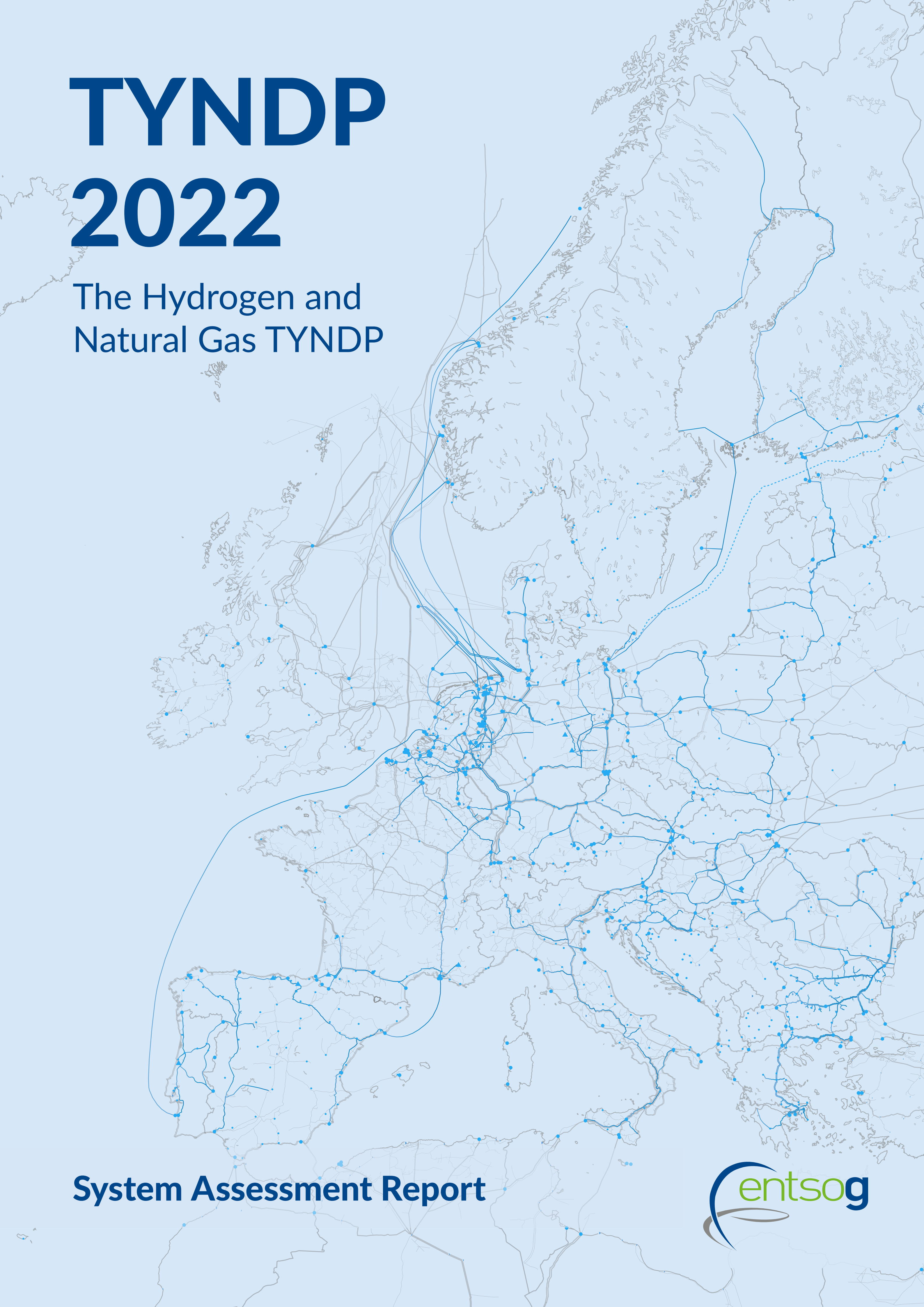
TYNDP 2022

The Hydrogen and Natural Gas TYNDP



System Assessment Report

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1 INTRODUCTION: TYNDP 2022

ENTSOG's TYNDP 2022, like previous editions, provides an overview of the European gas infrastructure and its future developments. It maps the integrated gas network according to a range of development scenarios. The TYNDP also includes a European supply adequacy outlook and an assessment of the network resilience. Processes for the TYNDP development already began in early 2022, when Russia commenced its war in Ukraine. The resulting impact on the energy markets was significant, and these considerations were included in the TYNDP 2022 assessments.

Robust actions are necessary to further support sustainability, security of supply (including independence from Russia and improving diversification), and to consider the acceleration of hydrogen deployment communicated in REPowerEU[1].

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 advance the energy transition, while increasing the resilience of the EU-wide energy system. The plan includes measures for increased production of biomethane, 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 work on this TYNDP started more than two years ago. Since then, there occurred rapid changes in the European gas market, including increased hydrogen ambitions of many countries and commercial players. This resulted in announcements of new projects that in individual cases were backed by agreements between Member States. It should therefore be noted that this infrastructure report cannot reflect all latest developments even at its publication date. Multiple major and known developments of 2022 could be considered and have been included. Thus, the results of this TYNDP's System Assessment should be complemented by the latest energy strategies of the Member States, for further and complete analyses.

1 https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en

ROLE OF SCENARIOS IN THE TYNDP

Building different and contrasted scenarios is the first important step to capture the interactions between the gas and electricity systems, therefore delivering the best foundation for the assessment of the infrastructure from an integrated system perspective.

NATIONAL TRENDS (NT), THE POLICY SCENARIO

The National Trends scenario is in line with national energy and climate policies (NECPs, national long-term strategies, hydrogen strategies, etc.) derived from the European targets. The gas (i. e., methane and hydrogen) demand and supply for this scenario is based on figures collected from the TSOs translating the latest policy- and market-driven developments as discussed at national level.

COP 21 SCENARIOS: CONTRASTED PATHWAYS TO ACHIEVE THE EU CLIMATE LAW AMBITION

The Distributed Energy scenario considers the decarbonisation of the European energy system from a distributed and local perspective. The gas (i.e., methane and hydrogen) demand reflects an evolution driven by a willingness of the society to achieve energy autonomy based on widely available indigenous renewable energy sources. This leads to a maximisation of renewable energy production in Europe and a strong decrease of energy imports.

Therefore, methane imports are decreasing, and methane flows are less following the traditional import supply corridors. On the contrary, new intra-European routes from areas with a high potential of renewable hydrogen production emerge based on the maximisation of hydrogen production within Europe.

The Global Ambition scenario considers the development of a wide range of renewable and low-carbon technologies (many being centralised) and the use of global energy trade as a tool to accelerate decarbonisation. Economies of scale lead to significant cost reductions in emerging technologies such as offshore wind, but also imports of renewable and decarbonised gases (i. e., methane and hydrogen) from competitive sources are considered as a viable option.

This is resulting in a relatively higher import share and using combined infrastructure of import routes and new intra-European routes to transport renewable and decarbonised gases (i. e., methane and hydrogen) that are produced locally.

2 FEEDBACK SECTION

2.1 FROM DRAFT TO FINAL TYNDP 2022

2.1.1 WHAT HAS HAPPENED SINCE THE DRAFT TYNDP PUBLICATION?

ENTSOG released the draft publication of TYNDP 2022 on 11 April 2023 and launched in parallel a public consultation until 19 May 2023, to allow for stakeholder engagement and continual improvement of the report.

On 25 April, within the public consultation period, ENTSOG hosted a TYNDP Presentation Day webinar open to all stakeholders. This webinar enabled a high-level introduction to the TYNDP 2022 and its role as part of EU regulation, providing a summary of the content and more insights into the results of the assessment. A wide range of stakeholders had the opportunity to ask questions and participate in discussions on the TYNDP process. A recording of the TYNDP presentation webinar is available on ENTSOG website[2].

On 26 May 2023, the draft TYNDP 2022 was submitted to ACER, together with the results of the public consultation, for its Opinion. The Opinion was issued on 14 July 2023 and includes ACER's noted improvements from the previous edition of TYNDP and recommendations for further improvement, categorised as short and the medium to long-term.

2.1.2 WHY A FEEDBACK SECTION?

This section aims at presenting the feedback received from both ACER and other stakeholders and describes how the relevant feedback could be addressed in the final TYNDP 2022. The way in which such feedback is addressed is covered in the feedback section itself, rather than in the related sections of the TYNDP, to better facilitate the overview. For other feedback not addressed in TYNDP 2022 but that could be taken into consideration for future editions of the TYNDP – this section indicates into which process it will feed.

The feedback assessment is presented to first respond to the ACER Opinion, covering both the short-term recommendations relating to the TYNDP 2022 and the medium to long-term recommendations for future editions of the TYNDP. This is followed by an analysis of the public stakeholder consultation feedback.

2.1.3 COMPARISON OF PAST ASSUMPTIONS AND PROJECTIONS OF GAS DEMAND AND SUPPLY WITH ACTUALLY OBSERVED (HISTORICAL) LEVELS

From one TYNDP edition to the next, ENTSOG critically reviews the TYNDP input data, in particular the demand scenarios and supply potentials. For each new TYNDP edition ENTSOG develops elements that are discussed as part of the stakeholder engagement process, and this comparison is a way to better formalise its usual formal analysis of assumptions.

2 https://www.entsog.eu/media/37070

2.1.3.1 Supply

Figure 2.1 compares the TYNDP 2022 supply potentials for 2025 with the actual historical EU imports. For Norway, Algeria, LNG, Azerbaijan and Libya, actual 2022 imports are similar to the range of the potentials expected for 2025 in TYNDP 2022.[3] Russian range has been disregarded because this supply source was minimised under all circumstances. In addition to Russian supply minimalisation, the minimum supply range of all other sources are no longer considered, focusing on the maximum supply potential.

As part of the TYNDP 2022 process, the supply potentials were amended to better correlate with the historical EU import.

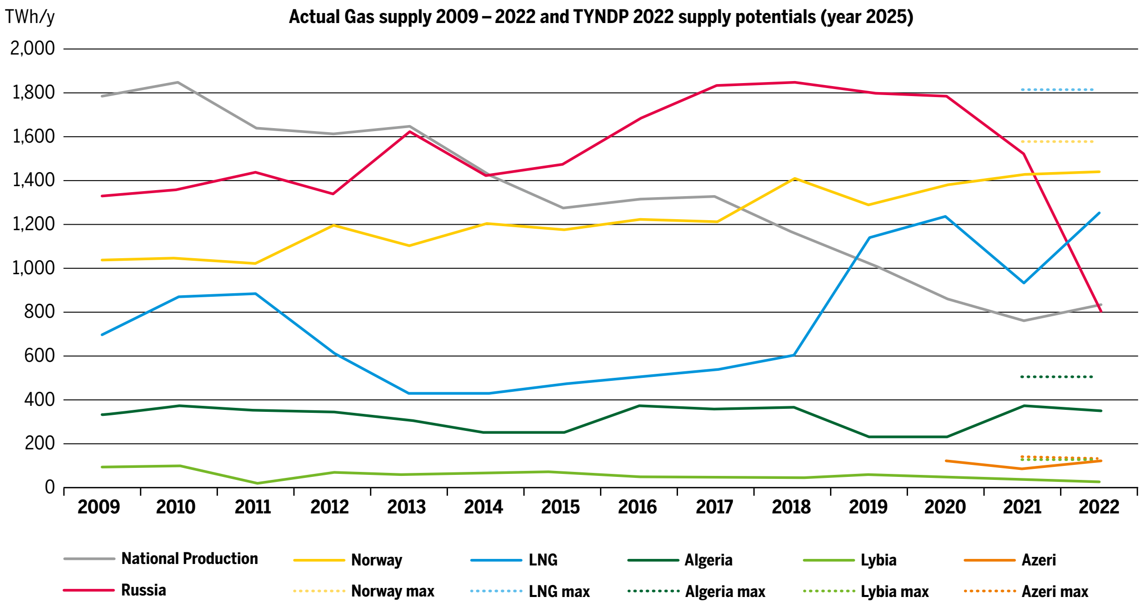


Figure 2.1 Actual Gas supply 2009–2022 and TYNDP 2022 supply potentials (year 2025)

2.1.3.2 Demand

TYNDP 2022 has three scenarios: National Trends, which is developed based on the collection of data from TSOs, and two COP 21 scenarios – Global Ambition and Distributed Energy – which are developed by the scenario building process.

As for previous TYNDP editions, total gas demand was made up of Final Gas Demand (defined as Residential & Commercial, Industrial and Transport sectors) and Gas Demand for Power Generation. Gas demand for Power Generation for all scenarios, jointly developed by ENTSOG and ENTSO-E, is derived from modelling results. During the data collection phase, gas and electricity TSOs worked together to assess gas installed capacity on a country level basis. Yearly Gas Demand for Power Generation averages is calculated from the average of all approved models across all climate years.[4]

The Best Estimate scenarios for 2022 and 2025 were based on the TSO perspective, reflecting all national and European regulations in place, whilst not conflicting with any of the other scenarios.

National Trends is the central policy scenario, designed to reflect the most recent EU Member States' National Energy and Climate Plans (NECP), submitted to the EC in line with the requirement to meet current European 2030 energy strategy targets.

In addition, ENTSO-E and ENTSOG have created two scenarios in line with the COP 21 targets (Distributed Energy and Global Ambition) with the objective to understand the impact on infrastructure needs against different pathways reducing EU-28 emissions to net-zero by 2050.

3 ENTSOG Data

4 TYNDP 2022 Scenario Report: Building Guidelines (entsos-tyndp-scenarios.eu), Chapter 4.1.

Global Ambition is a scenario compliant with the 1.5 °C target of the Paris Agreement and considering the EU's climate targets for 2030. It looks at a future that is led by development in centralised generation. Economies of scale lead to significant cost reductions in emerging technologies such as offshore wind, but also imports of energy from competitive sources are considered as a viable option.

Distributed Energy embraces a de-centralised approach to the energy transition. A key feature of the scenario is the role of the energy consumer (prosumer), who actively participates in the energy market and helps to drive the system's decarbonisation by investing in small-scale solutions and circular approaches.

Figure 2 shows the progression of EU level actual demand, versus the result of the TYNDP 2022 under National Trends, Global Ambition and Distributed Energy scenarios.

It is important to note that the demand levels shown reflect the actual weather conditions, whereas data collected for the scenarios represents yearly demand under average climatic conditions.

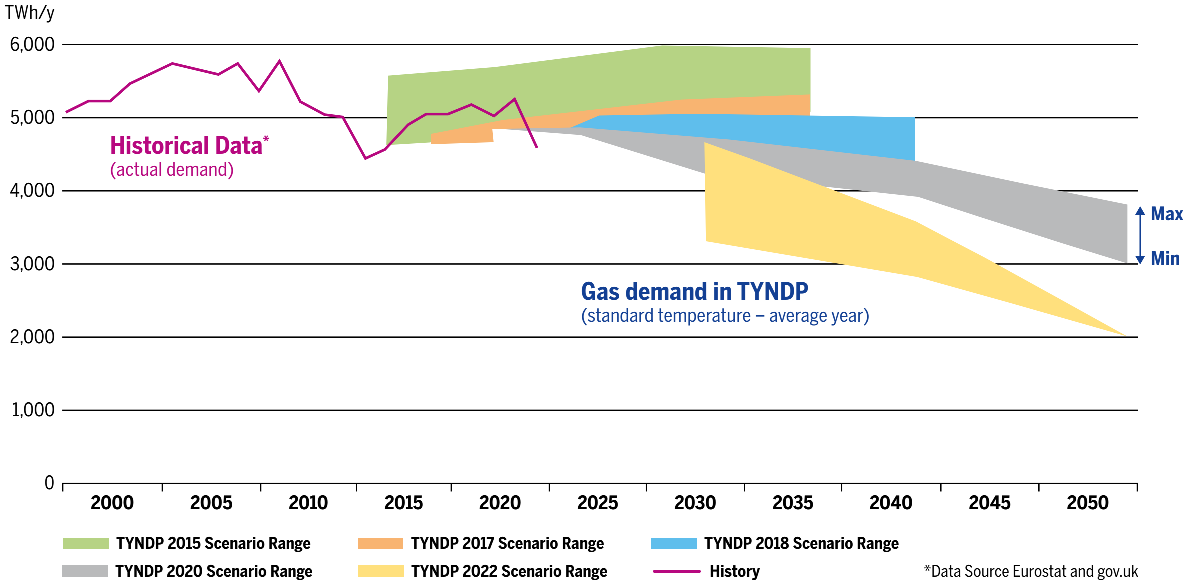


Figure 2.2 Actual EU Gas Demand 2000–2022, TYNDP Demand Scenario data (Data Source Eurostat and gov.uk)

Figure 2.2 shows a drop of around 11 % for gas demand between 2013 and 2014, driven by many factors: low coal and CO_2 prices with these fuels then replacing gas in the power generation mix; a continuation of slow economic growth; and a significantly warmer than average year, leading to significant reduction for heating.

The graph also shows that EU gas demand in 2015 saw a 4 % recovery from the previous year to 4,595 TWh, which can again be linked to a number of factors, with sectoral differences at a country level.

During 2016, EU gas demand increased again by 6.7 % to 4,903 TWh. The reduction in gas prices starting at the end of 2015 continued into first half of 2016, and although gas prices increased in the final quarter of the year, coal prices increased 68 % compared to same period in 2015. This meant gas competitiveness increased in the power generation market. Power generation analysis has shown a significant coal to gas switch in a number of countries during 2016, linked to the above-mentioned price situation, but also influenced by the ongoing Carbon Price Floor[5] policy in the UK.

In 2017, further increase in gas demand was observed, reaching 5,077 TWh (+3,5 %). The apparent coal to gas switch continues moderately. Gas prices were higher when compared to previous the year - strong demand of gas for power and storage injections have supported gas price in EU hubs during the summer and increase in gas demand in the winter.

In 2018, stabilisation in the context of gas demand was observed –5,080 TWh was reached, meaning that value was comparable to 2017. At the beginning of the year, Europe experienced an extreme cold spell. Gas hub tested to limit on the cold

5 https://www.gov.uk/government/publications/excise-notice-ccl16-a-guide-to-carbon-price-floor/excise-notice-ccl16-a-guide-to-carbon-price-floor

snap and prices reached multi-year highs. These circumstances led to declaration of early warnings in a few European countries and significant gas withdraw from storages was observed. During that summer, gas consumption was lower and allowed for gas storages filling. During the last quarter of 2018, there was a decrease of gas demand when compared with that of 2017.

The graph shows that in 2019, there was a preference for gas over coal in the power generation with an increase (when compared to 2018) of 5,171 TWh. The warm weather in the first quarter of the year enabled a transition to summer with considerably high gas volumes in storages. Plentiful supply, falling gas prices and flexibility during the first quarter of the year allowed for very high stock level to be reached at the beginning of the winter and moderate usage of gas inventories in the last quarter. In 2019, LNG strengthened its role in supplying Europe.

In TYNDP 2018, all scenarios have been realistically built, technically sound and based on forward looking policies, whilst also being ambitious in nature and aiming at reducing emissions. For the first time in 2018, the ENTSOs for gas and electricity have worked together, using their unique expertise to provide a broad, common and technically feasible joint set of scenarios. This is key to test the need and performance of possible future infrastructure in challenging but credible situations. Future scenario development processes will seek to enhance and improve gas and electricity interactions, looking for synergies, leading to better sharing of data and cooperation.

Following stakeholders' request for some continuity in the scenario storylines, TYNDP 2022 scenarios are built based on the TYNDP 2020 scenarios. However, the energy landscape is continuously evolving, and scenarios must keep up with the main drivers and trends influencing the energy system. All scenarios head towards a decarbonised future and have been designed to reduce GHG emissions in line with EU targets for 2030 and/or the United Nations Climate Change Conference 2015 (COP 21) Paris Agreement objective of keeping temperature rise below 1.5 °C.

2.2 ACER OPINION AND RECOMMENDATIONS

The full ACER Opinion on the draft TYNDP 2022 can be found on the ACER website[6]. The following section will provide responses in the same order as the Conclusions of the Opinion.

2.2.1 RECOGNITION OF IMPROVEMENTS

The ACER Opinion included the following recognition of improvements achieved in the process, methodology and outcome of the draft TYNDP 2022 when compared to TYNDP 2020:

a) A better presentation of the TYNDP features via dedicated visualisation tools;

b) The implementation of a common ENTSO-E and ENTSOG process for the development of scenarios for the TYNDP 2022 and the preparation of a stand- alone "scenario report";

c) The provision of a window of opportunity for NRAs to check input data for the submitted TYNDP candidate projects at an early stage, during December 2021;

d) The increased focus of the TYNDP on Energy Transition aspects and better alignment with the Green Deal decarbonisation goals. This is manifested by a dual gas system modelling approach that considers hydrogen and methane networks simultaneously and through collection of different types of hydrogen projects and network projects aimed at the injection of biomethane;

e) The consideration of the REPowerEU objectives reflected in the scenarios, even though not representing mandatory targets, and the projects eventually included in the TYNDP;

f) An open and transparent process for the collection of projects and detailed information and analysis of the projects' implementation schedule by type of project;

6 ACER_Opinion_06-2023_ENTSOG_draft_TYNDP_2022.pdf (europa.eu)

g) Information related to projects included in the last edition of the TYNDP and triggered by the incremental capacity process;

h) The collection and publication of methane emission mitigation measures for methane infrastructure projects.

