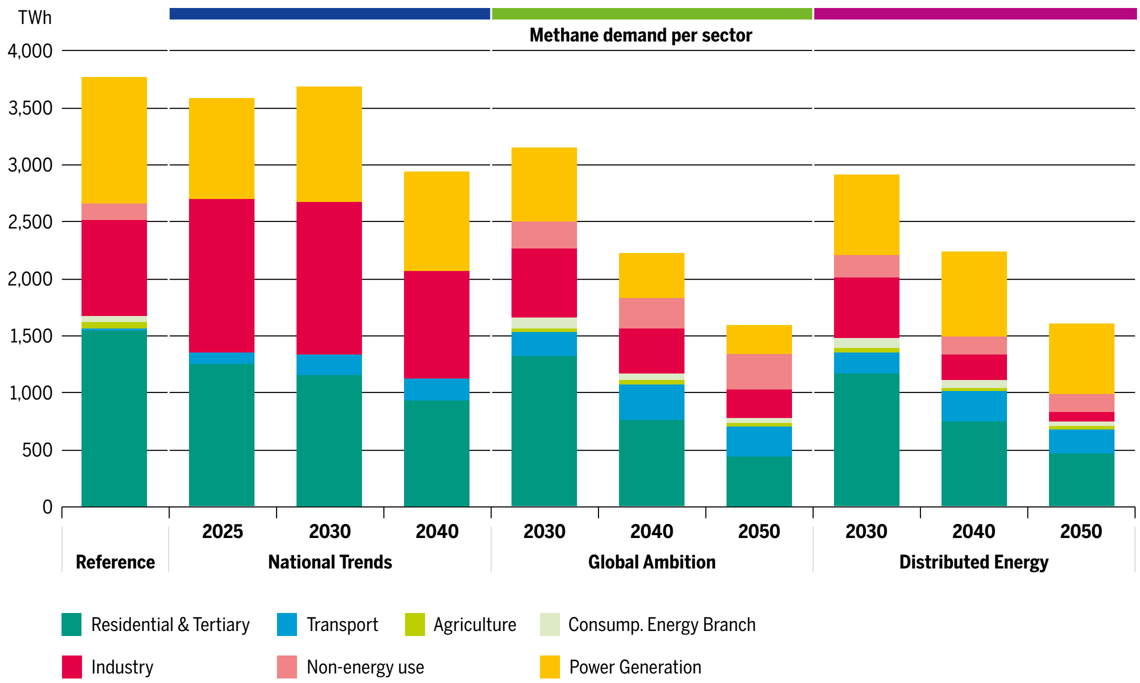


Figure 3: Methane (natural gas, synthetic methane and biomethane) demand per sector for EU27 (before REPowerEU update for Global Ambition and Distributed Energy for 2030)

Hydrogen as a key element to reach carbon neutrality

In all scenarios, the demand for hydrogen develops as of 2030 and hydrogen becomes the **main gas energy carrier in both COP 21 scenarios in 2050**. Today, hydrogen is mainly used as a feedstock for the industry. However, as the demand for clean gaseous energy increases to meet the COP 21 and EU climate and energy targets, hydrogen is mainly used for its energy content and as energy carrier by 2040 and its use as feedstock becomes less dominant over time.

The **National Trends scenario** considers the different national policies of the EU Member States that are currently under revision. Whereas some countries plan for the development of hydrogen to replace natural gas with objectives defined for 2030, some other countries plan for a more stepwise approach to move away from the most carbon intensive fuels, especially in the coal mining regions. Therefore, at EU level, this translates into a slower development of the hydrogen demand which is nevertheless steadily accelerating between 2025 and 2040 at EU level.

Most of the current (modelled for 2025) hydrogen produced locally (as feedstock mostly) in the industrial clusters is not included in the figures since they are not connected to any regional or national networks and currently produce their hydrogen from methane. This relates to hydrogen production mainly from methane through steam methane reforming (SMR) or autothermal reforming (ATR).

Both COP 21 scenarios require significant amounts of hydrogen to meet the COP 21 and EU climate and energy targets and reach carbon neutrality by 2050. **Hydrogen can be produced indigenously in the EU** to a significant extent, as well as be imported from some extra-EU countries, that have significant potentials to produce renewable, cost-competitive hydrogen and can be actors of a global clean hydrogen market. In addition, as identified in the Scenario Report, hydrogen production from methane through steam methane reforming (SMR) or autothermal reforming (ATR) in combination with carbon capture and storage (CCS) can support the development of the hydrogen demand by securing the supply and thereby accelerate the decarbonisation of the European economy. Furthermore, if biomethane is used instead of natural gas, those decarbonisation solutions can become carbon negative and help to recover from the carbon budget overshoot after 2050.

This is a key factor underpinning the investments into all hydrogen and biomethane infrastructure to be ready and start contributing to COP21 targets as soon as possible, even before 2030.

Picture: istockphoto.com

Gases (methane and hydrogen) are part of the solution towards net-zero 2050

TYNDP scenarios confirm the need for various renewable and decarbonisation technologies and the interdependence of the gas and electricity systems in reaching a net-zero European energy system by 2050.