2.2.2 SHORT-TERM RECOMMENDATIONS

The ACER Opinion provides for a number of short-term recommendations (Section 4, page 24) listed in the table below, in the order they appear in the ACER Opinion. The TYNDP topic to which these recommendations refer are also indicated in the table below.

ACER short-term recommendations	Related TYNDP topic	Paragraph in which the recommendation is handled
The comments and remarks of NRAs on the TYNDP 2022 projects, as contained in Annex I to this Opinion.	Additional section in the final TYNDP	2.2.2.3
Review and re-publish Annex D (methodology) with the aim of enhancing its comprehensiveness. This annex should provide detailed explanations of the assumptions and calculation steps underlying the methodology, particularly with regard to sustainability, and include practical examples illustrating how to interpret the indicators.	Methodology	Annex D
Complement Annex D by publishing all underlying data sets, qualitative assumptions, and formal hypotheses, as granular and disaggregated as possible, in an appropriate and predefined format, in line with Article 11(6) of the recast TEN-E Regulation.	Methodology	Annex D
The publication of a summary document indicating how feedback from the public consultation and from ACER's Opinion are taken into account for the final TYNDP 2022 and will be considered in future TYNDPs.	Additional section in the final TYNDP	Feedback chapter
Publish the project-specific CBA assessments results, including the Economic Performance Indicators, in line with Article 11(6) and Annex V of the recast TEN-E Regulation.	Project assessment	Project Fiches
Publish the "enhanced capacities" as well as the related conditions for these capacities to be made available by the respective TSOs.	System Assessment	2.2.2.1
Update information on how the incremental capacity process initiated in 2021 has evolved since June 2022.	Infrastructure Report	2.2.2.2

Table 2.1 Short-term ACER recommendations.

Addressing the ACER recommendations is indicated per related TYNDP topic.

2.2.2.1 Methodology and Assessment

Annex D

Annex D was updated by adding further information regarding the storages' behaviour, the cooperation between the hydrogen and the natural gas networks, the supplies merit order structure, the enhanced capacities application and the CO_2 emissions calculation. Simulation results were also published in form of tables in the revised Annex D.2.

Publication Project Fiches

Enhanced Capacities used under condition of "no Russian supply"

Enhanced Capacities are generally considered to be sensitive data and, in some cases, even as confidential information.

2.2.2.2 Infrastructure Report

Update Incremental capacity process initiated in 2021

During the Demand Assessment phase (in 2021), six TSOs/market areas received non-binding capacity requests from network users, but only in two cases incremental capacity has been offered in the binding auctions in July 2023, namely at the Polish-Ukrainian and the Belgian-German borders. At this time ENTSOG cannot provide more detailed information on the capacity process initiated in 2021 and cannot provide an update. The "monitoring" process is expected to start shortly after the final publication of TYNDP 2022.

2.2.2.3 NRA Comments on the TYNDP 2022 projects

During the TYNDP 2022 Project Collection process, ACER and NRAs were provided with the project data collected for their review and feedback. Promoters were informed on the informal preliminary comments provided by ACER and NRAs and could amend the information provided during the project data collection if deemed necessary. Therefore, the Draft TYNDP 2022 Annex A already includes the NRAs' feedback whenever considered by promoters.

Other information, such as the maturity of a project, is provided by ENTSOG based on the information submitted by the project promoters and after having applied specific rules as defined in the TYNDP 2022 Practical Implementation Document and in TYNDP 2022 Annex D (Methodology).

As part of its Opinion, ACER offered NRAs an opportunity to provide comments on the projects submitted to TYNDP 2022. These comments are available as an annex to ACER Opinion[7] and provide supplemental information on projects, in addition to the promoter information collected as part of TYNDP Annex A.

The comments from the NRAs in particular reflect recent project information and, in many cases, own NRAs views on projects benefits. In some cases, NRAs identified incorrect data.

Some project data have been updated after TYNDP 2022 project collection, and on some occasions reflected in national NDPs. Such updates are not included in the Final TYNDP 2022, to ensure consistency between the project information used to perform the TYNDP assessment, and the project information published. In this context, NRAs input on recent project information represents a valuable additional information for stakeholders even if not included in the Final version of TYNDP 2022.

In cases where NRAs refer to the actual merit of the project, it must be noted that TYNDP is based on transparent and consulted rules for project inclusion and assessment, ensuring a non-discriminatory process and prevention of conflict of interest.

7 ACER_Opinion_06-2023_ENTSOG_draft_TYNDP_2022.pdf (europa.eu)

Picture courtesy of ASTORA

2.2.3 MEDIUM-TERM AND LONG-TERM RECOMMENDATIONS

The following table illustrates the medium and long-term ACER Opinion recommendation and the TYNDP (or ENTSOG) processes where are, or can be, addressed.

ACER long-term recommendations (TYNDP20)	Related TYNDP/ENTSOG process
Implementing ACER's recommendations regarding scenarios, as provided in its framework guidelines for the joint TYNDP to be developed by ENTSOs	TYNDP Scenario Report
Improving the planning of future TYNDP processes	TYNDP process
Plan new TYNDP activities and consultations by the revised TEN-E Regulation	TYNDP Scenario Report/TYNDP System Assessment
Increasing stakeholders' engagement in the process	TYNDP process
Single data project collection	TYNDP process/TYNDP Project Collection
Improve alignment of project categories with infrastructure categories as defined in recast TEN-E Regulation	TYNDP/Practical Implementation Document
Include only "conventional" gas infrastructure projects in the TYNDP needed to address the assessed gaps	TYNDP/Practical Implementation Document
Require information from hydrogen infra-structure promoters on the status of market testing and consultations	TYNDP Project Collection
Update draft CBA Methodology following future Opinion of ACER, Member States', and stakeholders	CBA methodology
CBA project assessment for all projects	TYNDP/Project assessment
Encourage promoters to provide more information on costs	TYNDP/Practical Implementation Document
For methane projects consider the level of utilisation, and contractual and physical congestion for assessing the need for additional infrastructure	TYNDP/System assessment
Redesign the approach for the identification of infrastructure gaps	TYNDP/System assessment
Adapt the sustainability indicator	TYNDP/System assessment
Adapt the assumption under all SoS indicators by prioritising avoided methane demand curtailment over hydrogen demand curtailment.	TYNDP/System assessment
Incorporate an indicator for market integration	TYNDP/System assessment
Properly reflect differences in gas and hydrogen supply prices and if possible, align them with price assumptions	TYNDP/System assessment
Further development of contribution of methane and hydrogen storages	TYNDP/System assessment
Assessment of necessary adaptations of gas infrastructure to inject RES and decarbonised gases, and related costs	TYNDP/Project assessment
Develop ways for analysing and addressing methane and hydrogen emissions	TYNDP/Project assessment
Implement interlinked model jointly with ENTSO-E to analyse electrolysers and their impact on the grid	TYNDP/Project assessment
Publish all relevant input and output of TYNDP simulations and make them easily accessible and downloadable	TYNDP Publication

Table 2.2 Medium and long-term ACER recommendations.

2.2.3.1 Scenarios, planning and consultation of next TYNDP

TYNDP Scenarios

ENTSOG, together with ENTSO-E, have implemented a number of recommendations of the ACER Opinion 6/2020 in the TYNDP 2022 scenario building process and will consider further recommendations in the Scenario report itself.

Improving the planning of the future TYNDP processes and stakeholders' engagement

ACER recommends to better plan the future TYNDP processes to avoid recurrent delays in the development and the release of TYNDPs. Furthermore, ACER recommends a careful planning of new TYNDP activities and consultations introduced by the revised TEN-E Regulation. In general, ACER encourages ENTSOG to increase the involvement of stakeholders and of gas and hydrogen network operators in the TYNDP development process.

ENTSOG is constantly working on improving the TYNDP process, which includes lessons-learned and feedback received from ACER and other stakeholders. For upcoming stakeholder engagement processes within the TYNDP, ENTSOG makes every effort to effectively promote events and consultation phases open to all stakeholders. At the same time, it is important to underline that the implementation in each new TYNDP and of new updates due to feedback from stakeholders (including ACER's) there is an inevitable impact on the timeline and creates uncertainty for final publication. Several interactions with stakeholders and delays in responses have an impact on the timeline, but the priority for ENTSOG is to ensure that all stakeholders have an opportunity to contribute and provide their feedback.

For TYNDP 2024, as per ACER recommendation, ENTSOG intends to plan for the process in line with Articles 9(2) and 10 of Regulation 715/2009, and to publish the draft TYNDP mid-2024.

2.2.3.2 Collection of TYNDP projects

Project Data collection

ACER recommends implementing a common cut-off date for all types of projects within a single data collection process, which should be as close to the publication date of the TYNDP as possible.

In the current timeline for TYNDP 2024, ENTSOG foresees one single data collection for projects. However, it must be noted that after the closure of the Project Data Collection, ENTSOG is undertaking a comprehensive data quality check on received project data to ensure consistency and meaningful simulation later in the process. Data collection for projects is a long and important process for ENTSOG as it is a fundamental prerequisite to the modelling and simulations. The input data are the basis for the network assessment.

Project categories and mandatory data

ACER recommends improving the alignment of new project categories collected for TYNDP with the infrastructure categories as defined in the revised TEN-E regulation, and to include only "conventional" gas infrastructure projects in the TYNDP needed to address the assessed gaps.

ACER suggests that this could be achieved by filtering out "unrealistic" projects. Following the recommendation of ACER, projects with unrealistic timelines or those not addressing any apparent need should not be included in the TYNDP. ACER's last recommendation on this topic is to require mandatory information from hydrogen infrastructure promoters on the status of market testing and consultations and to consider such information for the identification of needs of hydrogen infrastructure projects.

ENTSOG is revising its Guidelines for Project Inclusion (GPI) after each TYNDP. Besides updates required by the revised TEN-E regulation, important input for the revision of this document is feedback received from ACER's Opinion and the stakeholder consultation on TYNDP 2022. In addition, ENTSOG is planning dedicated events for stakeholders to comment on the Draft GPI for TYNDP 2024.

The most current GPI will aim at better alignment with the revised TEN-E Regulation, which was published during the TYNDP 2022 process, and to synchronised collected project categories for a better harmonisation for the second PCI process under the revised TEN-E. For future TYNDP editions, the introduction of additional criteria in the project guidelines can help filter submitted projects. With decreasing methane demand, this also plays an important role. After the finalisation of the GPI, ENTSOG will adapt its project portal, to also include the configuration of new (mandatory) questions.

2.2.3.3 CBA Methodology and infrastructure needs assessments

ENTSOG is constantly working to improve indicators for each TYNDP application of its CBA Methodology.

Update draft CBA methodology

ENTSOG published a new draft single-sector Cost-Benefit Analysis (CBA) methodology for the assessment of hydrogen infrastructure, that was created on the basis of Article 11 of the Regulation (EU) 2022/869 on guidelines for trans-European energy infrastructure (TEN-E Regulation). This draft methodology was prepared with consideration of the feedback received during the extensive consultation of the preliminary methodology.

In addition, ENTSOG has submitted its draft CBA methodology to the Member States (MSs), the European Commission (EC), and ACER for opinion as required by regulation. Within three months after receipt of the opinion of ACER and MSs, ENTSOG will amend its methodology to take account of ACER and MS opinions, and finally submit it to the EC for approval.

Requiring CBA projects assessments for all the TYNDP projects instead of PCI applicants only

In line with Regulation (EU) 869/2022 ENTSOG undertakes project-specific cost-benefit analyses (PS-CBA) for all PCI/PMI candidate projects. While Regulation (EU) 860/2022 states that only projects "having reached a sufficient degree of maturity" must receive a PS-CBA, ENTSOG, assessing any project indicating its intention to apply for the following PCI selection process independently of their "maturity" level, already assesses a broader scope of projects and ensures a fair assessment of any of the PCI/PMI candidates.

Providing project cost information irrespective of their intention to apply for PCI status

ENTSOG supports and encourages maximum levels of transparency from promoters. At the same time, ENTSOG must respect the request for confidentiality for projects not applying for PCI/PMI selection process. Additionally, comparability is not an issue since those projects do not receive a project-specific cost-benefit analysis.

Consideration of level of utilisation and contractual and physical congestion of interconnection points for methane projects

In previous TYNDPs ENTSOG considered long-term capacity booking contracts (LTCB) as part of the market layer. This TYNDP 2022 System Assessment does not include LTCB. This does not have any impact of physical bottlenecks. For long-term supply contracts, those are already included at European level in the "minimum" defined for each supply source potential. The different supply sources' minimum values are based on publicly available literature, exchanges between ENTSOG and the main suppliers as well as on the stakeholder's feedback received during dedicated workshops. For TYNDP 2022 ENTSOG included an additional assumption for Russian supply minimisations which lead to a higher "minimum" for all other supply source potentials.

For physical congestions, which are often seen as flows, a careful interpretation of utilisation must be conducted as general statements are not constructive or feasible. For instance, a project could show a low level of utilisation, but consideration for an upstream bottleneck may be omitted. Alternatively, a project could show a high level of utilisation, but consideration of an alternative route that could replace it and would therefore guarantee security of supply could be omitted.

Consideration of physical congestion is already embedded in the way the many TYNDP 2022 indicators are calculated: a physical bottleneck will identify an infrastructure need. Flows resulting from ENTSOG simulations are just one of the possible solutions that the simulation tool might provide. The level of utilisation of existing infrastructure and submitted projects might differ from one simulation to another, depending on the underlying assumptions. To assess situations where existing infrastructure is prioritised, ENTSOG runs sensitivities on the value of the tariffs assumed for the projects. In the same way, the sustainability indicator computed for TYNDP 2022 considers, in the allocation of benefits to projects, that existing infrastructure are always prioritised.

Annex D provides more information on the approach taken.

Redesign the approach for the identification of infrastructure gaps

ENTSOG considers different hydrogen infrastructure levels in its draft CBA methodology for the assessment of hydrogen infrastructure. More specifically, for TYNDP 2024, ENTSOG proposes in this document three hydrogen infrastructure levels to be used in the TYNDP System Assessment:

- **Advanced hydrogen infrastructure level** that will be based on the existing network together with those projects whose status of implementation is more advanced and, therefore, with a higher likelihood of being successfully implemented.
- **PCI hydrogen infrastructure level** will consist of the advanced hydrogen infrastructure level and will additionally contain the latest list of hydrogen infrastructure projects of common interest (starting from the sixth PCI list, i. e., the first PCI list under the revised TEN-E Regulation once adopted).
- **TYNDP hydrogen infrastructure level** will consist of the PCI hydrogen infrastructure level as well as all remaining projects submitted to the TYNDP.

In a similar way, ENTSOG defines two natural gas infrastructure levels in its draft CBA methodology:

- **FID natural gas infrastructure level** should at least consider all the existing infrastructures together with projects having an FID status.
- **Advanced natural gas infrastructure level** will consider FID infrastructure level together with the projects meeting the criteria defined for advanced projects.

Definition of the conditions to be fulfilled and considered as advanced hydrogen and natural gas projects will be defined in the TYNDP 2024 Practical Implementation Document.

In addition, as detailed in section 2.2.3.3 CBA Methodology and infrastructure needs assessments, ENTSOG is currently in the process of preparing its final CBA Methodology taking into consideration the EC's, ACER's and MSs' opinions. Hydrogen infrastructure levels included in the final CBA methodology might differ if required by these opinions.

2.2.3.4 Modelling assumptions for the system assessment

Adapt the sustainability indicator

This potential demand fuel switch will be measured by societal benefit due to the GHG emissions variation indicator (B1) and societal benefit due to the non-GHG emissions variation indicator (B4) defined in the new CBA methodology.

These indicators consider the change of GHG (and non-GHG) emissions as a result of changing the generation mix of the electricity sector or the supply source used to meet hydrogen demand (including GHG emissions savings from replacement of alternative fuels in non-power sectors).

Adapt the assumption under all SoS indicators

In this edition of the TYNDP the cooperation between methane and hydrogen is assumed, i.e., the available infrastructure is used to equalise to the extent possible the curtailment rates of the different countries or balancing zones (e.g., natural gas customers could (partially) share the burden by curtailment to allow for blue hydrogen production to mitigate hydrogen supply disruptions). In the next TYNDPs ENTSOG will reevaluate this assumption.

Incorporate an indicator for market integration

Market integration is proposed to be measured by the social economic welfare indicator (B2) and cross-border impact of hydrogen transmission projects (B6) as defined in ENTSOG's revised draft CBA methodology. This draft CBA methodology is currently awaiting feedback from ACER, the EC, and the MSs.

Properly reflect differences in gas and hydrogen supply prices

The model is driven by the carbon content of each fuel and not by the prices, as price relation between methane and hydrogen in the future is unknown, and ultimately there are binding targets regarding the CO_2 emission despite the price of the fuels. Market Price assumptions in scenarios are used to establish merit order, not to assume specific price per each fuel.

Further develop the role and contribution of methane and hydrogen storages

In the next TYNDPs ENTSOG will work to further refine the proper representation of the role and contribution of methane and hydrogen storages.

2.2.3.5 Network adaptations for decarbonised gases and emissions and Interlinked Model

Adaptations of the gas infrastructure to enable the injection of higher shares of renewable and decarbonised gases and the costs, implications and challenges associated

The adoption of the project categories for TYNDP 2022, including a dedicated project category for hydrogen and biomethane was welcomed by stakeholders, confirming the relevance of renewable and decarbonised gases in the future. In the next TYNDPs new criteria will be introduced and additional question included to further reflect on the importance and to allow more insights in particular on cost.

Consider ways for analysing and addressing the issue of methane and hydrogen emissions

For TYNDP 2022, ENTSOG included dedicated questions addressing provisions and actions undertook by project promoters to reduce methane emissions. Based on the lack of experience and relevant publications on measuring and analysing hydrogen emissions, ENTSOG currently cannot further take them into account but will follow further developments and include hydrogen emissions in the analysis when possible.

Implementing improvements leading to the development of a consistent and interlinked electricity and gas networks and market model

ENTSOG, with ENTSO-E, have further improved their joint work on the Interlinked Model. The Interlinked Model was used for the first time for the assessment of PCI candidate projects within the Electrolyser facility category in the 1st PCI call under the revised TEN-E. In parallel, pilot assessments of hydrogen infrastructure project are ongoing to further develop the Interlinked Model for joint system assessment both on the gas and electricity side.

ENTSOG and ENTSO-E must first fulfil the mandate given in the TEN-E revision before further work on the system needs can be considered and applied. Although much of this work has started via the scenario development process, adding this step to the TYNDP requires a full methodological overhaul in the ENTSOG and ENTSO-E system needs processes, given the methodologies used by ENTSOG and ENTSO-E differ vastly. An interlinked system needs process must be built open the Interlinked Model once its development is complete.

2.2.3.6 Display of results

Publish all relevant input and output of TYNDP simulations, easily accessible and downloadable

ENTSOG is constantly working on improving the presentation of TYNDP simulations and has therefore introduced the visualisation platform. The visualisation platform is aiming for a interactive and user friendly accessibility of TYNDP results.

In the past, ENTSOG believes that the full data overview of output data has been seen as exhaustive and overwhelming by stakeholders. On that basis, the visualisation platform was developed. Addressing the request from the Opinion of ACER, simulation results were published also in form of the tables in the new Annex D.2.

2.3 PUBLIC CONSULTATION AND STAKEHOLDER FEEDBACK

ENTSOG opened the public consultation on draft TYNDP 2022 for six weeks from 11 April to 19 May 2023. In total ENTSOG received 13 replies.

2.3.1 ANALYSIS OF THE PUBLIC CONSULTATION FEEDBACK

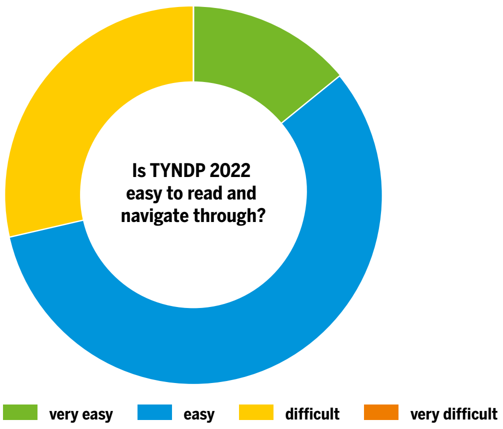


Figure 2.3 Is TYNDP 2022 easy to read and navigate through?

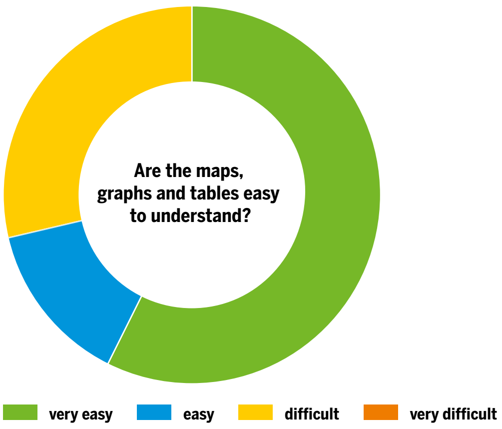


Figure 2.4 Are the maps, graphs and tables easy to understand?

For TYNDP 2020 ENTSOG introduced several improvements with the aim of a simple and clear presentation of TYNDP. This was welcomed by the stakeholder in the 2020 edition. ENTSOG continued with similar tools and approaches to keep an increased presentation for TYNDP 2022. These include, for example, dedicated website and tailor-made visualisation tools allow for interactive access to the main TYNDP features. However, based on received stakeholder feedback, a slight decrease of reader friendliness is reported for TYNDP 2022.

Most interesting topics

The overview of the topics identified as most interesting by stakeholders indicates that TYNDP is seen by a large share of stakeholders as a valuable source of European-wide information. In general, it can be seen that all parts are considered relevant and interesting. The most interesting topics are information on projects submitted for TYNDP 2022 and their assessment, the dual gas system assessment, as well as the impact of REPowerEU ambitions for the system assessment.

The collection and analysis undertaken by ENTSOG is a highly valuable source of information, as well as a necessary input to the simulations and the assessment of the infrastructure.

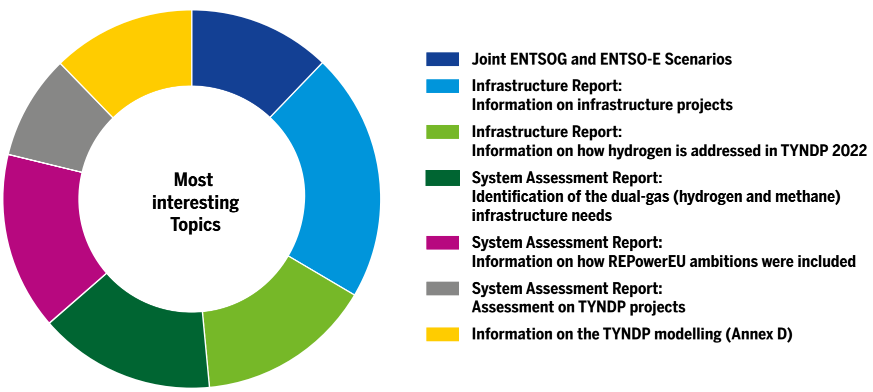


Figure 2.5 Most valuable elements in TYNDP 2022.

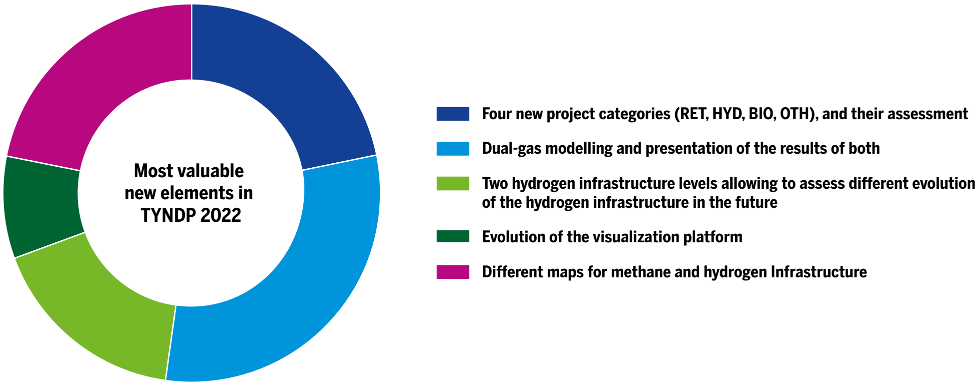


Figure 2.6 Most valuable new elements in TYNDP 2022.

New elements introduced for TYNDP 2022

ENTSOG introduced a number of new elements in TYNDP 2022 and stakeholders were consulted on these new elements. All new elements are considered as valuable by the stakeholders. For the first time, ENTSOG modelled a dual gas system for natural gas and hydrogen, and this was identified as most valuable, considered as presenting a possible pathway to decarbonise the networks.

With regards to the development of a hydrogen system, stakeholders found the introduction of new project categories very helpful including a particular category for hydrogen and different maps for methane and hydrogen infrastructure. Feedback suggests that it underlines the importance of the energy transition in the perspective of the EU's energy and climate objectives towards 2050 (Green Deal, REPowerEU, Hydrogen and Energy System Integration).

Furthermore, for the system assessment in the dual gas model, ENTSOG introduced two contrasted hydrogen infrastructure levels. A complete overview of the assumptions used for the two hydrogen infrastructure level can be found in Annex C.

TYNDP 2022 Annex C2[8] includes full details of hydrogen cross-border transmission capacities, import capacities (both liquid and pipeline) and injection and withdrawal capacities considered in the two infrastructure levels.

Hydrogen infrastructure level 1 was defined based on project submission data. Hydrogen infrastructure level 2 is a bottom-up infrastructure level that was based on the hydrogen infrastructure level 1 as minimum, and in addition, considers additional infrastructure assumptions – more specifically, higher hydrogen storage, import capacities, as well as higher cross-border capacities for some countries.

For more clarity, in the following tables from Annex C2, additional infrastructure assumptions considered in the hydrogen infrastructure level have been identified highlighted in blue.

8 https://www.entsog.eu/sites/default/files/2023-04/ENTSOG_TYNDP_2022_Annex_C2_H2_Capacities_per_country_230411.xlsx

TYNDP Annex C2 – intermediate		H_2 Transmission Yearly Capacity (GWh/d)			
From Country	To Country	Level	2030	2040	2050
Austria	Germany	Level 1	150	150	150
		Level 2	150	150	150
	Italy	Level 1	126	126	126
		Level 2	126	219	219
	Slovakia	Level 1	144	144	144
		Level 2	144	156	156
	Slovenia	Level 1	0	33	33
		Level 2	0	33	33
Belgium	France	Level 1	108	108	108
		Level 2	108	200	200
	Germany	Level 1	91	91	91
		Level 2	91	91	120
	Luxembourg	Level 1	0	0	0
		Level 2	0	14	20
	Netherlands	Level 1	48	72	120
		Level 2	120	192	240
	United-Kingdom	Level 1	0	0	0
		Level 2	0	200	200
Bosnia-Herzegovina	Croatia	Level 1	0	0	0
		Level 2	43.5	43.5	43.5
Bulgaria	Greece	Level 1	79.97	79.97	79.97
		Level 2	79.97	79.97	88
	Romania	Level 1	17.73	110.73	110.73
		Level 2	17.73	110.73	139.44
Croatia	Bosnia-Herzegovina	Level 1	0	0	0
		Level 2	43.5	43.5	43.5
	Hungary	Level 1	0	128.4	128.4
		Level 2	0	128.4	128.4
	Serbia	Level 1	0	0	0
		Level 2	63.8	63.8	63.8
	Slovenia	Level 1	0	16	16
		Level 2	0	16	16
Czechia	Germany	Level 1	144	144	144
		Level 2	144	144	319.2
	Poland	Level 1	0	0	0
		Level 2	0	30	30
	Slovakia	Level 1	0	0	0
		Level 2	0	156	156
Denmark	Germany	Level 1	151	290	290
		Level 2	151	290	290
Estonia	Finland	Level 1	100	100	100
		Level 2	100	200	200
	Latvia	Level 1	200	200	200
		Level 2	200	200	200

TYNDP Annex C2 – intermediate		H_2 Transmission Yearly Capacity (GWh/d)			
From Country	To Country	Level	2030	2040	2050
Finland	Estonia	Level 1	200	200	200
		Level 2	200	200	200
	Germany	Level 1	504	504	504
		Level 2	504	504	504
	Sweden	Level 1	666	666	666
		Level 2	910	910	910
France	Belgium	Level 1	108	108	108
		Level 2	108	200	200
	Germany	Level 1	204	204	204
		Level 2	204	243	243
	Spain	Level 1	216	216	216
		Level 2	216	216	216
	Switzerland	Level 1	0	0	0
		Level 2	1	100	100
Germany	Austria	Level 1	150	150	150
		Level 2	150	150	150
	Belgium	Level 1	91	91	91
		Level 2	91	91	120
	Czechia	Level 1	86	144	144
		Level 2	86	144	319.2
	Denmark	Level 1	151	290	290
		Level 2	151	290	290
	Finland	Level 1	504	504	504
		Level 2	504	504	504
	France	Level 1	192	192	192
		Level 2	192	243	243
	Netherlands	Level 1	12	12	12
		Level 2	244	380	559.2
	Poland	Level 1	100	100	100
		Level 2	100	120	227.14
	Switzerland	Level 1	0	0	0
		Level 2	0	168	240
Greece	Bulgaria	Level 1	75.51	75.51	75.51
		Level 2	75.51	75.51	88
Hungary	Croatia	Level 1	0	128.4	128.4
		Level 2	0	128.4	128.4
	Romania	Level 1	76.8	153.6	153.6
		Level 2	76.8	153.6	153.6
	Slovakia	Level 1	100	200	200
		Level 2	100	200	200
	Slovenia	Level 1	0	19.6	19.6
		Level 2	0	19.6	19.6
Ireland	United-Kingdom	Level 1	0	0	0
		Level 2	0	7.95	28.54

TYNDP Annex C2 – intermediate		H_2 Transmission Yearly Capacity (GWh/d)			
From Country	To Country	Level	2030	2040	2050
Italy	Austria	Level 1	168	168	168
		Level 2	168	168	168
	Slovenia	Level 1	0	19.6	19.6
		Level 2	0	19.6	19.6
	Switzerland	Level 1	88	88	88
		Level 2	88	88	88
Latvia	Estonia	Level 1	100	100	100
		Level 2	100	100	126.76
	Lithuania	Level 1	200	200	200
		Level 2	200	200	200
Lithuania	Latvia	Level 1	100	100	100
		Level 2	100	189.59	184.31
	Poland	Level 1	200	200	200
		Level 2	200	200	200
Luxembourg	Belgium	Level 1	0	0	0
		Level 2	0	14	20
Netherlands	Belgium	Level 1	48	72	120
		Level 2	120	192	240
	Germany	Level 1	375	375	375
		Level 2	375	380	559
Poland	Czechia	Level 1	0	0	0
		Level 2	0	30	30
	Germany	Level 1	200	200	200
		Level 2	200	200	227.14
	Lithuania	Level 1	100	100	100
		Level 2	100	171.51	171.51
Portugal	Spain	Level 1	81	81	81
		Level 2	81	81	81
Romania	Bulgaria	Level 1	17.73	110.73	110.73
		Level 2	17.73	110.73	139.44
	Hungary	Level 1	76.8	153.6	153.6
		Level 2	76.8	153.6	153.6
Serbia	Croatia	Level 1	0	0	0
		Level 2	63.8	63.8	63.8

TYNDP Annex C2 – intermediate		H_2 Transmission Yearly Capacity (GWh/d)			
From Country	To Country	Level	2030	2040	2050
Slovakia	Austria	Level 1	144	144	144
		Level 2	144	156	156
	Czechia	Level 1	144	144	144
		Level 2	144	156	156
	Hungary	Level 1	100	200	200
		Level 2	100	200	200
Slovenia	Austria	Level 1	0	16	16
		Level 2	0	16	16
	Croatia	Level 1	0	33	33
		Level 2	0	33	33
	Hungary	Level 1	0	19.6	19.6
		Level 2	0	19.6	19.6
	Italy	Level 1	0	19.6	19.6
		Level 2	0	19.6	19.6
Spain	France	Level 1	216	216	216
		Level 2	216	216	216
	Italy	Level 1	0	320	320
		Level 2	0	320	320
	Portugal	Level 1	81	81	81
		Level 2	81	81	81
Sweden	Finland	Level 1	666	666	666
		Level 2	910	910	910
United-Kingdom	Belgium	Level 1	0	0	0
		Level 2	0	200	200
	Ireland	Level 1	0	0	0
		Level 2	0	7.95	28.54
Switzerland	France	Level 1	0	0	0
		Level 2	0	100	100
	Germany	Level 1	0	0	0
		Level 2	0	168	240
	Italy	Level 1	135	135	135
		Level 2	135	135	135

Table 2.3 TYNDP 2022 Hydrogen cross-border capacities assumed in Hydrogen infrastructure level 1 and 2

TYNDP Annex C2 – intermediate		H_2 Transmission Yearly Capacity (GWh/d)			
From Country	To Country	Level	2030	2040	2050
Algeria	Italy	Level 1	448	448	448
		Level 2	448	448	448
	Spain	Level 1	0	0	0
		Level 2	0	245	245
Norway	Belgium	Level 1	0	0	0
		Level 2	0	200	200
	Germany	Level 1	414	414	414
		Level 2	414	414	414
Ukraine	Hungary	Level 1	0	150	150
		Level 2	0	150	150
	Romania	Level 1	0	171.8	171.8
		Level 2	0	171.8	171.8
	Slovakia	Level 1	240	240	240
		Level 2	240	312	312

Table 2.4 TYNDP 2022 Hydrogen pipeline import capacities assumed in Hydrogen infrastructure level 1 and 2

TYNDP Annex C2 – intermediate	LH_2 Transmission Yearly Capacity (GWh/d)			
LH_2 importing country	Level	2030	2040	2050
LH_2 Belgium > Transmission Belgium	Level 1	64.2	64.2	64.2
	Level 2	64.2	64.2	64.2
LH_2 France> Transmission France	Level 1	48	48	48
	Level 2	48	48	48
LH_2 Germany > Transmission Germany	Level 1	228	228	228
	Level 2	228	228	228
LH_2 Netherlands > Transmission Netherlands	Level 1	108	108	108
	Level 2	144	144	144
LH_2 United-Kingdom > Transmission UK	Level 1	0	0	0
	Level 2	92	92	92

Table 2.5 TYNDP 2022 Hydrogen liquid hydrogen import capacities assumed in Hydrogen infrastructure l evel 1 and 2

TYNDP Annex C2 – intermediate		H_2 Storage Capacity (GWh/d)			
Country		Level	2030	2040	2050
Austria	Injection	Level 1	0.00	0.00	0.00
		Level 2	6.61	33.32	60.23
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	6.61	33.32	60.23
Belgium	Injection	Level 1	0.00	0.00	0.00
		Level 2	13.68	83.52	83.52
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	16.82	146.16	226.00
Bulgaria	Injection	Level 1	0.00	0.00	0.00
		Level 2	2.19	12.10	12.10
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	1.93	13.81	20.74
Croatia	Injection	Level 1	0.00	0.00	0.00
		Level 2	0.00	12.23	12.23
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	0.00	12.23	12.23
Czechia	Injection	Level 1	0.00	0.00	0.00
		Level 2	8.65	40.87	71.55
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	12.00	71.55	88.35
Denmark	Injection	Level 1	3.16	3.16	3.16
		Level 2	28.80	28.80	28.80
	Withdraw	Level 1	9.50	9.50	9.50
		Level 2	28.80	28.80	28.80
Estonia	Injection	Level 1	0.00	0.00	0.00
		Level 2	3.39	4.48	4.63
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	3.35	7.87	7.87
Finland	Injection	Level 1	0.00	0.00	0.00
		Level 2	12.13	27.03	27.03
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	5.13	47.39	47.39

TYNDP Annex C2 – intermediate		H_2 Storage Capacity (GWh/d)			
Country		Level	2030	2040	2050
France	Injection	Level 1	8.00	8.00	8.00
		Level 2	40.00	40.00	179.62
	Withdraw	Level 1	8.00	8.00	8.00
		Level 2	40.00	40.00	120.67
Germany	Injection	Level 1	25.08	34.08	34.08
		Level 2	153.00	328.00	649.00
	Withdraw	Level 1	29.07	38.07	38.07
		Level 2	458.00	983.00	1,943.00
Greece	Injection	Level 1	35.00	35.00	35.00
		Level 2	35.00	35.00	35.00
	Withdraw	Level 1	35.00	35.00	35.00
		Level 2	35.00	35.00	42.48
Hungary	Injection	Level 1	0.00	0.00	0.00
		Level 2	10.39	30.26	52.97
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	15.32	41.52	83.75
Ireland	Injection	Level 1	0.00	0.00	0.00
		Level 2	2.77	7.50	12.77
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	3.04	8.27	14.27
Italy	Injection	Level 1	0.00	48.12	146.82
		Level 2	0.00	48.12	146.82
	Withdraw	Level 1	0.00	76.90	146.09
		Level 2	0.00	76.90	146.09
Lithuania	Injection	Level 1	0.00	0.00	0.00
		Level 2	0.00	8.07	8.07
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	0.00	13.68	13.68
Latvia	Injection	Level 1	0.00	9.00	9.00
		Level 2	2.58	9.00	9.00
	Withdraw	Level 1	0.00	15.00	15.00
		Level 2	15.00	15.00	15.00

TYNDP Annex C2 – intermediate		H_2 Storage Capacity (GWh/d)			
Country		Level	2030	2040	2050
Netherlands	Injection	Level 1	0.00	0.00	0.00
		Level 2	36.00	360.00	480.00
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	36.00	360.00	480.00
Poland	Injection	Level 1	0.00	0.00	0.00
		Level 2	0.00	2.00	2.00
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	1.00	13.00	17.00
Portugal	Injection	Level 1	0.00	0.00	0.00
		Level 2	2.40	2.55	13.10
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	2.55	2.83	19.19
Romania	Injection	Level 1	0.00	0.00	0.00
		Level 2	10.39	20.45	35.90
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	15.13	37.23	46.35
Slovakia	Injection	Level 1	8.10	8.10	8.10
		Level 2	8.11	25.06	25.06
	Withdraw	Level 1	15.10	15.10	15.10
		Level 2	15.10	27.75	27.75

TYNDP Annex C2 – intermediate		H_2 Storage Capacity (GWh/d)			
Country		Level	2030	2040	2050
Slovenia	Injection	Level 1	0.00	0.00	0.00
		Level 2	0.55	6.81	7.19
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	0.68	6.65	7.19
Spain	Injection	Level 1	71.00	71.00	71.00
		Level 2	71.00	71.00	78.39
	Withdraw	Level 1	142.00	142.00	142.00
		Level 2	142.00	142.00	142.00
Sweden	Injection	Level 1	0.00	0.00	0.00
		Level 2	17.17	19.23	23.93
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	24.71	28.35	29.48
United Kingdom	Injection	Level 1	0.00	0.00	0.00
		Level 2	19.87	92.45	127.71
	Withdraw	Level 1	0.00	0.00	0.00
		Level 2	26.75	130.50	155.93

Table 2.6 TYNDP 2022 Hydrogen storage capacities in Hydrogen infrastructure level 1 and 2

3 SUSTAINABILITY AND INDEPENDENCE

3.1 A SUSTAINABILITY-ORIENTED TYNDP

TYNDP 2022 SCENARIOS SUPPORT THE EUROPEAN CLIMATE AMBITIONS

The TYNDP 2022 assesses the European infrastructure gaps against sustainability-oriented scenarios, considering either national policies as defined by the Member States' National Energy and Climate Policies (NECPs, national long-term strategies, hydrogen strategies, etc.) or the objectives as defined in the Paris agreement (COP 21). All scenarios therefore comply with European and national ambitions as displayed in Figure 3.1.

Furthermore, building on the ever-improving interlinked model developed jointly by ENTSO-E and ENTSOG, the COP 21 scenarios – Distributed Energy and Global Ambition – utilise new sector-coupling methodologies and dedicated modelling tools to optimise overall system efficiencies and flexibility as well as to better capture the interactions and new dynamics at the interfaces between various end-use sectors, at various geographical scales and with other carriers (Power-to-Gas and Power-to-liquid).

TYNDP 2022 for the first time builds scenarios modelled hydrogen systems and electrolysis at pan-European scale.