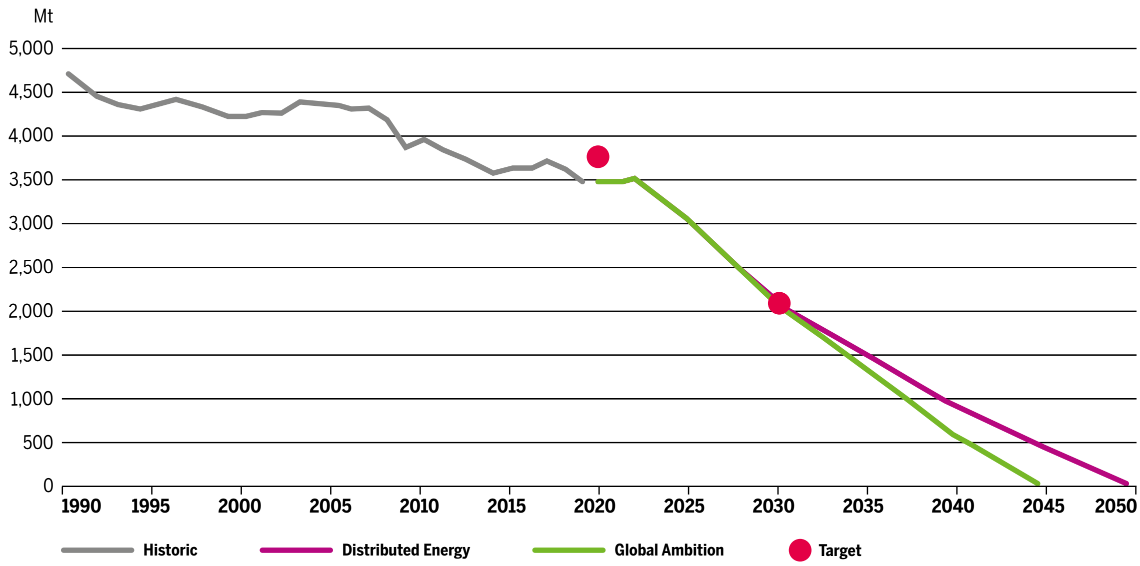


Figure 4: GHG emissions in Distributed Energy and Global Ambition (before REPowerEU adjustments for 2030)

TYNDP 2022 scenarios confirm that power-to-gas is a key technology to integrate electricity from variable renewables to a larger scale. It optimises the usage of fluctuating renewable energy production, allows for seasonal energy storage that otherwise could only be offered by hydro storages, and opens affordable long-distance transport options. Since the electricification of the heat market drives up the winter demand for electricity, flexible methane- and hydrogen-fired power plants play an increasingly crucial role, translating into flexibility needs of the gas systems. The most extreme climatic stress cases are therefore covered by the System Assessment.

Underlining the goal of European energy independence, the COP 21 scenarios show lower total energy import needs than the EU Impact Assessment scenarios.

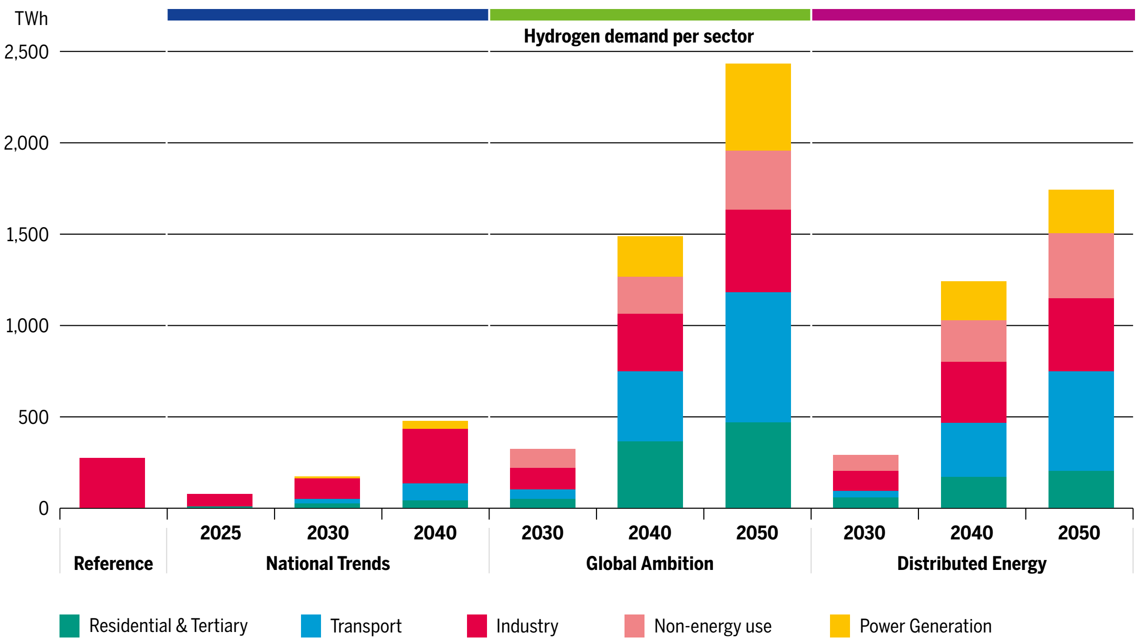


Figure 5: Hydrogen demand per sector for EU27
(before REPowerEU update for Global Ambition and Distributed Energy in 2030)

1.3 **ADJUSTMENT** OF THE **TYNDP 2022** TO **REPowerEU**

The invasion of Ukraine by Russia on 24 February 2022 has led to a major overhaul of energy policy objectives in terms of energy security and diversification of supply.

The REPowerEU Plan, published by the European Commission, is Europe's collective response to the global energy market disruptions caused by Russia's invasion of Ukraine. It is a plan for reducing energy consumption, accelerating the production of clean energy and diversifying energy supplies to reduce Europe's dependency on Russian natural gas. **The REPowerEU Plan sets out a series of measures to accelerate the energy transition, while increasing the resilience of the EU-wide energy system. The plan includes measures for increased production of biomethane, targeted investments in gas infrastructure as well as proposals for LNG and hydrogen purchases from alternative supply sources. The TYNDP 2022 development process was adjusted and modified to include these ambitions into the perspective of the infrastructure development and its assessment.**

The TYNDP 2022 scenarios, published in April 2022, could not address and consider the requirements of the REPowerEU Plan that were published later. To include these ambitions into the perspective of the infrastructure development and its assessment, the TYNDP 2022 scenarios for 2030 were therefore adjusted by ENTSOG, in alignment with the EC. The aim was to keep the main findings of the published TYNDP 2022 Scenario Report, in particular those linked to the use of electricity, while considering the major changes regarding gas supply. **Therefore, ENTSOG has amended the TYNDP COP 21 scenarios – Distributed Energy and Global Ambition – for the year 2030 according to the REPowerEU Plan and its objectives of 10 mt domestic green hydrogen production and 10 mt hydrogen import.**

Data of the updated scenario will be made available on the **TYNDP visualisation platform**.