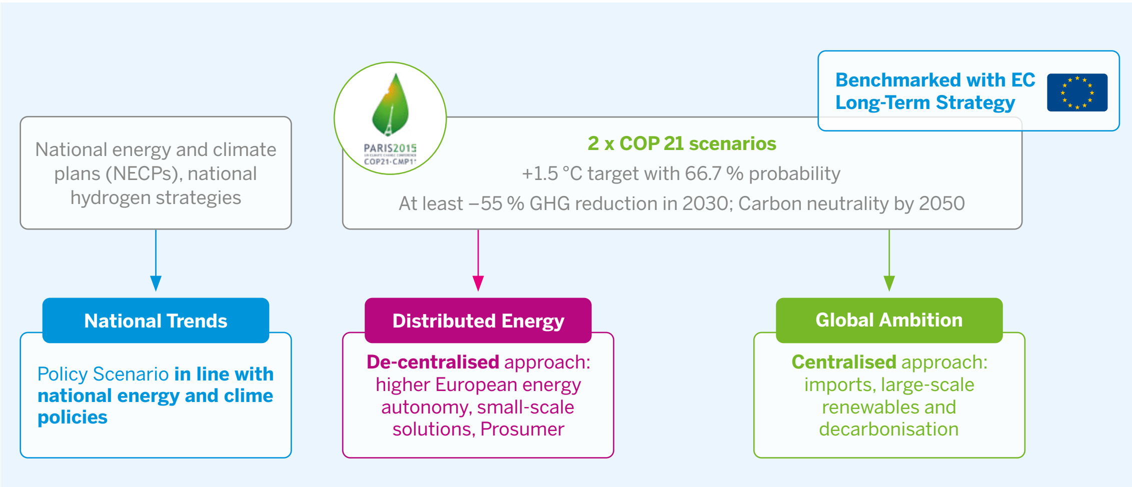


Figure 3.1 TYNDP 2022 scenarios: storylines

3.2 COP 21 SCENARIOS MEET THE 2030 TARGETS AND REACH CARBON NEUTRALITY BY 2050

The TYNDP 2022 assessment reflects the infrastructure needs to reach a net-zero energy system in Europe by 2050. Both Distributed Energy and Global Ambition foresee a reduction of GHG emissions of at least 55 percent by 2030 compared to the 1990 level. Distributed Energy reaches carbon neutrality by 2050[9] and Global Ambition already achieves carbon neutrality around 2045.

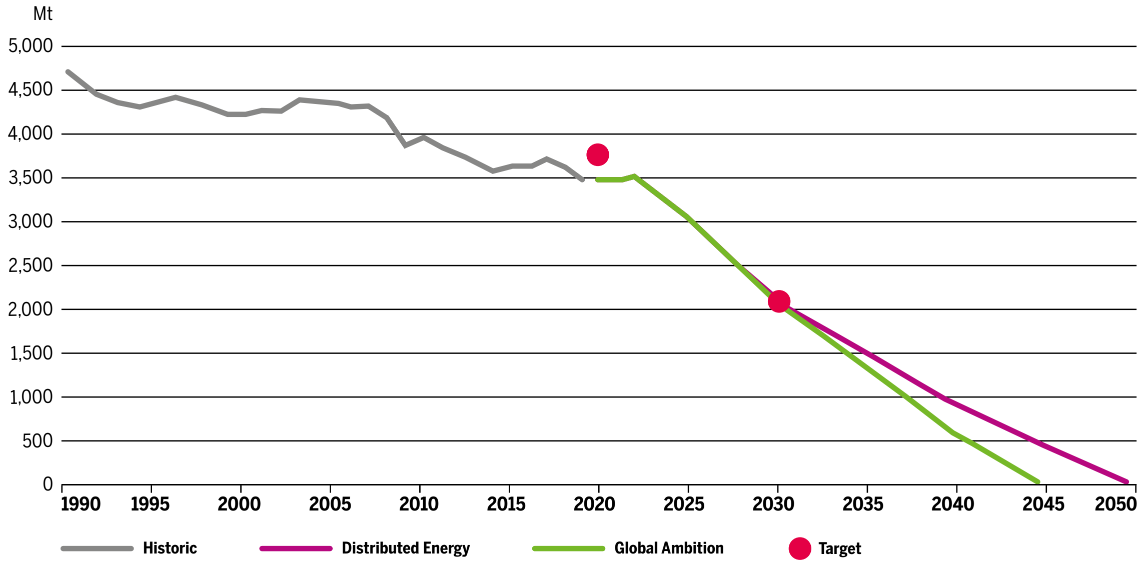


Figure 3.2 GHG emissions in Distributed Energy and Global Ambition

In the TYNDP 2020, ENTSOG and ENTSO-E used an EU-28 carbon budget based on population for the period of 2018 until 2100. For the TYNDP 2022, ENTSOG and ENTSO-E benchmark their scenarios against a carbon budget based on population, as well as a carbon budget based on equity[10]. To this end, the carbon budgets were recalculated, now considering the EU-27 scope and the historic emissions in 2018 and 2019. Table 3.3 provides an overview of the estimated carbon budget threshold following different methodologies. In 2018 and 2019 the EU already consumed a substantial part of the remaining carbon budget. As a result, the remaining EU-27 carbon budget is 35.1 Gt CO_2eq by population and 26.7 Gt CO_2eq by equity.

Method	Based on population			Based on equity		
Period	2018–2100	2020–2100	Delta	2018–2100	2020–2100	Delta
EU-27	42.2	35.1	−17 %	33.8	26.7	−21 %
UK	6.2	5.3	−15 %	4.7	3.8	−20 %
EU-28	48.5	40.4	−17 %	38.5	30.5	−21 %

Table 3.3 Remaining carbon budget expressed in Gt of CO_2 equivalents

The cumulative emissions of Distributed Energy and Global Ambition have been assessed and benchmarked against aforementioned carbon budget thresholds. Figures 3.4 and 3.5 provide an overview. It can be concluded that with the current pace of annual GHG emissions, an overshoot of the calculated budget seems unavoidable. By 2022 it is expected that the EU-27 already consumed

9 Carbon neutrality (or net zero) means having a balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks. Removing carbon oxide from the atmosphere and then storing it is known as carbon sequestration, for example through land use, land use change and forestry (LULUCF).

10 The main approaches to define the European share in the global carbon budget are based on population or on equity. A methodology based on population assumes that all earth citizens are allowed to emit the same amount. A methodology based on equity assumes that developed nations should take responsibility for their high-carbon path to industrialisation during the 19th and 20th centuries. The calculation based on equity provides a lower carbon budget for the EU than a calculation based on population.

between 30 % and 40 % of the remaining carbon budget, depending on the calculation method. Despite the ambitious decarbonisation trajectories set in both the scenarios, the carbon budget based on population is reached around 2032. The budget based on equity is reached around 2027.

In Global Ambition the net cumulative emissions peak around 2045. Renewable energy combined with carbon capture and storage (CCS) contributes to bending the curve and recovering from the carbon budget overshoot.

Total cumulative emissions add up to 44.8 Gt by 2050, which means an overshoot of 9.7 Gt based on population and 18.0 Gt based on equity. Distributed Energy shows slightly higher cumulative emissions of 51.3 Gt, which represents an overshoot of between 16.2 and 24.5 Gt. This means that in both scenarios net negative emissions must be achieved after 2050 to reach the 1.5 °C target by 2100, with BECCS or direct aircapture (DAC) technologies for example.

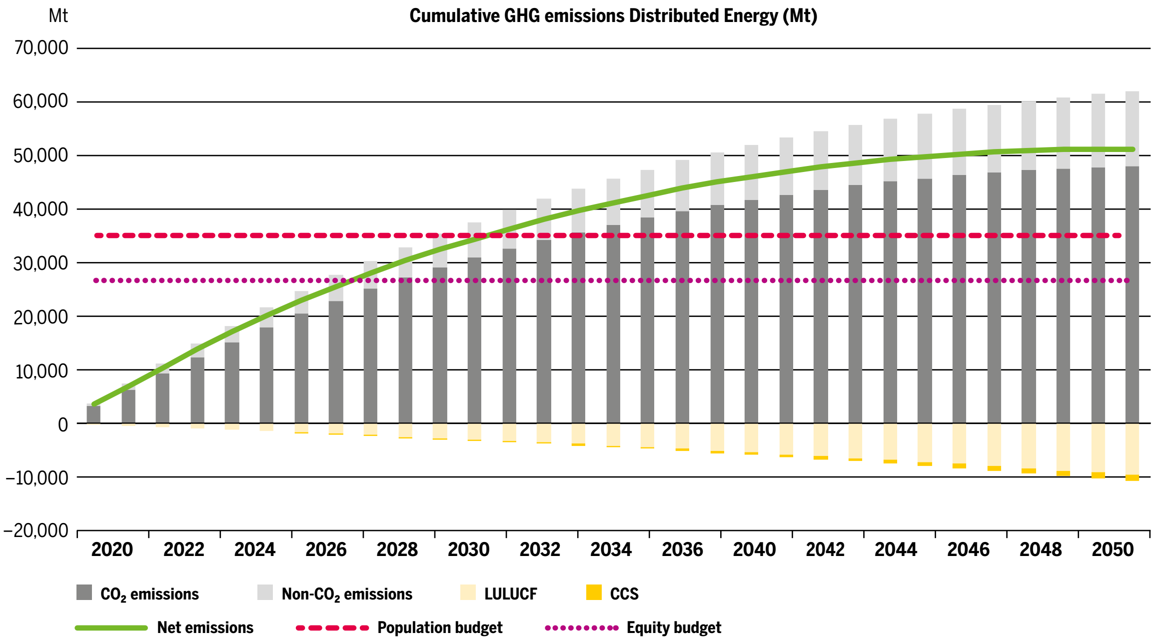


Figure 3.4 Cumulative emissions in the COP 21 scenarios – Distributed Energy

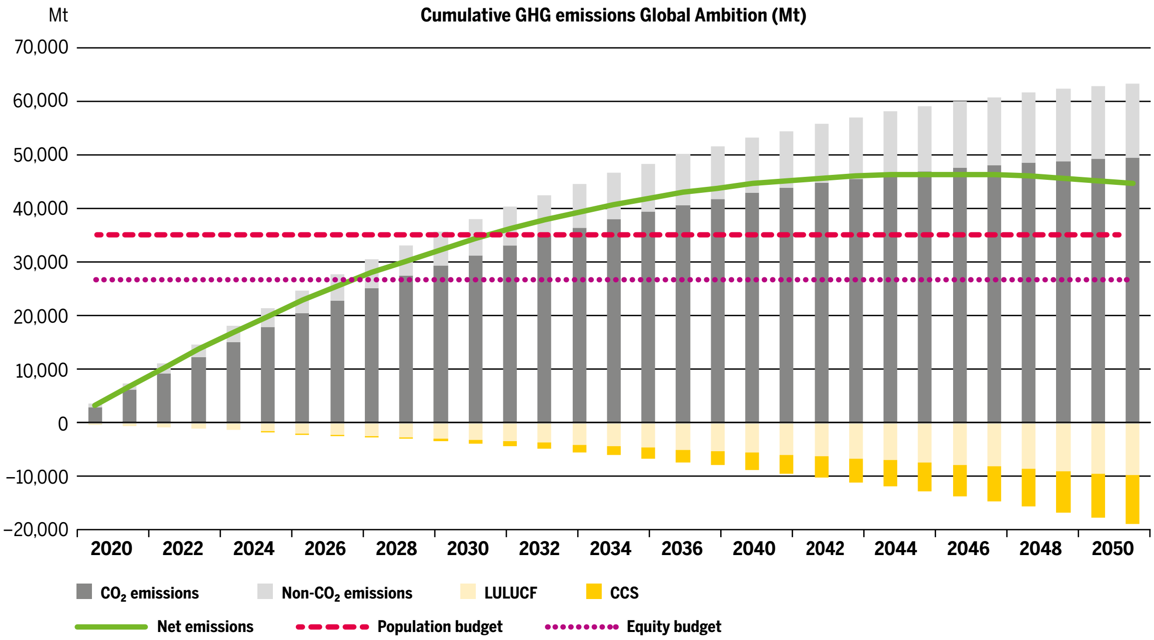


Figure 3.5 Cumulative emissions in the COP 21 scenarios – Global Ambition

3.2.1 WITH ELECTRIFICATION, GAS DEMAND FOR POWER BECOMES MORE SEASONAL AND CRITICAL

As electrification increases significantly in Global Ambition and to an even greater extent in Distributed Energy, the structure of the gas demand evolves as the demand for electricity becomes more seasonal and variable, requiring more flexibility amongst others from the gas system as well. As electrification increases, the seasonality of the gas demand remains significant since the heating demand shift towards electrification is compensated by the increasing seasonality of the electricity demand.

Furthermore, as the energy system relies on variable renewables to produce electricity and gas, the gas supply becomes sensitive to climatic events as well as the energy demand. This combined climatic sensitivity increases the need for flexibility. This translates in the scenarios by a higher winter demand for power, especially during climatic events like Dunkelflaute[11] when gas demand for power generation increases to compensate for the absence of wind and solar energy during periods of several days.

The role of gas in power generation strongly evolves along the time horizon. First, there is a need to distinguish methane from hydrogen. In the present scenarios the increasing role of hydrogen in final demand translates into a similar evolution for gas-fired power generation with hydrogen replacing progressively a part of methane in this sector for the 2040- and 2050-time horizon.

Secondly, methane is progressively decarbonised offering the opportunity of flexible renewable and low carbon generation. While methane is now mostly natural gas, the share of biomethane increases along the time horizon to become fully decarbonised by 2050 in Distributed Energy.

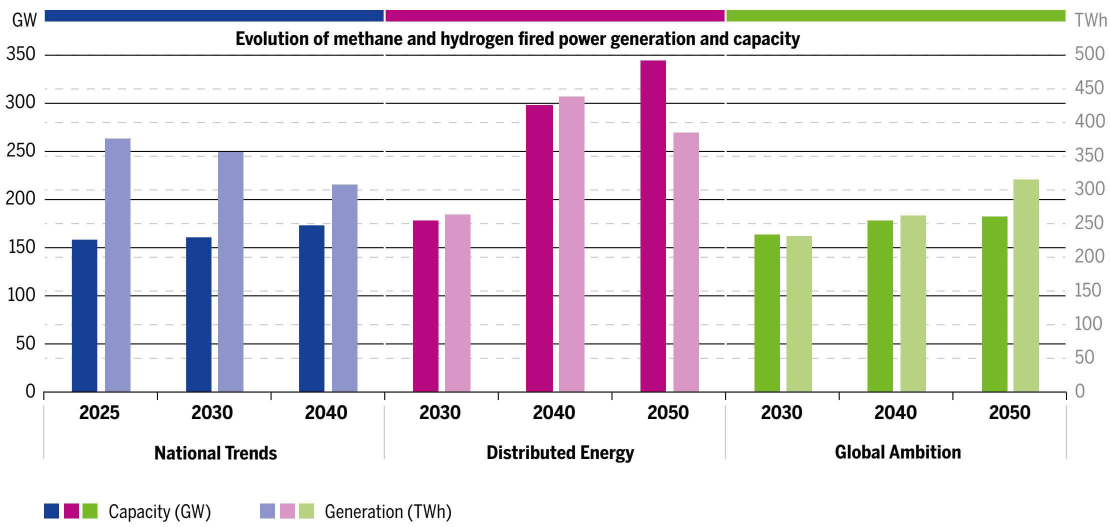


Figure 3.6 Gas demand for power generation (Capacity and Generation)

3.2.2 METHANE AND HYDROGEN: TWO COMPLEMENTARY ENERGY CARRIERS NEEDED TO MEET THE EU ENERGY AND CLIMATE OBJECTIVES IN AN EFFICIENT WAY

Europe has significant potentials for producing renewable methane (e. g., biomethane) and hydrogen. Methane can also be associated with CCS technologies to be decarbonised and, using steam methane reforming (SMR), autothermal reforming (ATR), pyrolysis or other technology, converted to hydrogen. The analysis of the supply potentials for methane and hydrogen shows that for an efficient decarbonisation and to limit its dependence on imports, the EU needs to make use of all its sources

11 "Kalte Dunkelflaute" or just "Dunkelflaute" (German for "cold dark doldrums") expresses a climate case, where in addition to a 2-week cold spell, variable RES electricity generation is low due to the lack of wind and sunlight.

of renewable energy in both Distributed Energy and Global Ambition scenarios. Therefore, for cost and energy efficiency reasons both methane and hydrogen demand coexist in both scenarios, to a different extent and with different evolutions depending on the storylines. The comparison of National Trends and the COP 21 scenarios shows that, in many countries, current national policies do not always have a long-term vision post 2030 and do not consider yet a shift of the gas demand from methane towards hydrogen, nor do they consider significant CCU/S capacities.

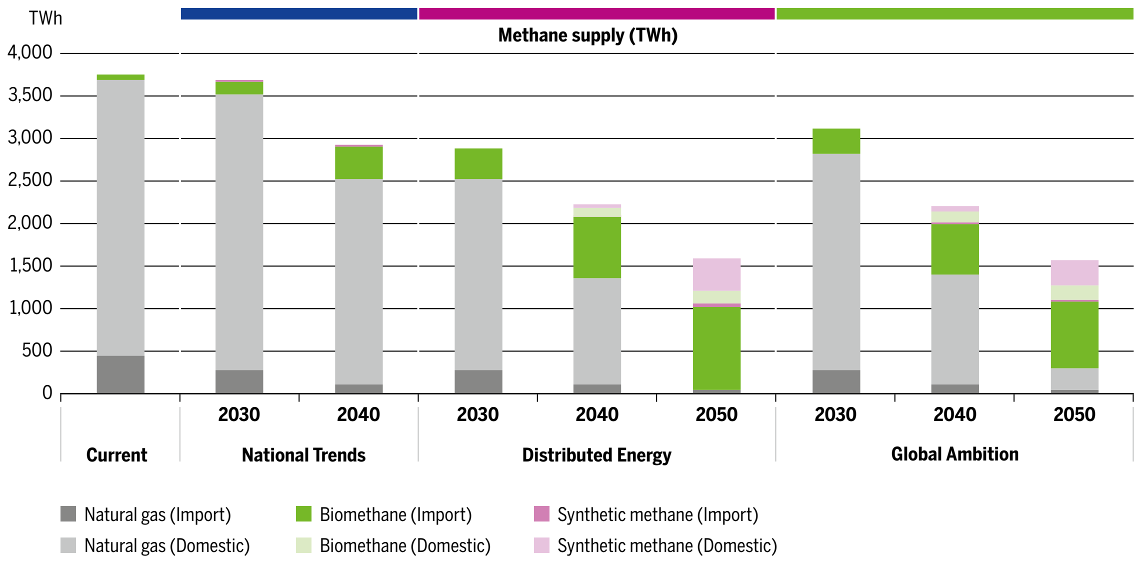


Figure 3.7 Methane supply for EU27

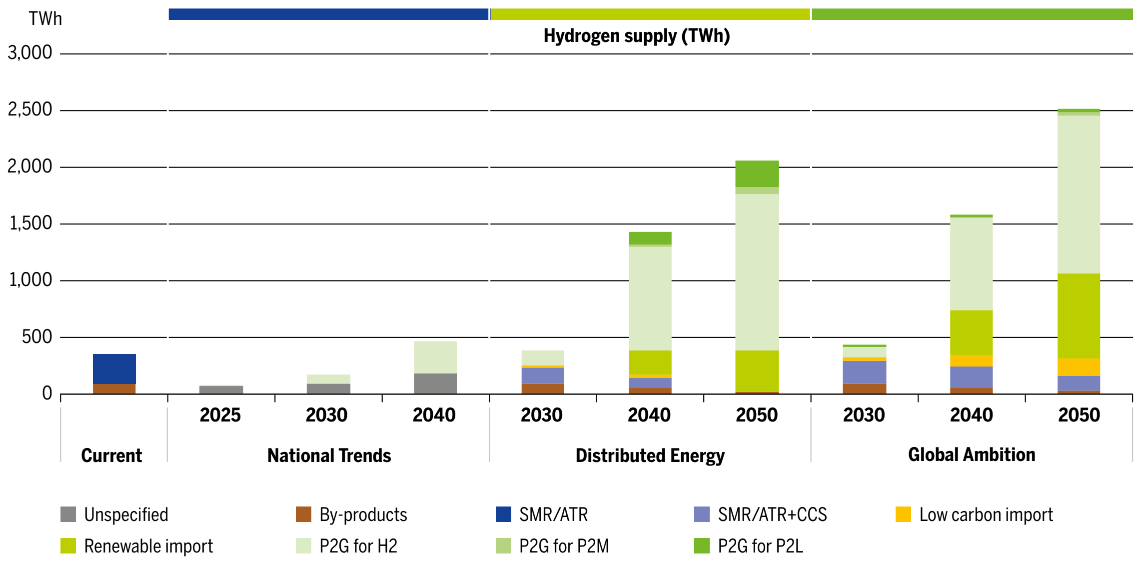


Figure 3.8 Hydrogen supply for EU27

3.2.3 THE DECARBONISATION OF THE GAS SUPPLY CAN BE DONE IN MANY WAYS

Gas can either be produced from renewable energy such as biomass producing biomethane or wind and solar energy producing hydrogen. Furthermore, decarbonised hydrogen can be produced with natural gas with different technologies such as SMR/ATR associated with carbon capture and storage technologies. Both COP 21 scenarios consider all types of technologies to a greater or lesser extent following their storyline. Each technology comes with its level of decarbonisation that is considered in the computation of the GHG emissions of each scenario to keep track of their carbon budget expenses. For instance, biomethane can be considered as carbon neutral or carbon negative if associated with CCS.

With the development of renewable hydrogen, biomethane and decarbonisation technologies, the EU can decarbonise its gas production by 2030 in Global Ambition and by 2040 in Distributed Energy. The EU indigenous production is largely decarbonised in 2040 in National Trends but not entirely, with about 100 TWh of remaining unabated natural gas.

Distributed Energy shows the highest development of indigenous production capacities and a higher role for biomethane and hydrogen since the local production is prioritised. In Global Ambition, the indigenous production of methane and hydrogen also significantly increases but to a lesser extent compared to Distributed Energy.

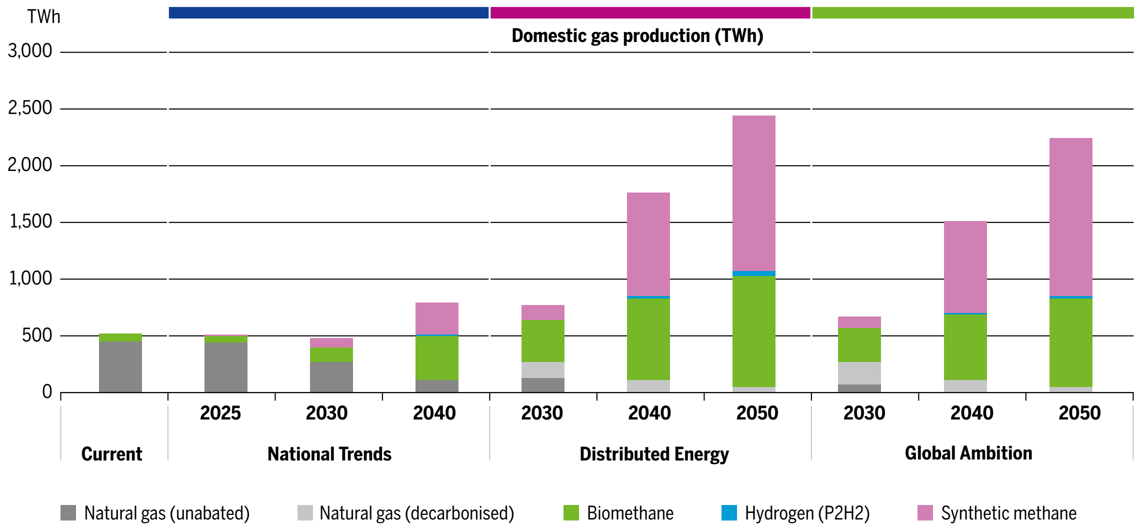


Figure 3.9 EU27 annual gas production per scenario (before REPowerEU adjustments)

3.2.4 IMPORT CAPACITIES ARE KEY TO ENSURE THE TRANSITION AND SECURITY OF SUPPLY

With increasing system integration, the EU energy system increasingly relies on electricity and gas renewables to satisfy its energy demand since significant production capacities can be developed in the EU. Therefore, the EU energy demand only marginally relies on coal and oil, and liquids in general, which reduces the need for carbon intensive energy imports.

COP 21 scenarios show lower energy import needs compared to the EU Impact Assessment scenarios. However, the TYNDP 2022 scenarios confirm the need for gas import capacities to ensure the transition (production of decarbonised energy besides the development of renewable technologies) and to ensure the security of energy supply (see Security of supply chapter).

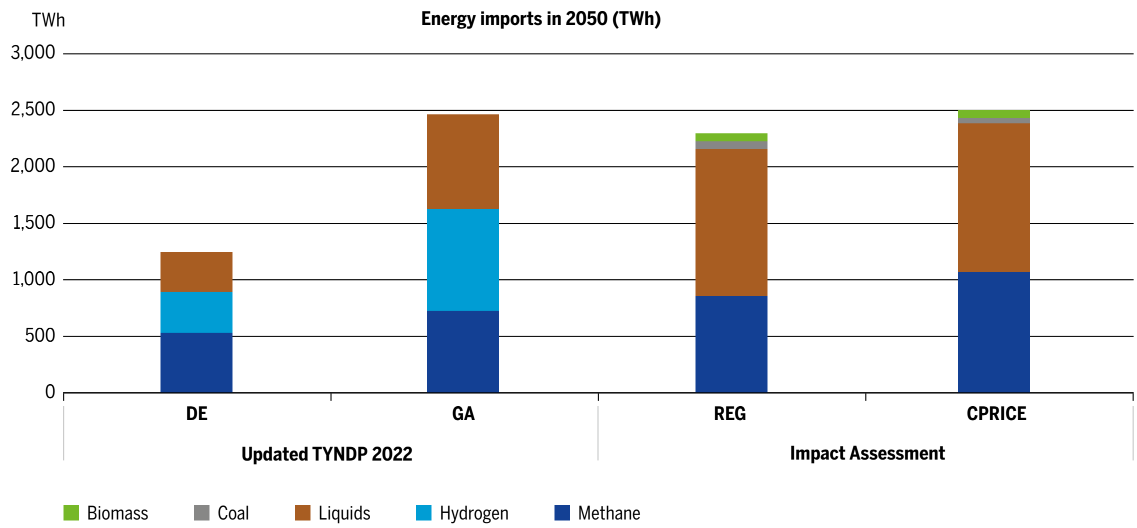
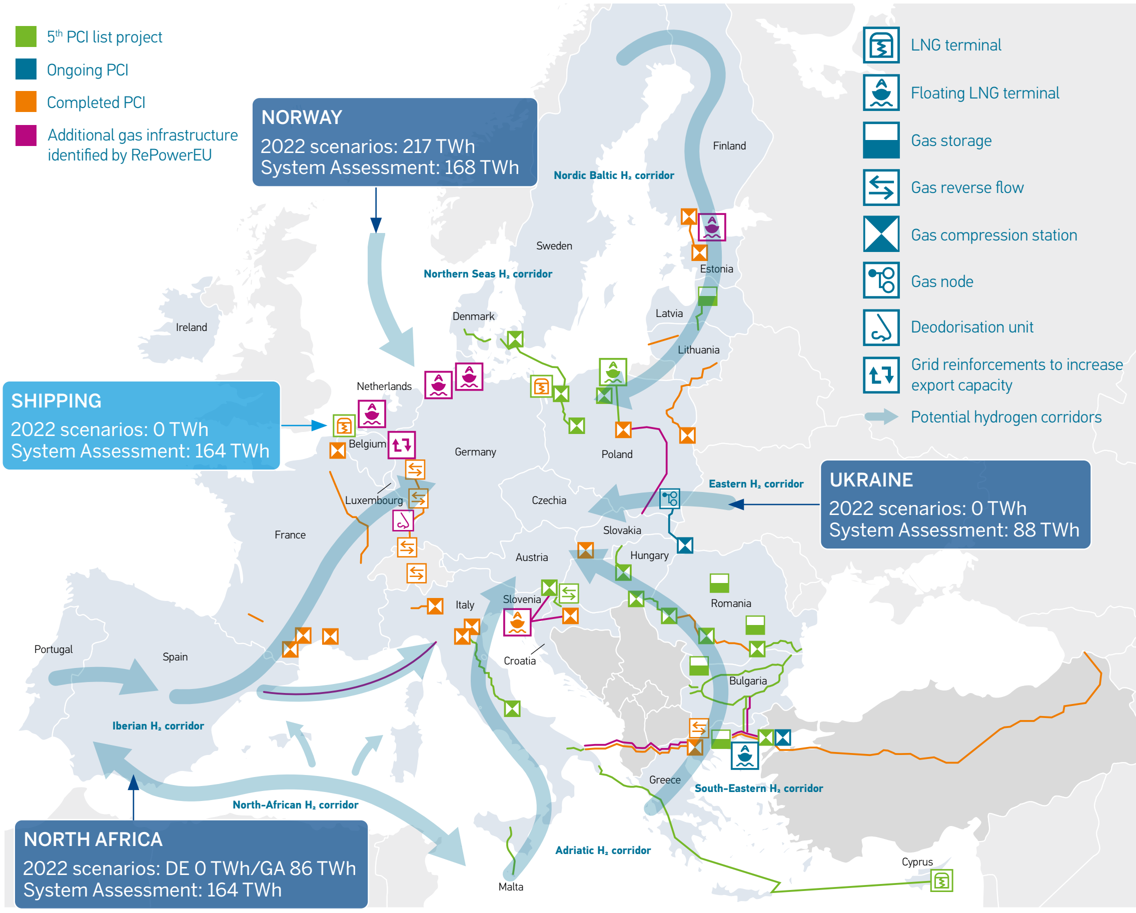


Figure 3.10 Energy imports to the EU in 2050 in TYNDP 2022 scenarios and EU Impact Assessment

3.3 ADJUSTMENT OF THE TYNDP 2022 TO REPowerEU – TO INCREASE EU INDEPENDENCE

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 TYNDP 2022 scenarios, published in April 2022, could not address and consider the requirements of the REPowerEU Plan. To include these ambitions into the perspective of the infrastructure development and its assessment, the TYNDP 2022 scenarios were adjusted by ENTSOG. The aim was to keep the main findings of the published TYNDP 2022 report, in particular, 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.



2022 scenarios: H_2 potential before adjustment to RePowerEU
System Assessment: H_2 projects collected for TYNDP 2022 and PCI process

REPowerEU 2030 Target	
Pipeline	200 TWh
Shipping	133 TWh

Figure 3.11 Updated potential extra EU H_2 supply in 2030

In a first step, the domestic renewable hydrogen production in 2030 was adjusted to explore how to supply the 10mt of domestic renewable hydrogen. To keep the impact on the electricity system minimal, the additional hydrogen production was added via electrolysers producing renewable hydrogen connected to dedicated renewables only. The renewables necessary are taken from the upper expansion limit per country for 2040 to maintain a consistent development of the RES deployment. The alternative of directly taking the developed 2040 scenarios would have resulted in a massive overshoot of hydrogen production compared to the REPowerEU's 2030 targets and was therefore dismissed.

In a second step, the import quantities and sources were adjusted to meet the 10 mt hydrogen import target. The import corridors mentioned in REPowerEU were considered and assigned with a capacity based on submitted projects[12] within the framework of the TYNDP 2022 project collection.

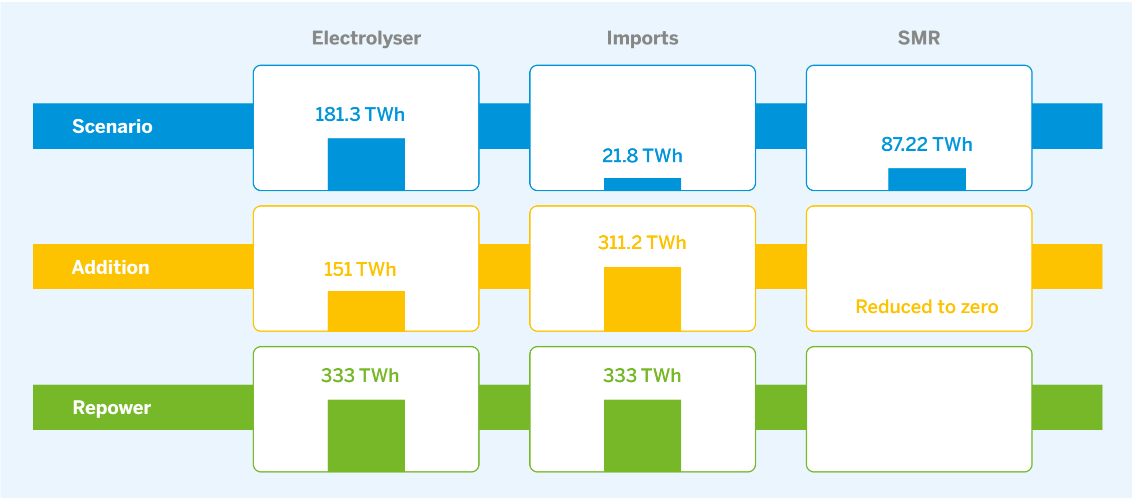


Figure 3.12 Reconstruction of hydrogen supply – Distributed Energy as example

In a third and last step, the hydrogen demand was increased to match the increased hydrogen supply. The identified gap of the hydrogen demand is distributed proportionally among the countries, considering country specific views. According to the REPowerEU plan, hydrogen will be used primarily in industry and transport sectors. The added hydrogen demand was assigned to these two sectors with an 80/20 ratio for industry and transport respectively. The added hydrogen demand was then subtracted from the natural gas demand for these two sectors.

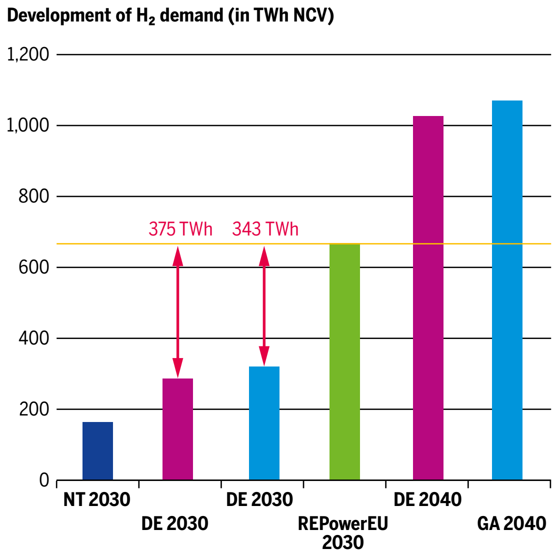


Figure 3.13 Adjustment of H_2 demand[13]

12 Detailed information about the project collection is provided in the Infrastructure Report

13 Hydrogen extra demand was subtracted from the natural gas demand for industry and transport sectors

3.4 HYDROGEN TYNDP 2022

For the previous TYDNP edition, ENTSOG introduced a new project infrastructure category for Energy Transition Projects. The TYNDP 2020 included 75 Energy Transitions Projects. Following the EU Green Deal and the revision process of the TEN-E Regulation, ENTSOG decided to further evolve this category by replacing this category by four new categories allowing more sector-related insights and displaying development trends. The TYNDP 2022 includes 215 investments relevant for these four new categories. They concern 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)

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

In addition, hydrogen projects included different subcategories of hydrogen infrastructure projects, 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 terminal 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)

The TYNDP 2022 is the first one that includes Hydrogen infrastructure levels. These include not only Hydrogen infrastructure projects (as defined in the Practical Implementation Document of the TYNDP 2022) submitted to the TYNDP 2022, but also additional Hydrogen infrastructure projects that were submitted by December 2022 to the first PCI selection process under the revised TEN-E Regulation.

The addition of hydrogen projects submitted to the PCI project submission in the TYNDP 2022 edition is explained by the specific relationship between the TYNDP 2022 cycle and the ongoing first PCI selection process. As for the first PCI selection process, previous project submission to the TYNDP 2022 edition was not set a mandatory condition, unlike previous and future TYNDP/PCI processes.

Projects by infrastructure type

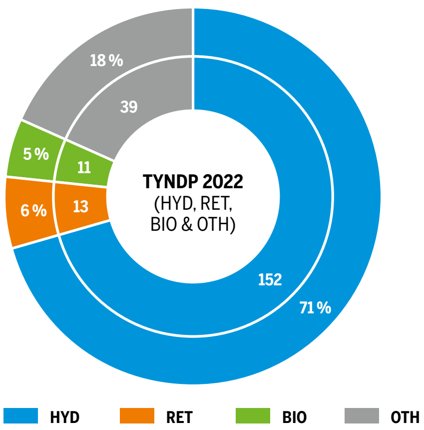


Figure 3.14 Projects representing new project categories included in the TYNDP 2022 per type of infrastructure (absolute number of respective investments and the equivalent share).

Project promoters submitted 112 natural gas infrastructure projects (i. e., transmission, UGS and LNG projects) to the TYNDP 2022. For comparison, project promoters had submitted 142 methane infrastructure projects to the TYNDP 2020.

Investments by infrastructure type

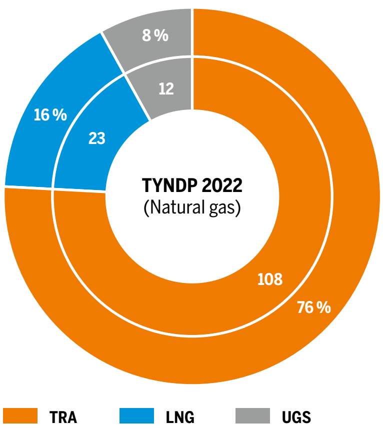


Figure 3.15 Projects representing methane categories included in the TYNDP 2022 per type of infrastructure (absolute number of respective investments and the equivalent share).

Picture courtesy of TAP

3.5 CONCLUSION

Gases are part of the solution towards net-zero 2050

The 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.

Indeed, as the energy transition will create a change in the use of primary energies depending partly on the level of electrification and on whether it is produced locally or centralised, gases as an energy carrier and their decarbonisation play a key role.

Adequate regulatory support is needed

New infrastructure projects may contribute to sustainability, decarbonisation, market integration, competition and diversification of gas supply sources or routes. It is therefore important that the European regulatory framework continues ensuring adequate support to infrastructure developments that will allow to meet current and future needs.

Coordinated and coherent interaction between electricity and gases (including natural gas, biomethane, synthetic methane, and hydrogen)

To achieve climate goals under the European Green Deal in a cost-efficient way, a coordinated and coherent interaction between electricity and gases (including natural gas, biomethane, synthetic methane, and hydrogen) is essential. Such an integrated approach addresses the development of crucial future infrastructure connections in an efficient and technology-neutral manner. Such an approach also reflects the increasing demand for hydrogen and the essential role of power-to-gas technologies.

Independence from Russia

The invasion of Ukraine by Russia on 24 February 2022 led to a major overhaul of energy policy objectives in terms of energy security and diversification of supply. Future gas infrastructure evolution must consider the ongoing decarbonisation trend and a need to reduce Russian gas supply dependence and critical supply source dependence in general.

4 SECURITY OF SUPPLY NEEDS

Security of supply needs are assessed by measuring the ability of the European gas systems to ensure the continuity of methane and hydrogen supply to all countries under various stress conditions.

This section assesses the resilience of the European gas system to cope with various stressful events:

- Climatic stress
- Supply source disruptions
- Infrastructure disruptions

The resilience of the methane and hydrogen system is measuring by which degree the respective demand can be satisfied under the mentioned stress cases. It is expressed as the share of the demand that is curtailed (curtailment rate) or as the absolute value of unsatisfied demand (demand curtailment). It can be applied to methane as well as hydrogen. This indicator is calculated at country or balancing zone level over the full time horizon of the TYNDP assessment. Thereby, cooperation is assumed, i. e. the available infrastructure will be used to equalise to the extent possible the curtailment rates of the different countries or balancing zones.

4.1 DEMAND ELASTICITY

It was observed in the past that high demand events, especially if combined with a tight supply or infrastructure situation, result in prices increases that cause demand reductions. However, such demand elasticity is subject to various assumptions that differ from one country to the other.

When assessing the impact of climatic stress on gas infrastructure (i. e., methane or hydrogen), the demand is considered static and is 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.

An extra assumption was made for the H_2 Infrastructure Level 2, on top of the input cap used for hydrogen production in Level 1, additional last-resort hydrogen production from methane was introduced to mitigate hydrogen demand curtailments by using surplus methane supply potentials. This can be interpreted as a flexible hydrogen supply potential on top of the scenario values. It could alternatively be read as a proxy for a fuel-switch from hydrogen to methane during the periods of hydrogen demand curtailment (with an inaccuracy due to the conversion loss of hydrogen production using methane), creating an infrastructure-induced scenario sensitivity for information.

It can be assumed that the part of the demand that is not satisfied on a yearly (or even seasonal) basis would not materialise at all.

4.2 INFRASTRUCTURE LEVELS[14]

As in previous TYNDP editions, the project status[15] is the basis for the definition of methane infrastructure levels:

Existing Methane Infrastructure level

The Existing Methane Infrastructure level is composed of the existing network + FID projects having their commissioning date no later than 31 December 2022.

The Existing Methane Infrastructure level will be the basis for the following infrastructure levels (PCI and Advanced), as it represents the minimum level of methane infrastructure development that will be considered in the TYNDP 2022 System Assessment.

Advanced Infrastructure level

The Advanced Infrastructure level is composed of the Existing Methane Infrastructure level + FID projects + advanced projects.

The Advanced Infrastructure level broadens the range of the TYNDP 2022 System Assessment by including the advanced methane projects on top of the existing and FID infrastructure to complement the infrastructure gaps identification.

PCI Infrastructure level

The PCI Infrastructure level is composed of the Existing Methane Infrastructure level + FID projects + methane infrastructure projects included in the 5th PCI list.

The PCI Infrastructure level is composed by existing infrastructures, infrastructure projects having FID status (whatever their PCI status is) and infrastructure projects labelled as PCIs in the 5th PCI selection process (not having their FID taken yet). Although it includes projects of different maturity, this infrastructure level allows to build a bridge between past PCI selection processes, and it also enables the assessment of the 5th list of methane PCI projects.