Picture courtesy of the European Commission

Hydrogen and Natural Gas TYNDP 2022 – how hydrogen and biomethane projects will drive the decarbonisation

Already for the previous edition (TYNDP 2020), ENTSOG introduced a new project infrastructure category for Energy Transition Projects. The TYNDP 2020 included 75 Energy Transition Projects. Following the EU Green Deal and the revision process of the TEN-E Regulation, ENTSOG decided to further evolve this single project category in four different new categories, better allowing for sector-specific insights and displaying development trends.

The TYNDP 2022 includes 215 investments relevant for these four new categories, concerning 26 countries. The new categories are:

- **New or repurposed infrastructure to carry hydrogen (HYD)**
- **Projects for retrofitting infrastructure to further integrate hydrogen (RET)**
- **Biomethane development projects (BIO)**
- **Other infrastructure-related projects (OTH)**

Overall, 358 investments are covered by the TYNDP 2022 out of which 143 are natural gas projects. They were submitted by more than 60 different project promoters including both Transmission System Operators (TSOs) and third-party promoters. The collection was facilitated by ENTSOG's decision to to re-open the project collection process with the purpose of including relevant projects in the light of security of supply after the Russian invasion of Ukraine, in line with European Commission REPowerEU targets.

The extensive data collection carried out for TYNDP 2022, allowed for the consideration of hydrogen infrastructure levels as a first step on the assessment and analysis of hydrogen infrastructure.

Among these new infrastructure categories detailed above, hydrogen infrastructure projects were collected as part of the dedicated new hydrogen project category.

Moreover, hydrogen infrastructure projects were divided into different subcategories of hydrogen infrastructure, such as:

- **On-shore or off-shore hydrogen transmission pipelines** (newly constructed or repurposed from natural gas pipelines) including pipelines enabling hydrogen imports from extra-EU countries.
- **Newly constructed or repurposed liquefied hydrogen terminals** including hydrogen embedded in other chemical substances with the objective of injecting the hydrogen into the grid.
- **Hydrogen storages** (newly constructed or repurposed from natural gas infrastructure).

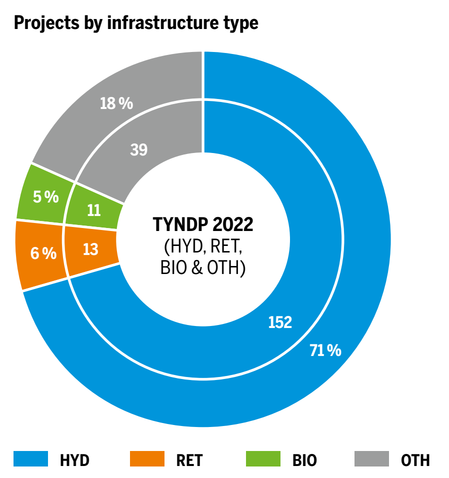


Figure 6: Projects representing new project categories included in the TYNDP 2022 per type of infrastructure (absolute number of respective investments and the equivalent share including PCI candidates).

Hydrogen infrastructure levels

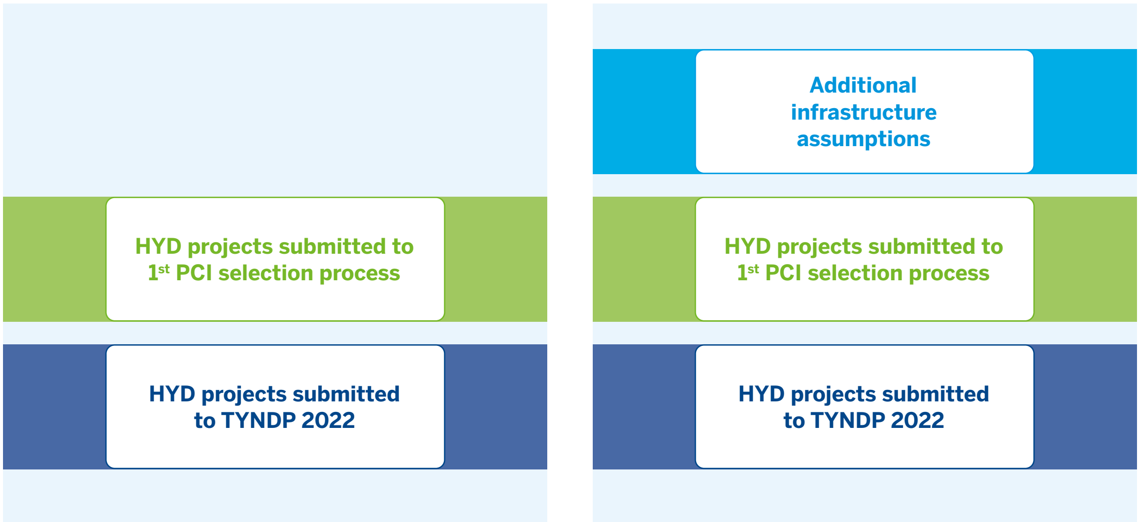
For the first time, in TYNDP 2022 edition, ENTSOG has introduced hydrogen infrastructure levels. These include not only hydrogen infrastructure projects submitted in December 2021 and June 2022 to the TYNDP 2022, but also those additional hydrogen infrastructure projects that were candidated by December 2022 to the first PCI selection process under the revised TEN-E Regulation.

Hydrogen infrastructure is at an early stage of development compared to natural gas infrastructure. Unlike natural gas, hydrogen infrastructure levels can only be defined with the consideration of planned projects, as there is no existing infrastructure in place. In comparison with the natural gas infrastructure levels, the hydrogen infrastructure levels are not based on project status that reflect their maturity. For comparison, natural gas infrastructure reaches already for the existing infrastructure level a considerable level of maturity for most European countries, since it has been gradually developed over the years.

In the TYNDP 2022, two hydrogen infrastructure levels were included:

Hydrogen infrastructure level 1:

Hydrogen infrastructure level 2:



Hydrogen Infrastructure level 1 is a project-based infrastructure level, composed of all hydrogen projects submitted by project promoters to the TYNDP 2022 (including infrastructure that was submitted as hydrogen-ready[2]) as well as hydrogen projects submitted by project promoters to the first PCI selection process under the revised TEN-E Regulation.