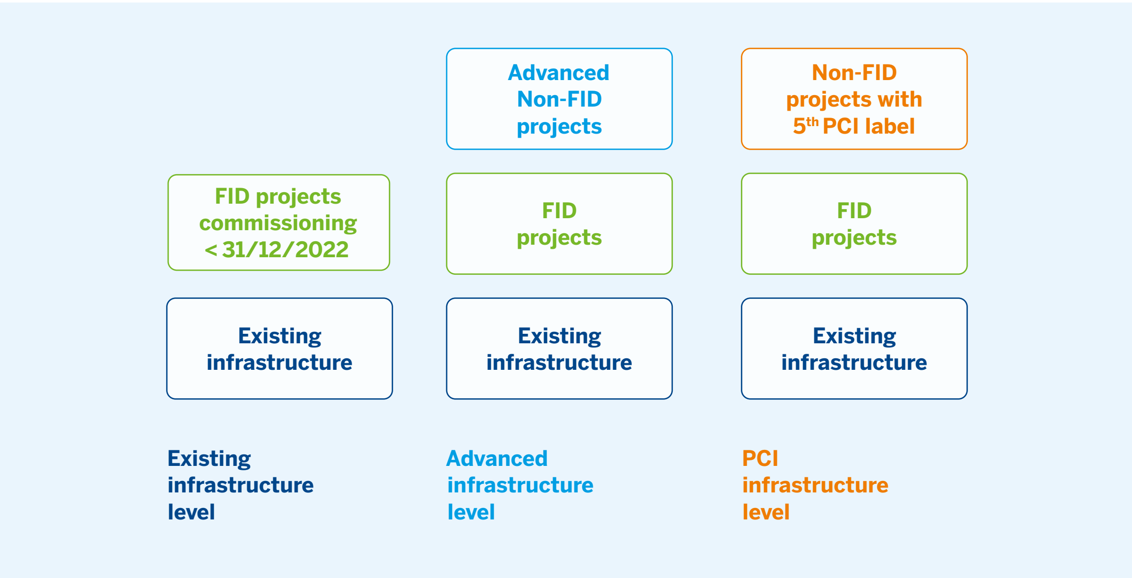


Figure 4.1 Methane infrastructure levels in TYNDP 2022

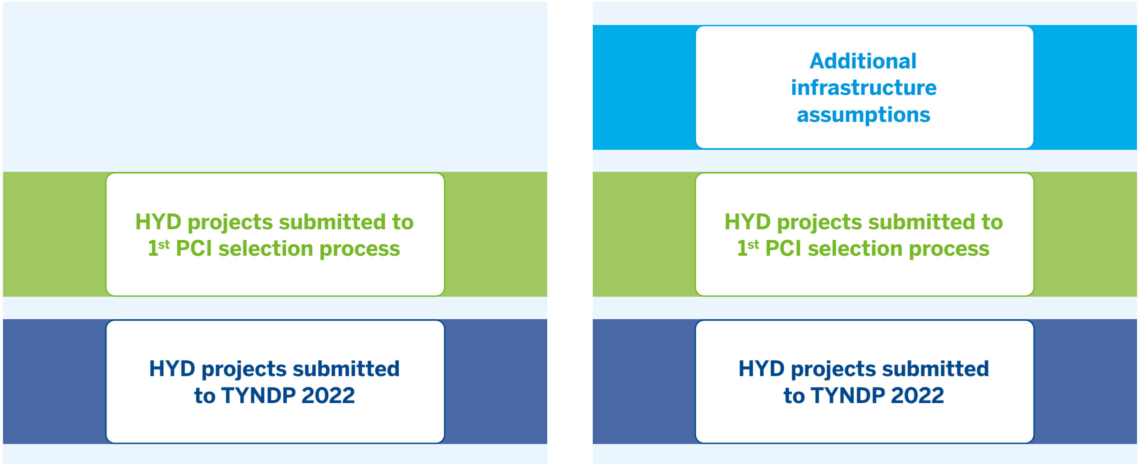
14 Detailed information about the project collection is provided in the Infrastructure Report

15 TYNDP time stamp (1 January 2023 for existing infrastructure and PCI project collection for projects)

Unlike methane, hydrogen infrastructure levels can only be defined with the consideration of planned projects, as there is no existing infrastructure in place. **The TYNDP 2022 works with two contrasted hydrogen infrastructure levels:**

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[16]) 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 needed to enable policy objectives, such as the 2030 hydrogen imports targets defined by the REPowerEU Plan.

Figure 4.2 Hydrogen Infrastructure levels in TYNDP 2022

Infrastructure levels are the basis for the identification of infrastructure gaps in the TYNDP 2022 System Assessment. An innovation of the TYNDP 2022 is the dual assessment of methane and hydrogen infrastructure. This is achieved by combining each natural gas infrastructure level with both hydrogen infrastructure levels in the TYNDP System Assessment and coupling them by hydrogen production using methane.

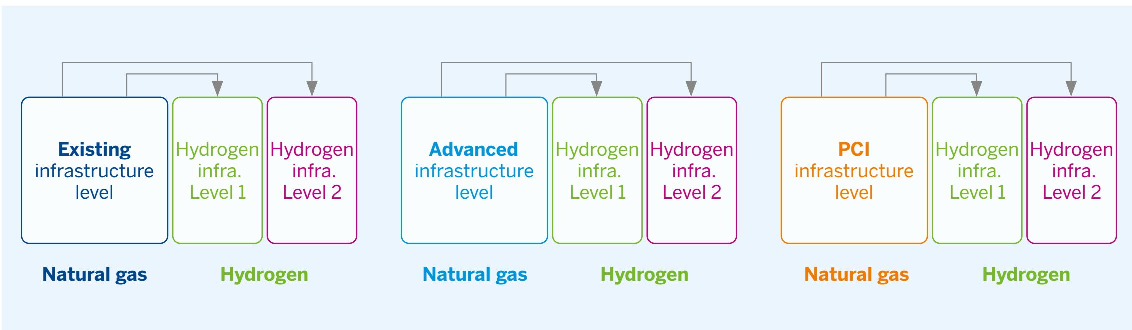


Figure 4.3 Natural gas and Hydrogen infrastructure levels in the System Assessment

For more details on the different Infrastructure levels and the related projects, please consult the TYNDP 2022 Infrastructure Report. Extra details and explanations can be also found in Annex D.

16 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 to be considered for this System Assessment.

5 SUSTAINABILITY

Reducing CO_2 emissions and thereby their significant contribution to the greenhouse effect and global warming is considered as high priority in the EU.

Together with other ways to reduce the carbon dioxide emitted from the energy sector, hydrogen is a promising clean form of fuel that only produces water vapor when burned and does not release GHG emissions such as CO_2, or air pollutants such as NO_X, SO_2 and particulate matter. In addition, hydrogen can be produced also from (bio)-methane coupled with CCS and renewable energy sources such as solar and wind energy, making it a sustainable energy source.

To guide the energy transition, initial steps should promote hydrogen by establishing a favorable market environment, encouraging research and innovation and establishing viable transport and distribution networks.

Both Distributed Energy and Global Ambition scenarios show how under normal conditions, without any supply disruption cases, the H_2 Infrastructure Level 2 achieves higher CO_2 savings compared to H_2 Infrastructure Level 1.

The total CO_2 emissions are thereby calculated by applying an assumed specific emission factor[17] to the consumed hydrogen, or the produced hydrogen from SMR with CCS, as well as to the consumed natural gas (except for national production of biomethane and synthetic methane based on power-to-gas). The fact that hydrogen demand is curtailed to a considerable extent, especially for H_2 Infrastructure Level 1, causes some uncertainty over the total emissions calculation. In H_2 Infrastructure Level 2, the missing hydrogen is produced using methane, to the extent possible, on top of the potential maximum SMR defined by the scenarios.

However, also other fuel-switches are thinkable, resulting in different emission factors and thus different total emissions. In the following graphs, the curtailed demands for hydrogen and methane per year, per scenario, and per infrastructure level combination are provided. To make the results between the infrastructure levels comparable for this exercise and not to reward demand curtailments by attributing them with 0 emissions, the curtailed H_2 demand is multiplied by the emission factor for SMR with CCS and the curtailed CH_4 demand is multiplied by the emission factor of natural gas. Thus, the difference in emissions displayed in the graphs is solely linked to the ability of the different infrastructure levels to use electrolytic hydrogen produced from non-CO_2-emitting sources instead of hydrogen from SMR with CCS. If the curtailed hydrogen demand had been assumed to be substituted by other sources, e. g., by non-abated SMR, or simply had remained in the methane market, the resulting emissions would be much higher.

All graphs displayed in this chapter show combined CO_2 emissions from methane and hydrogen for the Reference case.

17 The emission factors are stated in the Scenario Building Guidelines on pages 25 and 26
https://2022.entsos-tyndp-scenarios.eu/wp-content/uploads/2022/04/TYNDP_2022_Scenario_Building_Guidelines_Version_April_2022.pdf

5.1 2030 YEARLY CO_2 EMISSIONS

H_2 Infrastructure Level 1 results show that the United Kingdom, Ireland, Luxembourg, Slovenia, Serbia and Cyprus face demand curtailment, without these curtailment higher CO_2 emissions would be expected for both Distributed Energy and Global Ambition.

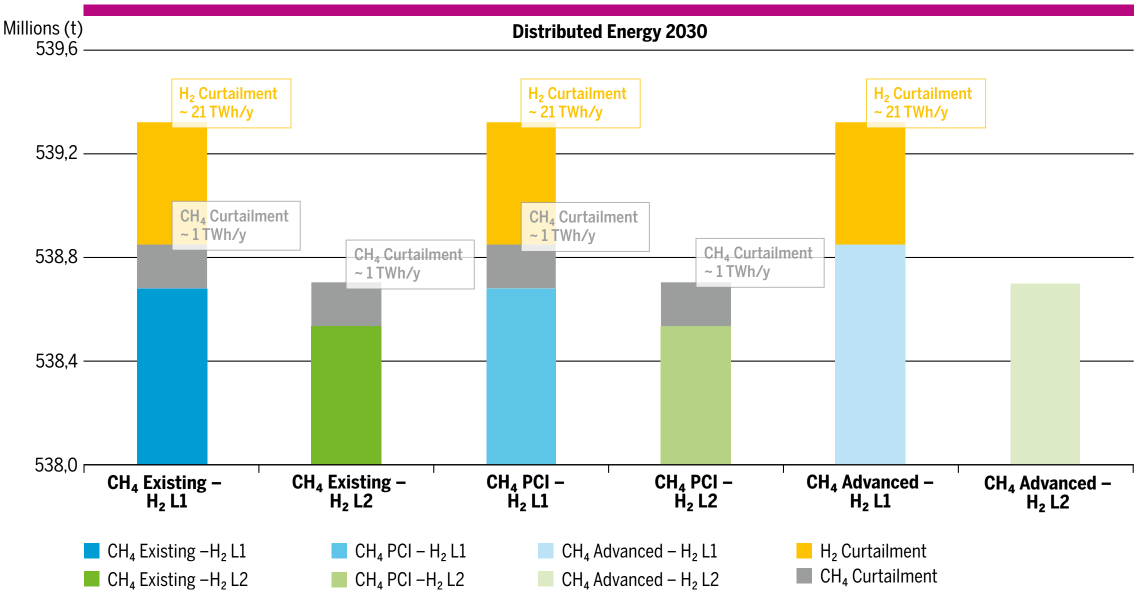


Figure 5.1 CO_2 emissions H_2 Levels 1 and 2 in 2030 Distributed Energy (million tons/year) combined CH_4 & H_2

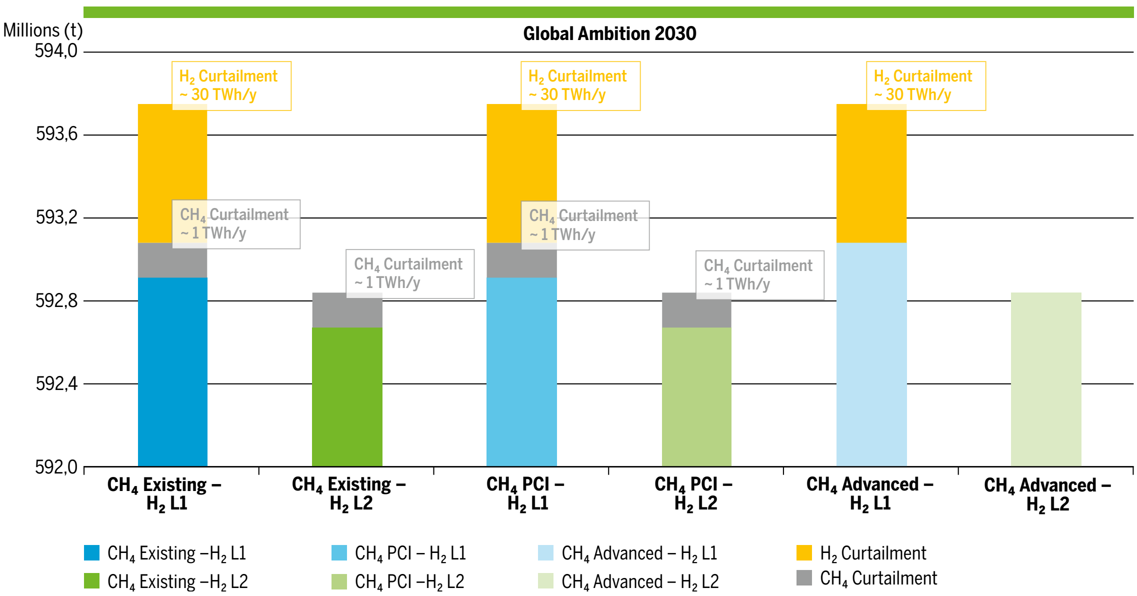


Figure 5.2 CO_2 emissions H_2 Levels 1 and 2 in 2030 Global Ambition (million tons/year) combined CH_4 & H_2

5.2 2040 YEARLY CO_2 EMISSIONS

H_2 Infrastructure Level 1 results show a slight demand curtailment in all Europe for Distributed Energy and a higher one, above 10 %, for Global Ambition. Without this demand curtailment higher CO_2 emissions would be expected for both scenarios.

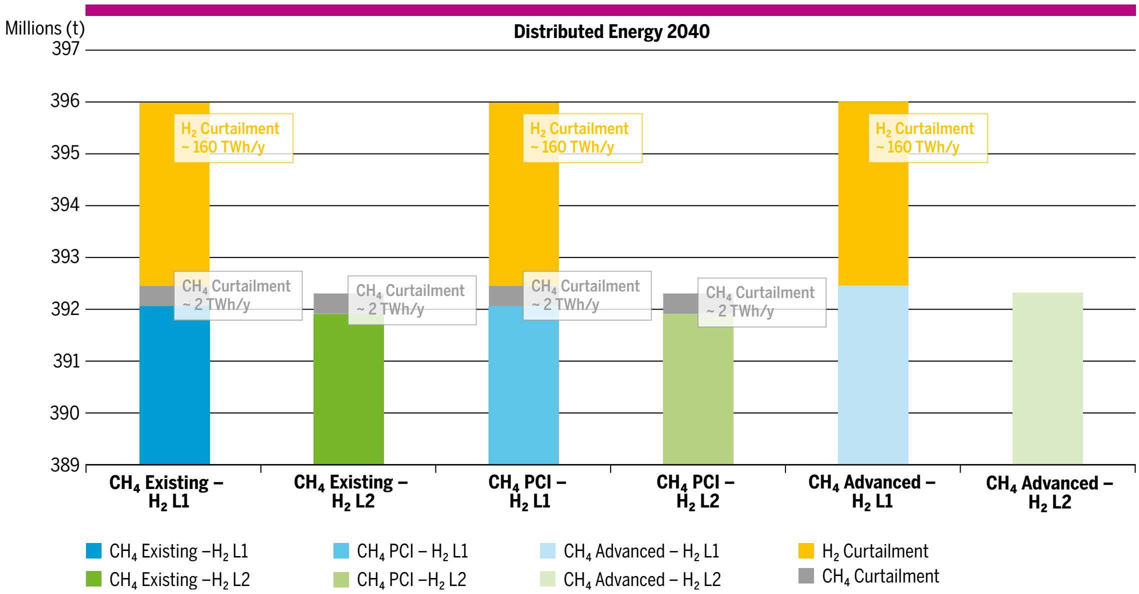


Figure 5.3 CO_2 emissions H_2 Levels 1 and 2 in 2040 Distributed Energy (million tons/year) combined CH_4 & H_2

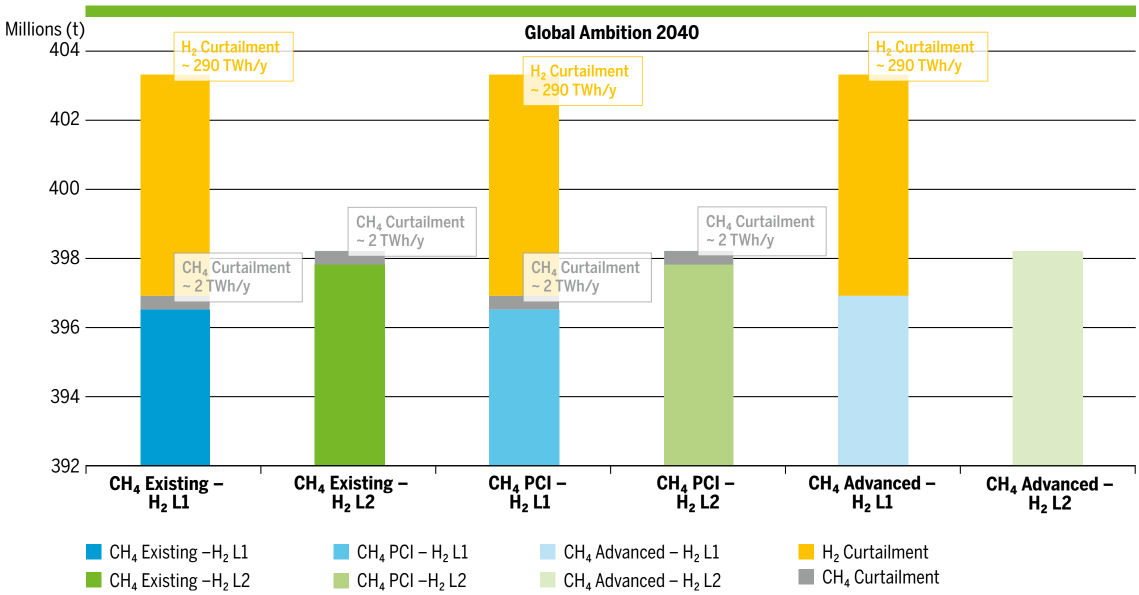


Figure 5.4 CO_2 emissions H_2 Levels 1 and 2 in 2040 Global Ambition (million tons/year) combined CH_4 & H_2

5.3 2050 YEARLY CO_2 EMISSIONS

H_2 Level 1 results show a slight demand curtailment in all Europe for Distributed Energy, above 10 %, and a higher one for Global Ambition, above 20 %.

Without these demand curtailments higher CO_2 emissions would be expected for both scenarios in 2050.

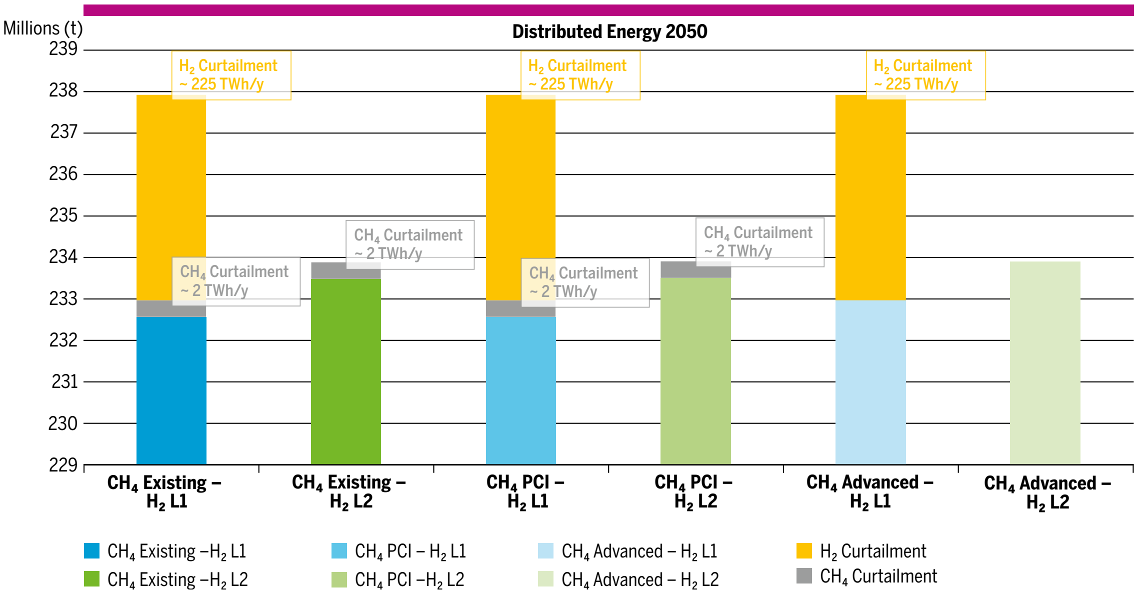


Figure 5.5 CO_2 emissions H_2 Levels 1 and 2 in 2050 Distributed Energy (million tons/year) combined CH_4 & H_2

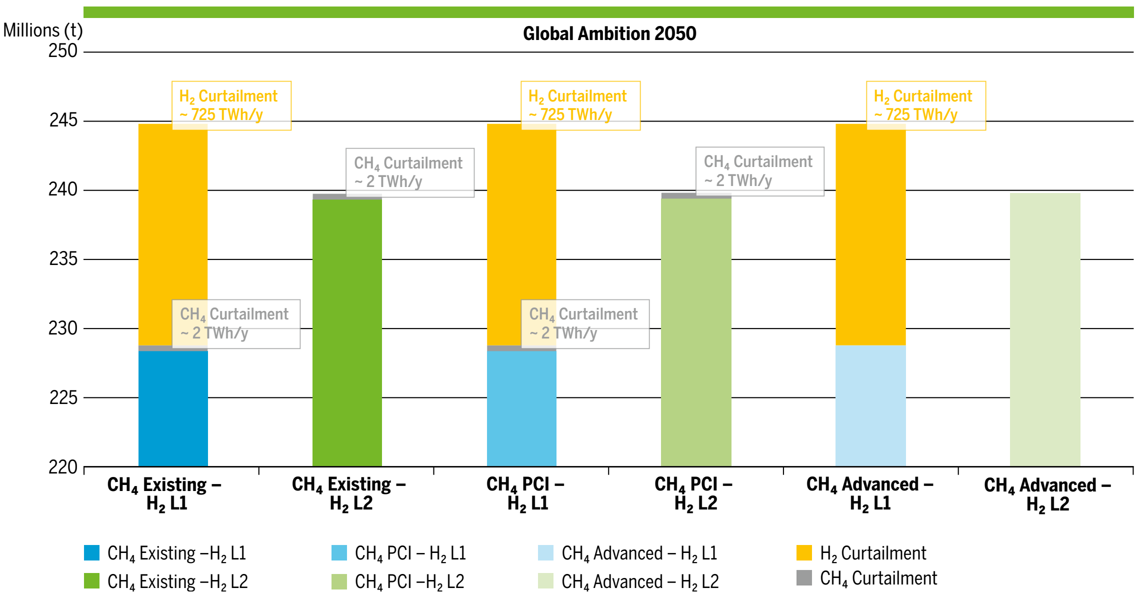


Figure 5.6 CO_2 emissions H_2 Levels 1 and 2 in 2050 Global Ambition (million tons/year) combined CH_4 & H_2

6 SUPPLY MIXES

Underground natural gas storages are the most common and efficient way to store energy. These facilities are considered to be highly secure due to their underground location, below the earth's surface in salt caverns or porous geological formations such as sedimentary rocks or aquifers, designed to prevent any leakage of stored gas.

During the summer months, when energy demand is low, the gas system is used to inject natural gas into underground storages to ensure security of supply.

In winter or for market reasons, the gas is extracted from underground storages and transported through the gas pipelines to meet heating demand of homes, buildings and businesses, and also to electricity generation plants like combined cycle gas turbines (CCGTs). The gas stock should be carefully monitored to ensure that sufficient gas is available to meet demand at all times.

In the same way, future hydrogen storages can improve security of supply in Europe even more by providing a long-term solution with an efficient and clean energy source that helps to reduce the general EU dependence on imports.

6.1 SUPPLY MIXES UNDER PEAK DEMAND SITUATIONS

Under high demand situations the supply and demand balance depends on a significant share of the methane underground gas storage utilisation while the overall need of methane supply imports decrease over the years. The gas infrastructure for methane and the project based for hydrogen are both needed to enhance the security of gas supply in Europe in the different scenarios and years with enough new H_2 import capacities and storages.

The following charts illustrate the evolution in the different scenarios.

DESIGN CASES

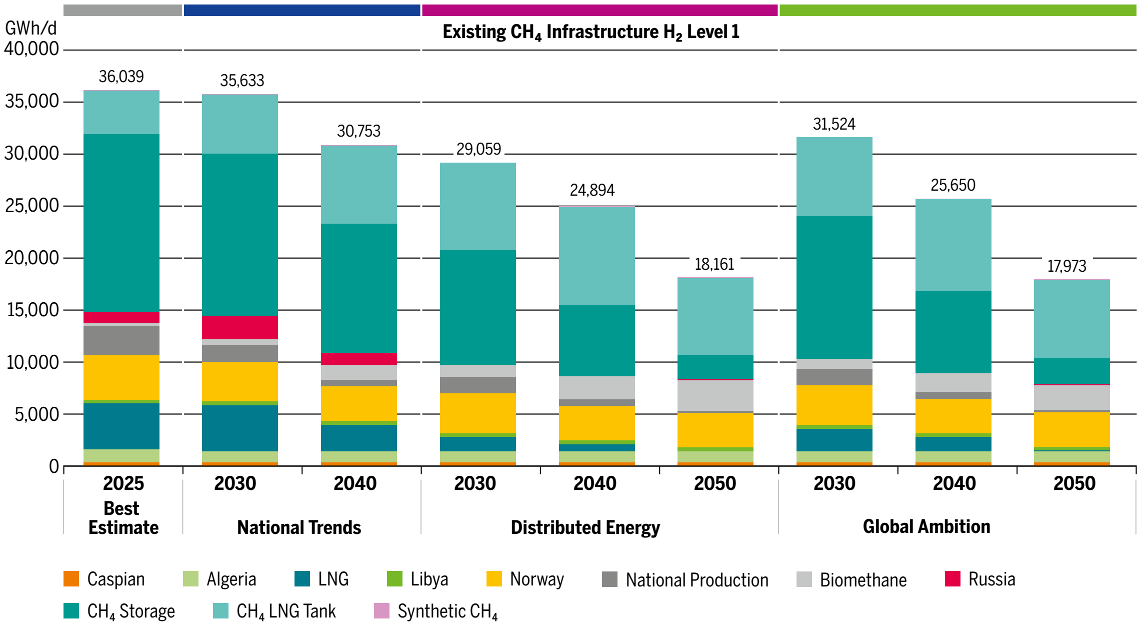


Figure 6.1 CH_4 Supply Results for Peak Demand in Existing CH_4 Infrastructure H_2 Level 1

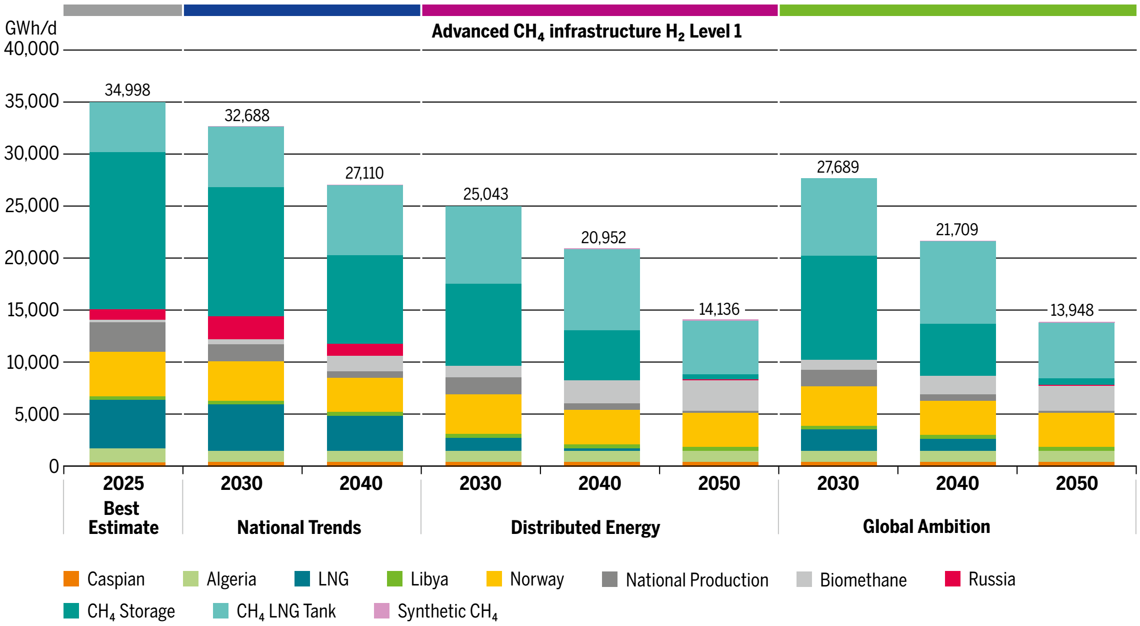


Figure 6.2 CH_4 Supply Results for Peak Demand in Advanced CH_4 Infrastructure H_2 Level 1

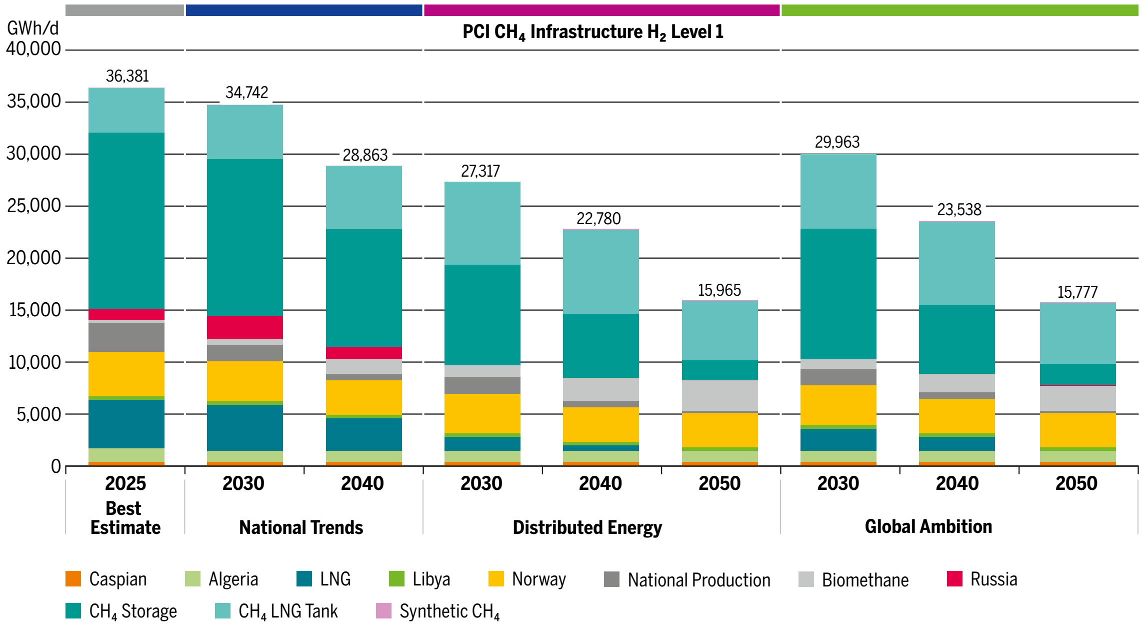


Figure 6.3 CH_4 Supply Results for Peak Demand in PCI CH_4 Infrastructure H_2 Level 1

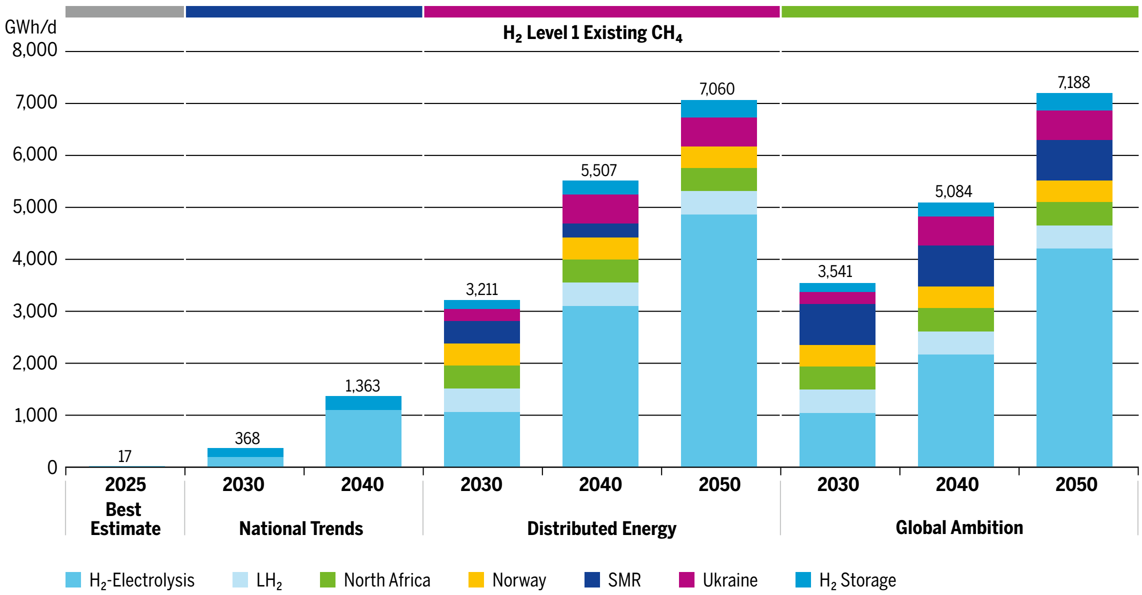


Figure 6.4 H_2 Supply Results for Peak Demand in Existing CH_4 Infrastructure with H_2 Level 1

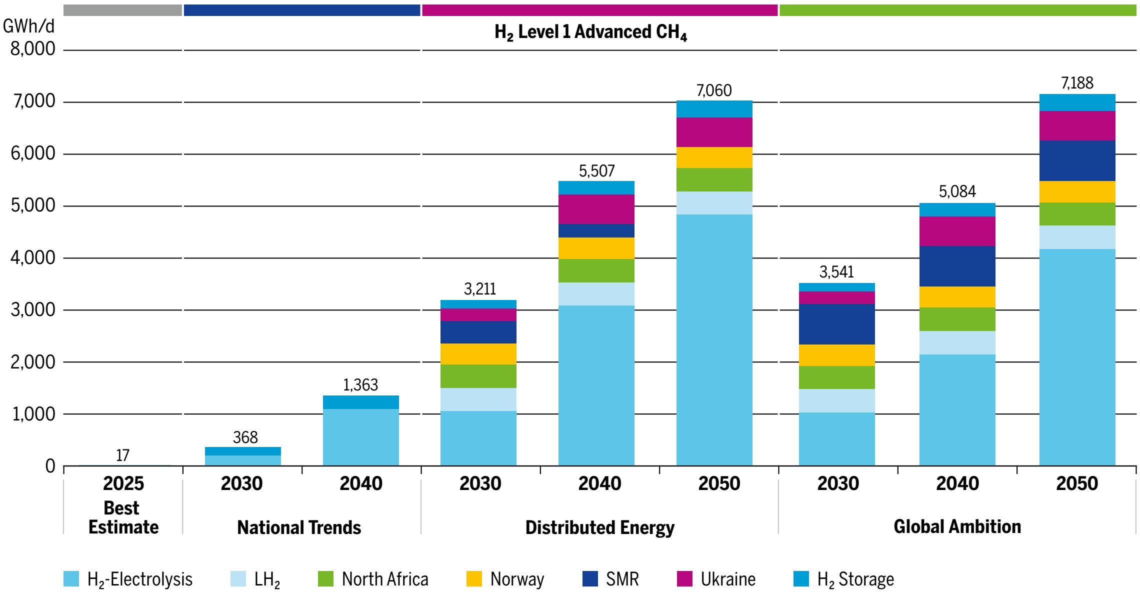


Figure 6.5 H_2 Supply Results for Peak Demand in Advanced CH_4 Infrastructure with H_2 Level 1

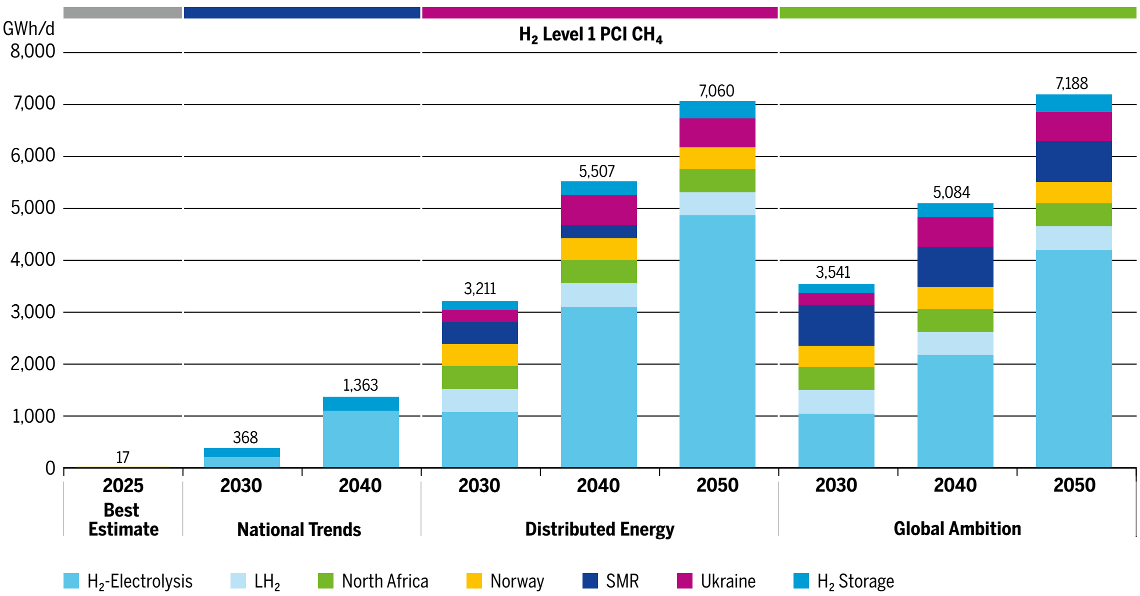


Figure 6.6 H_2 Supply Results for Peak Demand in PCI CH_4 Infrastructure with H_2 Level 1

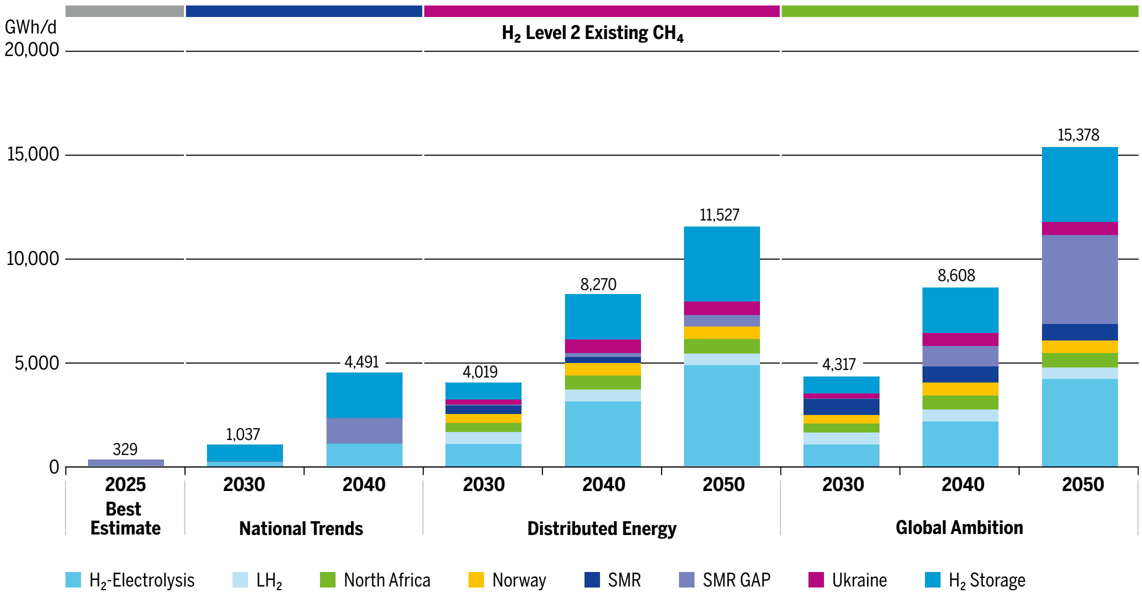


Figure 6.7 H_2 Supply Results for Peak Demand in Existing CH_4 Infrastructure with H_2 Level 2