Hydrogen Infrastructure level 2 is defined as a policy-based infrastructure, composed of Hydrogen Infrastructure level 1 and additional infrastructure assumptions that were developed by ENTSOG together with the TSOs to enable policy objectives, such as the 2030 hydrogen imports targets defined by the REPowerEU Plan.

Figure 7: Hydrogen infrastructure levels in TYNDP 2022[3].

2 Hydrogen projects that apply for the PCI status will undergo a thorough eligibility check by the European Commission. Since this eligibility check was not completed during the preparation of this document, no project that fulfilled the formal submission criteria to the TYNDP 2022 was rejected by ENTSOG. The inclusion of a project in the TYNDP is neither an endorsement by ENTSOG nor by an EU body.

3 PCI candidates projects can be found in the Hydrogen map

1.4 ENTSOG TYNDP: NATIONAL EXPERTISE AT THE SERVICE OF THE EUROPEAN ENERGY AND CLIMATE AMBITIONS

The TYNDP 2022 relies on expertise of the European gas and electricity TSOs. TSOs are at the interface of production operators, mid-stream, LNG, hydrogen terminal and storage operators, downstream consumers, and distribution systems. They operate national networks and the largest cross-border energy infrastructure, backbone of the European energy market and are essential to the cooperation between Member States to ensure the security of the energy supply of the EU.

An inclusive and transparent TYNDP

Continuing a tradition of high transparency, all methodologies, input data, technical data and results are available for download on the **ENTSOG website**.

To further clarify the neutrality of ENTSO-E and ENTSOG in the TYNDP processes, the associations will further improve and reinforce stakeholder involvement in the next TYNDP editions, to ensure neutrality and transparency along the process.


Picture courtesy of Teréga

2 THE GAS INFRASTRUCTURE: AN EFFICIENT AND RELIABLE ASSET TO DECARBONISE THE FUTURE ENERGY SYSTEM AND TO REDUCE RUSSIAN GAS SUPPLY DEPENDENCE

Natural gas infrastructure was developed continuously based on the TEN-E requirements *"to enhance security of supply, market integration, competition, and sustainability"*. Especially through new interconnections between European countries and the linking with different sources through import pipelines and LNG terminals, a certain flexibility was achieved that led to converging market prices across Europe, redundancies against technical unavailabilities of individual import routes, and a certain coal-to-gas switch.

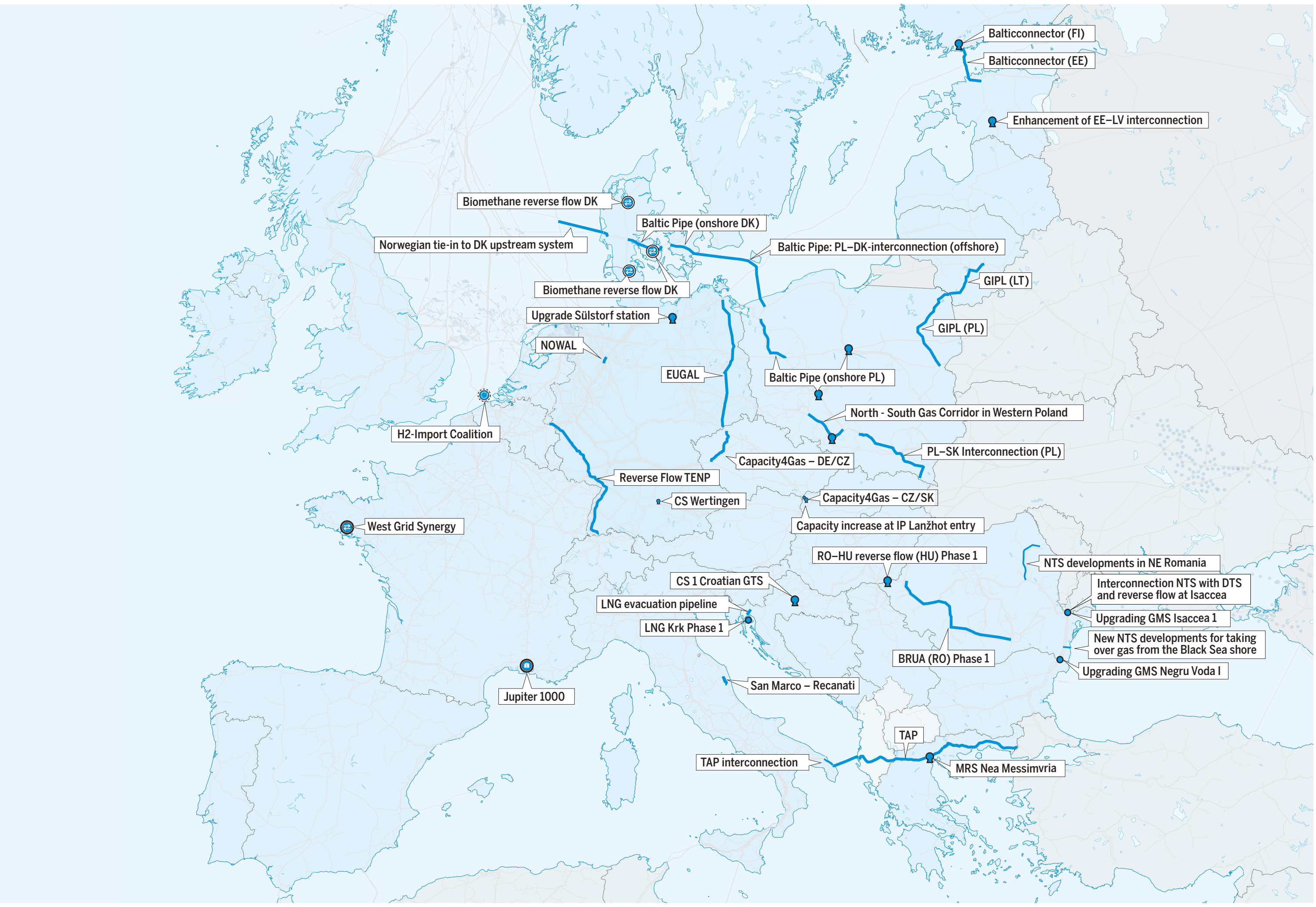


Figure 8: Map of projects commissioned since 2020

In parallel, rising volumes of biomethane were injected. The Russian invasion of Ukraine in 2022 impacted previous planning assumptions, whereas the achieved gas system flexibilities, demand reductions, and swift construction of new LNG infrastructure could be an interim measure to prevent the triggering of the European crisis level.

Since the TYNDP 2020, progress has been made in terms of gas infrastructure projects. 32 investments that were already part of the TYNDP 2020 were completed between both TYNDP editions. The commissioning of all these investments further contributes to the development of the European gas system, enhancing the level of market integration, security of supply, competition and sustainability.

Some other projects have been submitted to TYNDP 2022 and were commissioned in the following months directly after the end of the project submission phase (commissioning date before 31 December 2022).

2.1 INDEPENDENCE FROM RUSSIA

In TYNDP 2020, one of the conclusions was that in all scenarios, Europe depends on Russian gas to satisfy its demand in 2020, 2025 and 2030 and to a lesser extent in 2040. At EU-level, the assessment showed that gas infrastructure allows to make use of the maximum supply potential of all the other gas sources. However, this was not enough to cover the overall EU gas demand. This indicated that Europe relied on Russian gas supply to achieve its balance between supply and demand.

Because of the significant natural gas demand reduction in both scenarios, **Distributed Energy and Global Ambition scenarios show no need for Russian gas in 2030 and 2040**, when assuming the minimisation of Russian gas. However, in policy scenarios that are in line with national energy and climate policies (National Trends and Best Estimate[4]), a supply disruption of Russian gas in many cases leads to methane demand curtailment for average winters. Additional infrastructure in the PCI infrastructure level improves the situation for the National Trends scenario, while the Advanced infrastructure level allows to minimise associated curtailments through additional LNG import capacities and improved interconnections. Remaining possible methane curtailment for the Advanced infrastructure level is then within a range of the demand response that was observed in reaction to high gas prices in 2022, i. e., below 20 %. It should thereby be noted that the demand in the National Trends scenario is based on information collected before the war, when Russia was still considered as a reliable supplier. The scenario therefore also does not reflect demand measures taken by the Member States in 2022. In the National Trends scenario, demand for natural gas is increasing until 2030, and afterwards decreasing. This explains the observed higher curtailments in 2030 compared to 2040.

4 Best Estimate is the bottom-up scenarios used for 2025. More details can be found in TYNDP Scenarios 2022 report

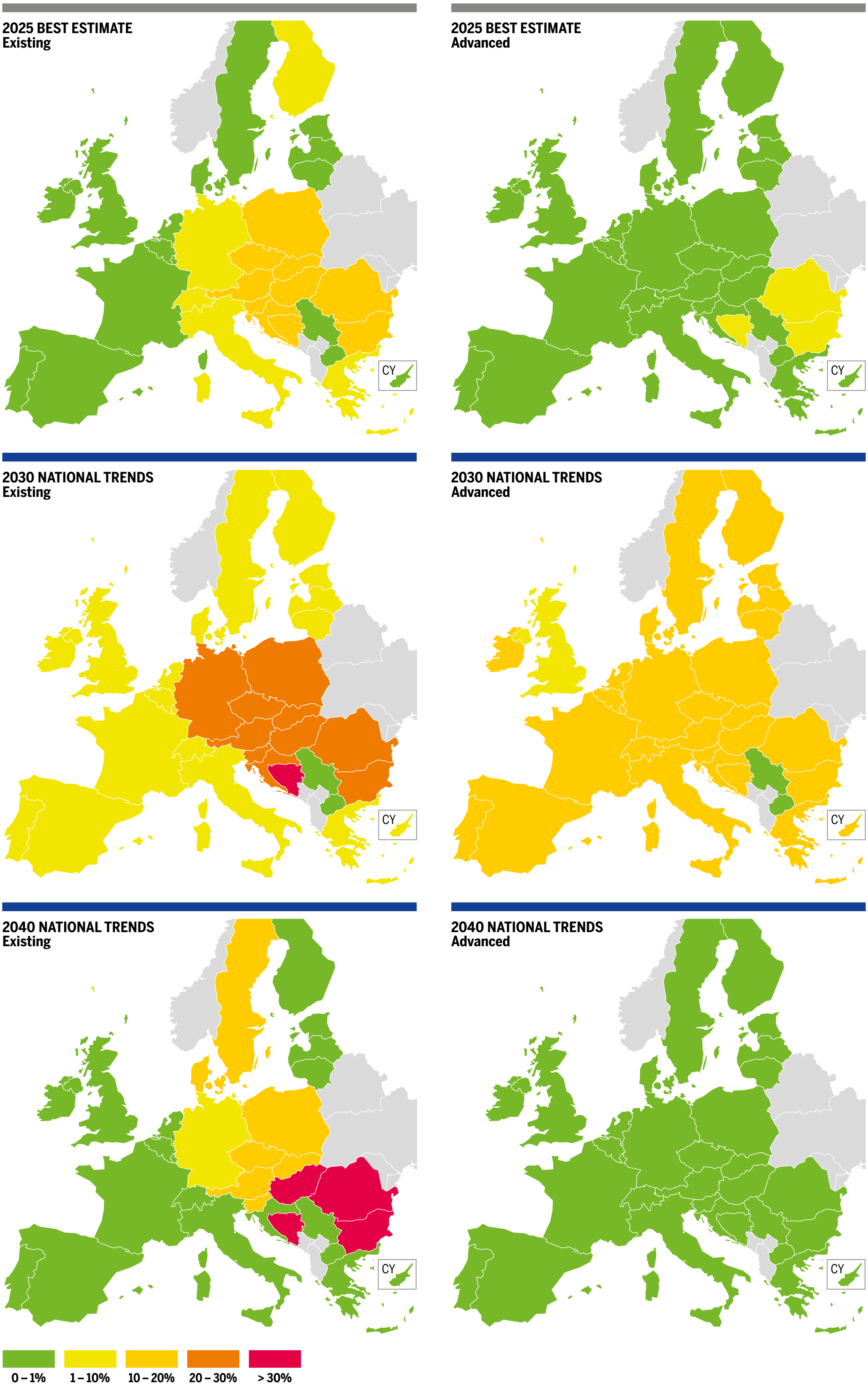


Figure 9: Average curtailment rate of the countries' natural gas demand for different years derived from yearly simulations, when assuming no gas supplies from Russia – existing methane infrastructure level (left) vs. advanced methane infrastructure level (right, including fast track projects deployed as a response to the invasion of Ukraine by Russia in 2022), both in combination with H_2 Infrastructure level 1.

2.2 DUAL GAS SYSTEM – HYDROGEN, NATURAL GAS

With the work undertaken in the last two years, ENTSOG confirms that its model is fit for hybrid network assessment where both methane and hydrogen coexist, and that the relevant projects can be assessed.

ENTSOG has developed a **dual gas system modelling approach** considering hydrogen and methane networks simultaneously. The topology refers to both, the existing methane infrastructure and the planned methane and hydrogen infrastructure. Both topologies are interconnected, allowing to capture interactions between both gases and assess the role of the transmission system of both fuels in satisfying demand under different scenarios, infrastructure storylines and specific events. The full range of the simulation results are presented in the System Assessment Report.

Infrastructure levels are the basis for the identification of infrastructure gaps in the TYNDP 2022 System Assessment. For the first time, the TYNDP 2022 will include a dual assessment of natural gas and hydrogen infrastructure: by combining each natural gas infrastructure level with both hydrogen infrastructure levels in the TYNDP System Assessment. As an existing infrastructure level is not yet available for the hydrogen system, ENTSOG has identified a possible hydrogen network according to the information provided by promoters in their project submission for TYNDP/PCI process (i. e., H_2 infrastructure levels 1 and 2) as explained above. For this reason, the results of the TYNDP simulations, presented in System Assessment report, show what could be reached (in 2030, 2040, 2050) under the hypothesis of a full commissioning of the planned hydrogen infrastructures that are not yet in place. Therefore, even in configurations where no demand curtailment is identified, these results should not be read as absence of hydrogen infrastructure needs. On the contrary, the full availability of the infrastructures composing the H_2 infrastructure levels is assumed in order to avoid demand curtailment. Indeed, if planned infrastructures were not developed, demand curtailment would materialise for given scenarios at rates progressively increasing with the number of planned projects not actually realised.

It should be noted that the simulation results are determined by the behaviour of the model, and assumptions on infrastructure developments. The model does not factorise commercial supply agreements. Furthermore, the results are driven by the demand and supply figures that, in some specific cases, refer to scenarios that have been defined a few years ago (i. e., National Trends).

High hydrogen ambitions – room for smart investments

Two hydrogen infrastructure storylines allow to assess ambitions and targets considering the role of hydrogen in the future. The H_2 Infrastructure level 1 is based only on the submitted projects and in many simulation cases these projects alone would not allow to satisfy demand, e. g., in countries that are not connected to neighbouring countries in 2030 and cannot balance themselves. Within an average year without a stress case, eventual hydrogen demand curtailments show seasonal behaviours. While the electrolytic hydrogen production is lower in winter due to reduced amounts of available zero emission electricity, hydrogen demand is elevated during colder months, e. g., for power generation. In 2040 and 2050, in the Distributed Energy scenario, additional hydrogen storages could mitigate the curtailments since during summer the hydrogen import options cannot be utilised up to their technical capacity. Instead, in most countries, demand curtailments are observed in winter 2040 and in autumn and winter 2040. In 2040 and 2050, in the Global Ambition scenario, all import options are used up to their technical capacity, however the electrolytic hydrogen production is not sufficient in winter. In 2050, demand curtailment with a seasonal profile is even unfolding in every month and country.

It could be questioned whether the part of the hydrogen demand that is not satisfied on a yearly (or even seasonal) basis would materialise or instead remained with another energy carrier. Establishment of hydrogen projects is therefore beneficial to prevent the usage of more carbon intensive alternatives, which would risk the climate goals included in the scenarios. At the same time, if demand is not satisfied on a yearly basis, any additional stress case (climatic stress, infrastructure disruption or supply disruptions) may result in higher demand curtailment. This situation could be mitigated by additional hydrogen projects.

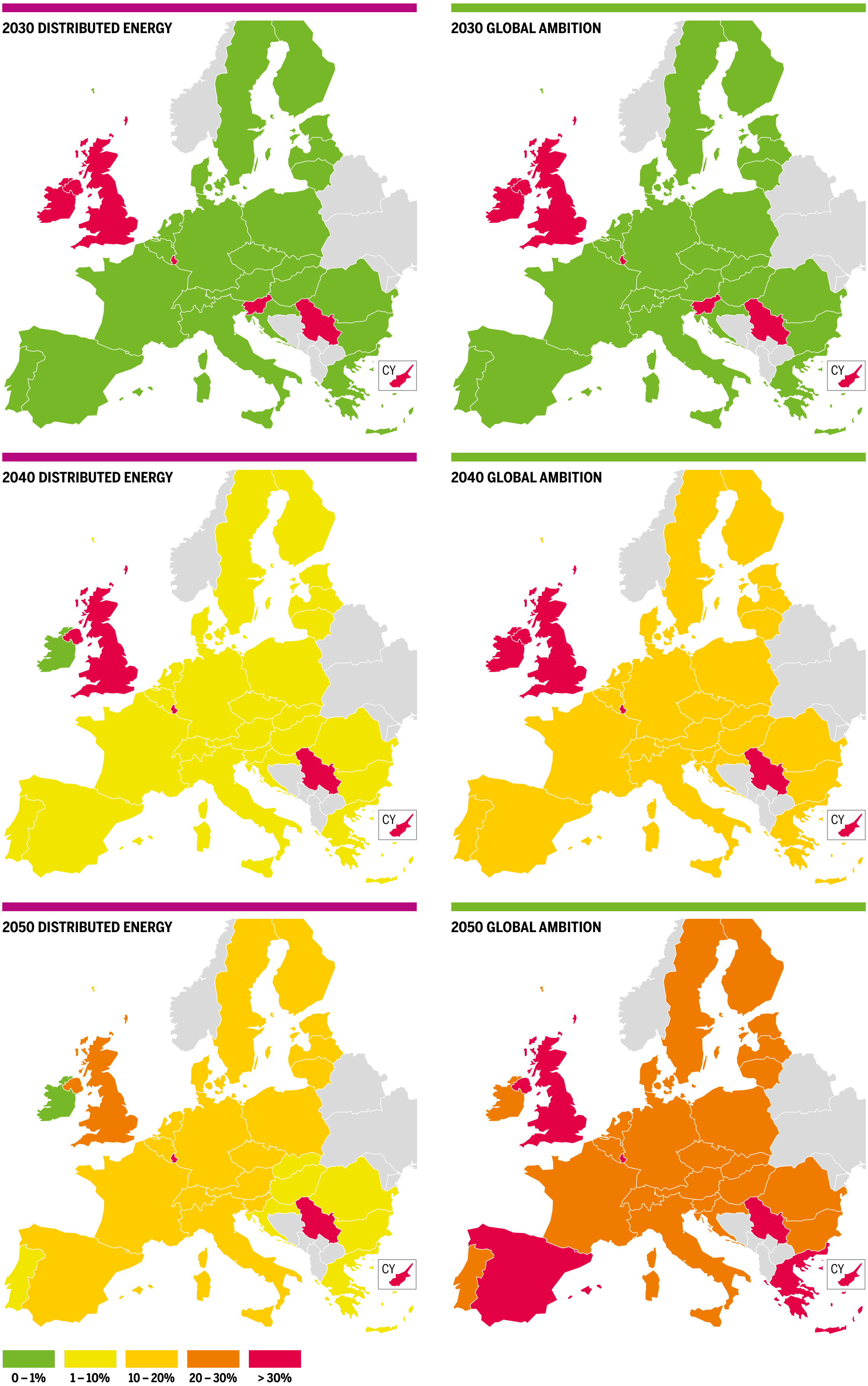


Figure 10: Yearly simulations in the absence of a climatic stress case as well as a supply source disruption, assuming a minimisation of Russian gas imports (reference case) – project-based H_2 Infrastructure level 1 (considering only the hydrogen production from methane as defined in the scenarios).

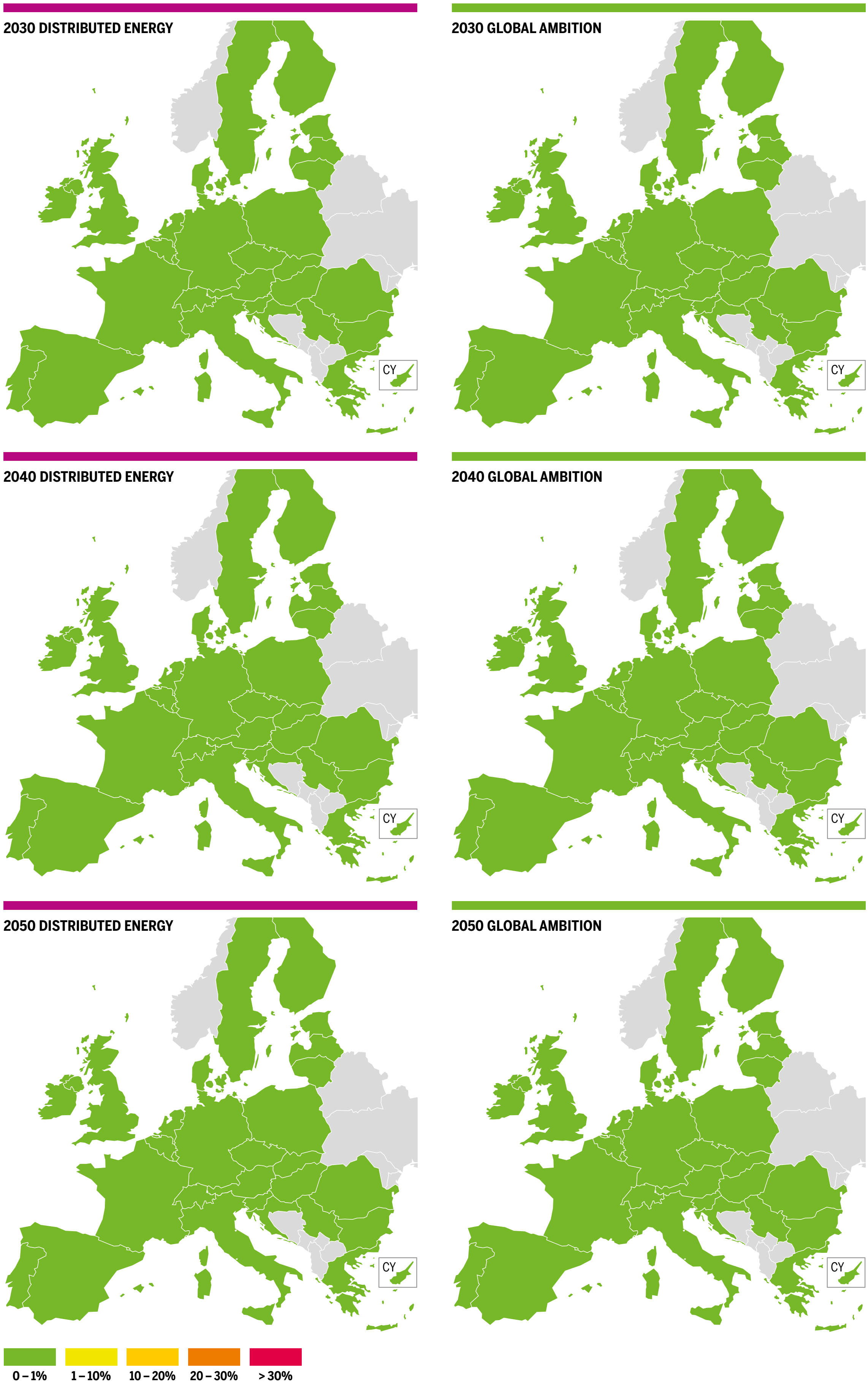


Figure 11: Yearly simulations in the absence of a climatic stress case as well as a supply source disruption, assuming a minimisation of Russian gas imports (reference case) – policy-based H_2 Infrastructure level 2 (with additional production of hydrogen from methane beyond the values defined in the scenarios Scenario Report).

When assessing the **impact of climatic stress on gas infrastructure** (i. e., methane or hydrogen), the demand is considered static and not responding to the possibility of the supply deficit or price signals. This assumption is necessary to perform a consistent assessment across the different years and the different scenarios of the TYNDP.

To be consistent and transparent, the level of exposure to curtailment is always presented in percentages of the demand assuming no demand reaction to the different stressful events. It can also be interpreted as the required demand reduction to prevent demand curtailment.

H_2 Infrastructure level 2 (policy-based) includes all projects and the additional infrastructure assumptions needed to enable policy objectives. Exclusively for the H_2 Infrastructure level 2, additional hydrogen production from natural gas was introduced that goes beyond the values defined in the scenarios to mitigate hydrogen demand curtailments by using surplus methane supply potentials of each country (whereas this would also have been required for the H_2 Infrastructure level 1 to avoid demand curtailments, but was not introduced to show contrasted results). This can be interpreted as a flexible hydrogen supply potential on top of the scenario values, mitigated in terms of sustainability if combined with CC(U)S. Hydrogen production from methane allows for the indirect usage of methane storages to satisfy the seasonal hydrogen demand, mitigating the crucial role of dedicated hydrogen storages.


Picture courtesy of TAP

3 **TYNDP 2024** ON ITS WAY

ENTSOG is committed to the carbon-neutral future of the energy system in Europe. The TYNDP 2022 has proven ENTSOG's ability to provide dual assessments of interlinked hydrogen and methane systems.

The TYNDP 2024 will build on scenarios that are established with the help of an interlinked model including electricity. Also, the CBA methodology will be upgraded for the TYNDP 2024. **ENTSOG aims for new CBA indicators for hydrogen infrastructure projects based on cross-sector assessments. ENTSOG is consulting its preliminary draft CBA methodology. This will allow for more complete assessments, including costs and benefits triggered by the projects for the overall energy system as well as the impact of projects on CO_2 emissions reduction.** Currently, ENTSOG and ENTSO-E are assisting the PCI selection process by conducting project-specific CBAs for electrolyser projects submitted as candidate under the revised TEN-E Regulation. Thereby, ENTSOG and ENTSO-E can showcase their cross-sectoral capabilities with an exercise similar to the proposed future CBAs. Therefore, ENTSOG is well on track in preparation for the upcoming TYNDP 2024.

Looking forward to 2024!

LIST OF **FIGURES**

LIST OF **ABBREVIATIONS**

ACER	Agency for the Cooperation of Energy Regulators
ATR	Autothermal Reforming
Bcm/Bcma	Billion cubic meters/Billion cubic meters per annum
BIO	Biomethane Development Projects
CBA	Cost-Benefit Analysis
CCS	Carbon Capture and Storage
EC	European Commission
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSOG	European Network of Transmission System Operators for Gas
EU	European Union
FID	Final Investment Decision
GIE	Gas Infrastructure Europe
GWh	Gigawatt hour
HYD	Hydrogen
LNG	Liquefied Natural Gas
LULUCF	Land Use, Land-Use Change and Forestry
Mt	Megatonne
MWh	Megawatt hour
NDP	National Development Plan
OTH	Other Infrastructure-Related Projects
PCI	Project of Common Interest
RET	Projects for Retrofitting Infrastructure to further integrate Hydrogen
RES	Renewable Energy Sources
SMR	Steam Methane Reforming
SoS	Security of Supply
TSO	Transmission System Operator
TWh	Terawatt hour
TYNDP	Ten-Year Network Development Plan
UGS	Underground Gas Storage (facility)

COUNTRY CODES (ISO)

AL	Albania
AT	Austria
AZ	Azerbaijan
BA	Bosnia and Herzegovina
BE	Belgium
BG	Bulgaria
BY	Belarus
CH	Switzerland
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
DZ	Algeria
EE	Estonia
ES	Spain
FI	Finland
FR	France
GR	Greece
HR	Croatia
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
LY	Libya
MA	Morocco
ME	Montenegro
MK	North Macedonia
MT	Malta
NL	Netherlands, the
NO	Norway
PL	Poland
PT	Portugal
RO	Romania
RS	Serbia
RU	Russia
SE	Sweden
SI	Slovenia
SK	Slovakia
TM	Turkmenistan
TN	Tunisia
TR	Turkey
UA	Ukraine
UK	United Kingdom

LEGAL **DISCLAIMER**

The TYNDP was prepared by ENTSOG on the basis of information collected and compiled by ENTSOG from its members and from stakeholders, and on the basis of the methodology developed with the support of the stakeholders via public consultation. The TYNDP contains ENTSOG own assumptions and analysis based upon this information.

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Publisher ENTSOG AISBL
Avenue de Cortenbergh 100
1000 Brussels, Belgium

Co-Authors Mads Boesen, Hubert Bolesta, Maria Castro, Arturo de Onis Romero-Requejo, Mareike Dollinger, Diana Fathelbajanova, Joan Frezouls, Alexander Kättlitz, Pierre Marani, Dante Powell, Thilo von der Grün, Arnaud Weissrock, Kacper Żeromski, Nemo KG, INV WG, SCN WG, WGSB, Stefano Astorri, Jacques Rebérol, Louis Watine

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ENTSOG AISBL
Avenue de Cortenbergh 100 | 1000 Brussels, Belgium
Tel. +32 2 894 51 00

info@entsog.eu | www.entsog.eu