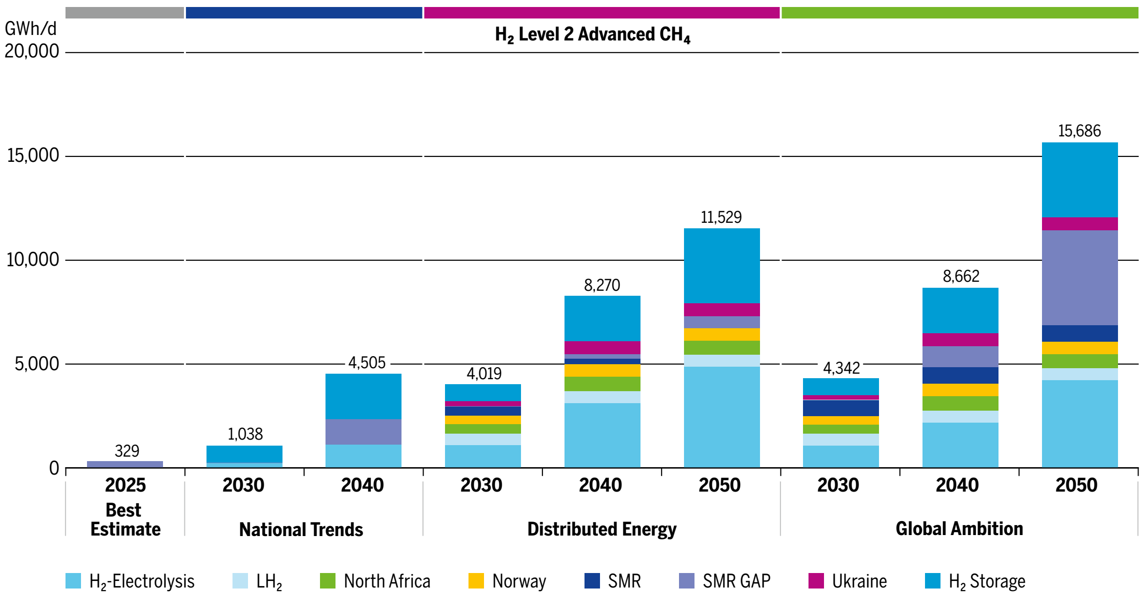


Figure 6.8 H_2 Supply Results for Peak Demand in Advanced CH_4 Infrastructure with H_2 Level 2

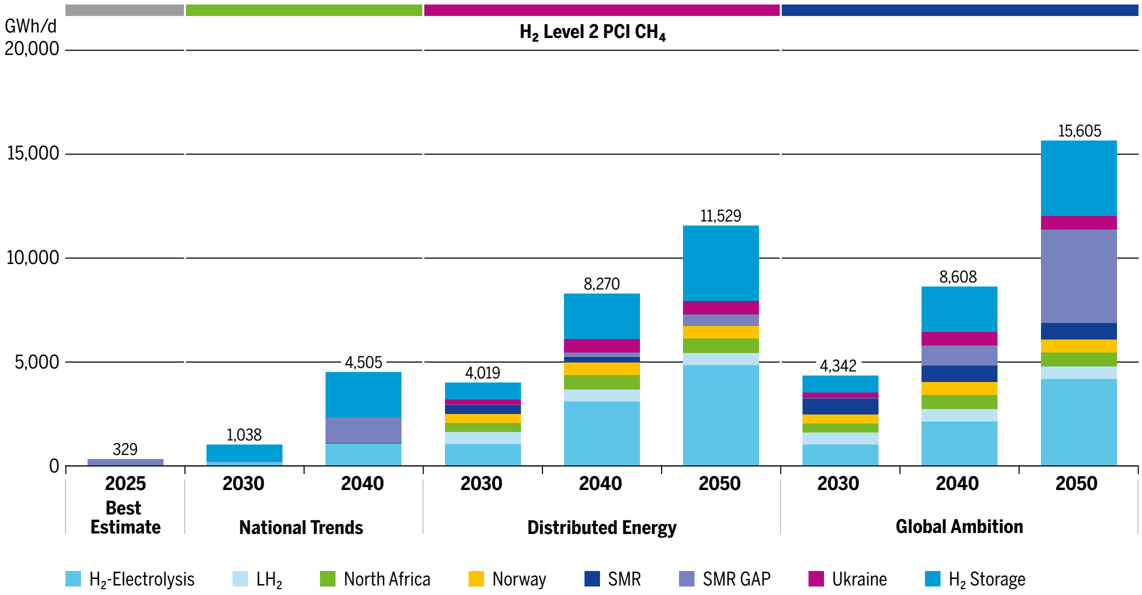


Figure 6.9 H_2 Supply Results for Peak Demand in PCI CH_4 Infrastructure with H_2 Level 2

6.2 SUPPLY MIXES FOR YEARLY DEMAND

This analysis investigates the differences of the contrasted supply mixes in the European yearly supply and demand balance. This is achieved through supply configurations intended at minimising Russian gas.

Conventional natural gas production declines over the years and, even with the expected ramp-up of the biomethane production, the supply and demand balance relies on rather stable levels of import shares from Norway, LNG, North Africa and the Caspian.

Regarding hydrogen in Global Ambition and Distributed Energy, for any of the two infrastructure levels, there is a high expectation to reach already by 2030 a very ambitious national production basis together with several import sources (Norway, LH_2, North Africa and Ukraine) all taking-off at the same time.

The evolution of the supply mixes share for the PCI and Advanced infrastructure level follow the same trend as for the Existing Methane Infrastructure level.

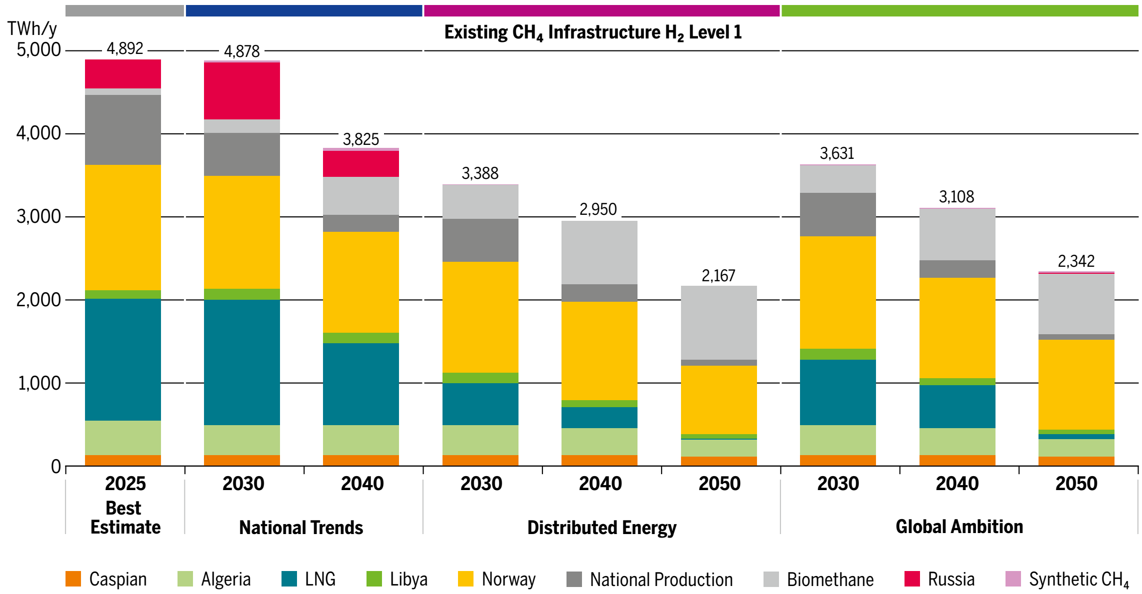


Figure 6.10 CH_4 Yearly Supply Results in Existing CH_4 Infrastructure with H_2 Level 1

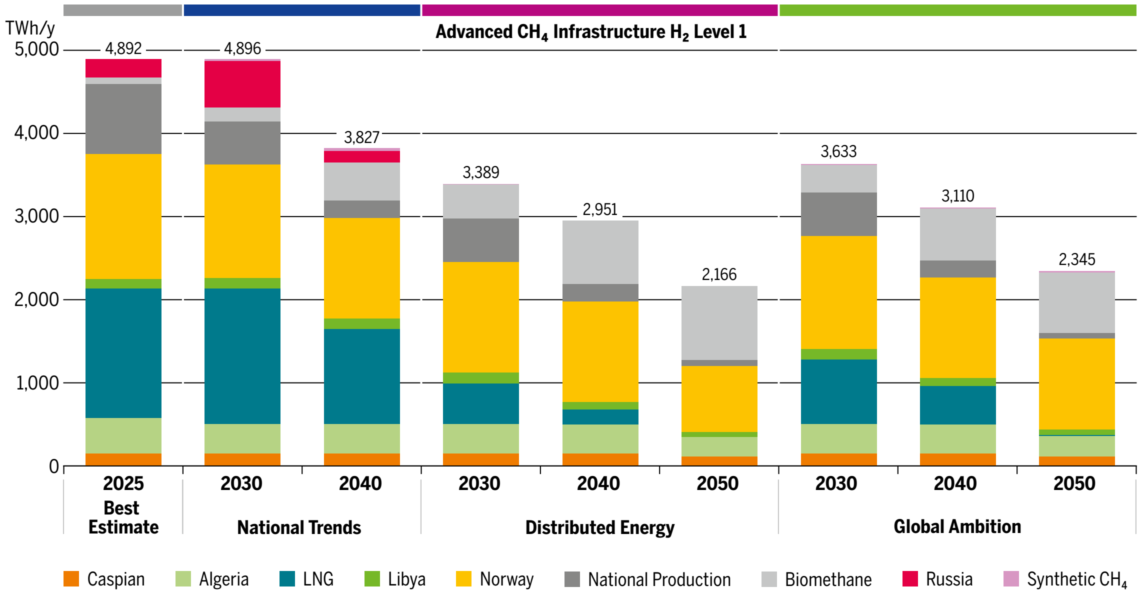


Figure 6.11 CH_4 Yearly Supply Results in Advanced CH_4 Infrastructure H_2 Level 1

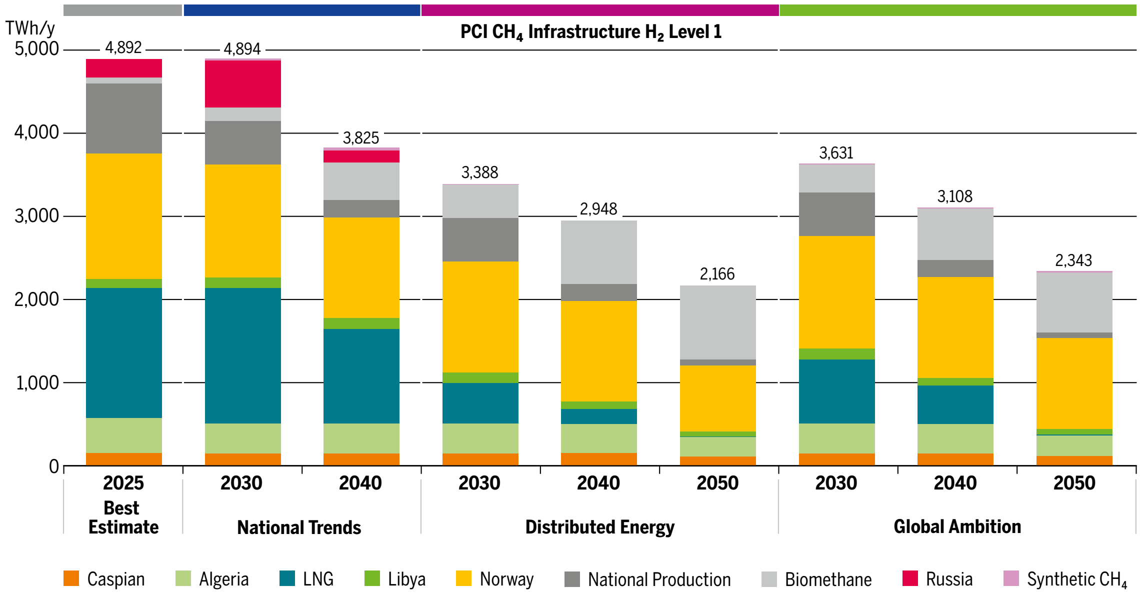


Figure 6.12 CH_4 Yearly Supply Results in PCI CH_4 Infrastructure H_2 Level 1

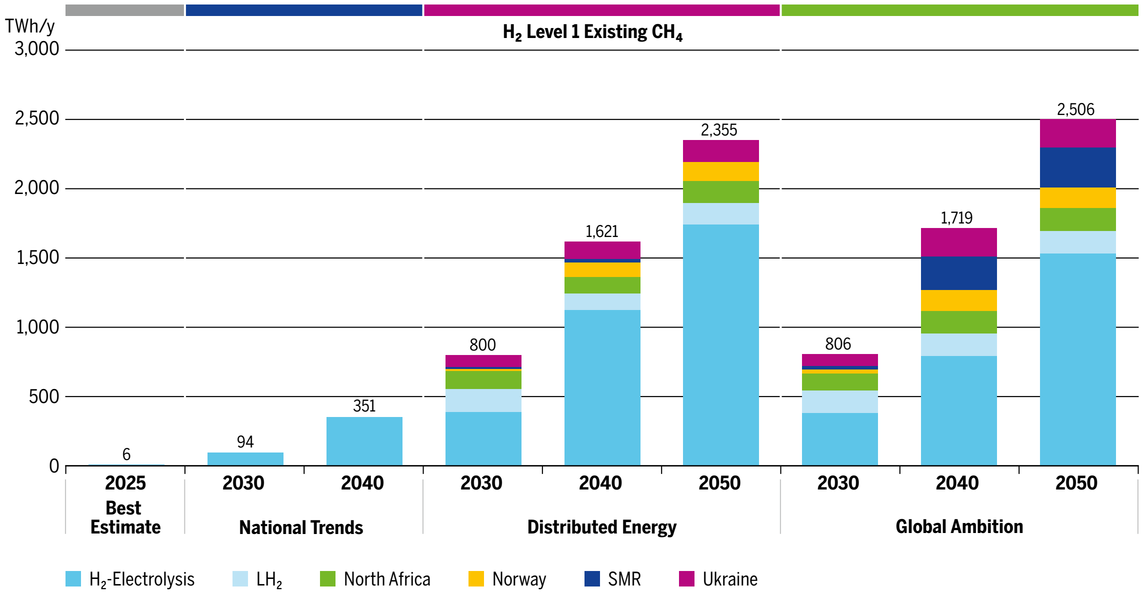


Figure 6.13 H_2 Yearly Supply Results in Existing CH_4 Infrastructure with H_2 Level 1

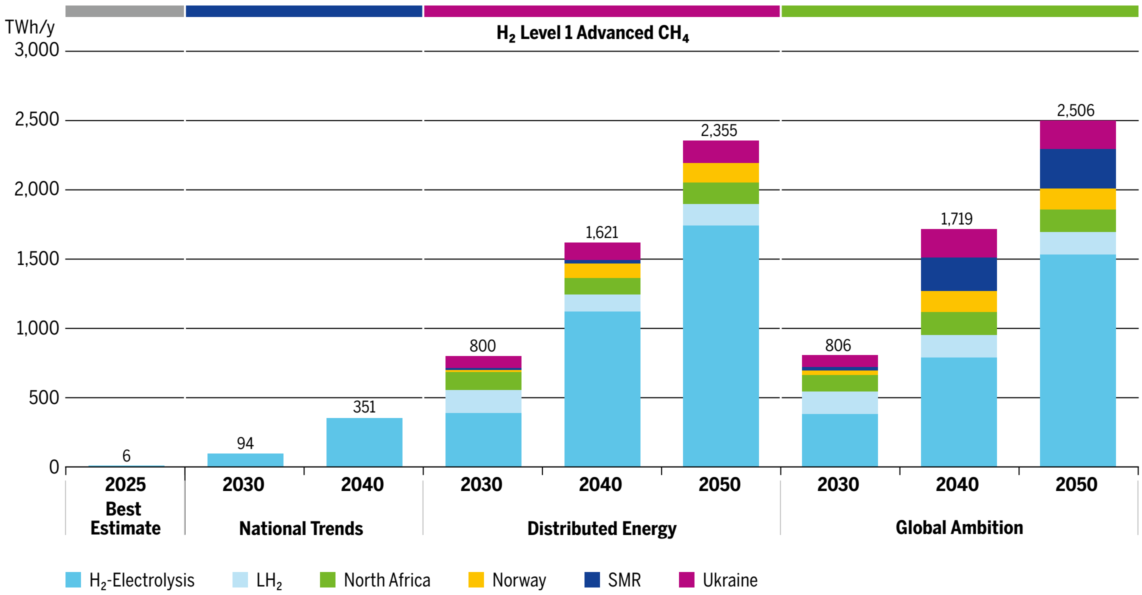


Figure 6.14 H_2 Yearly Supply Results in Advanced CH_4 Infrastructure with H_2 Level 1

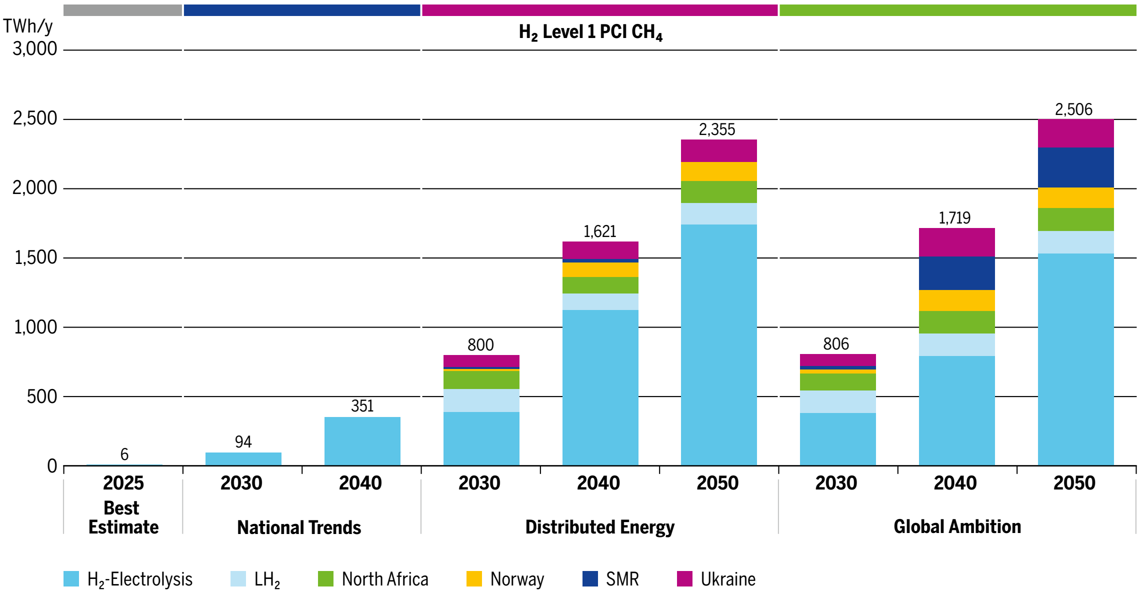


Figure 6.15 H_2 Yearly Supply Results in PCI CH_4 Infrastructure with H_2 Level 1

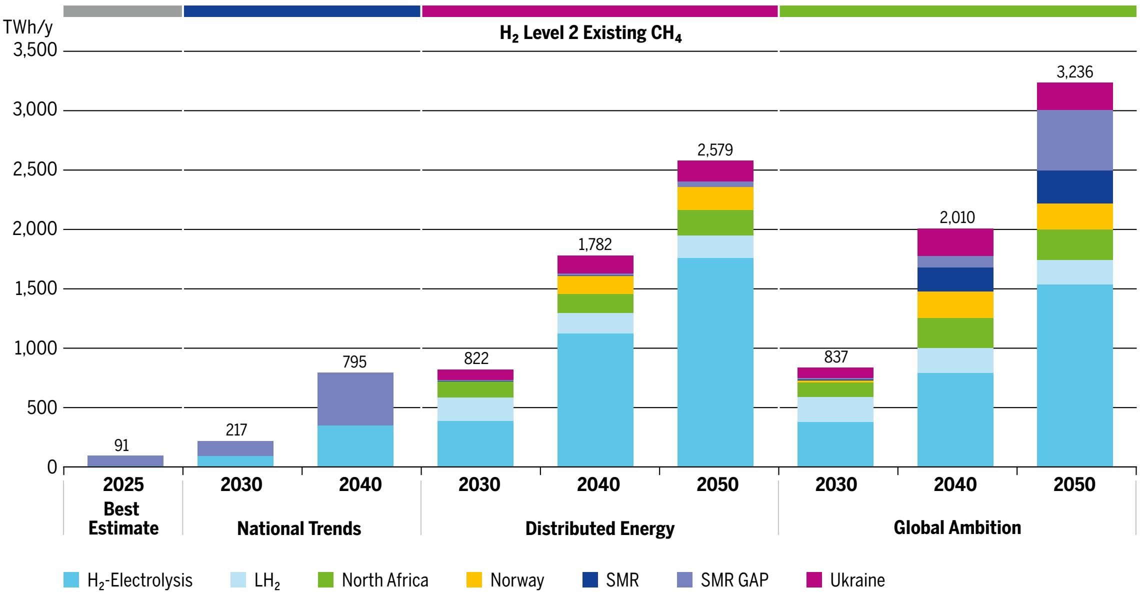


Figure 6.16 H_2 Yearly Supply Results in Existing CH_4 Infrastructure with H_2 Level 2

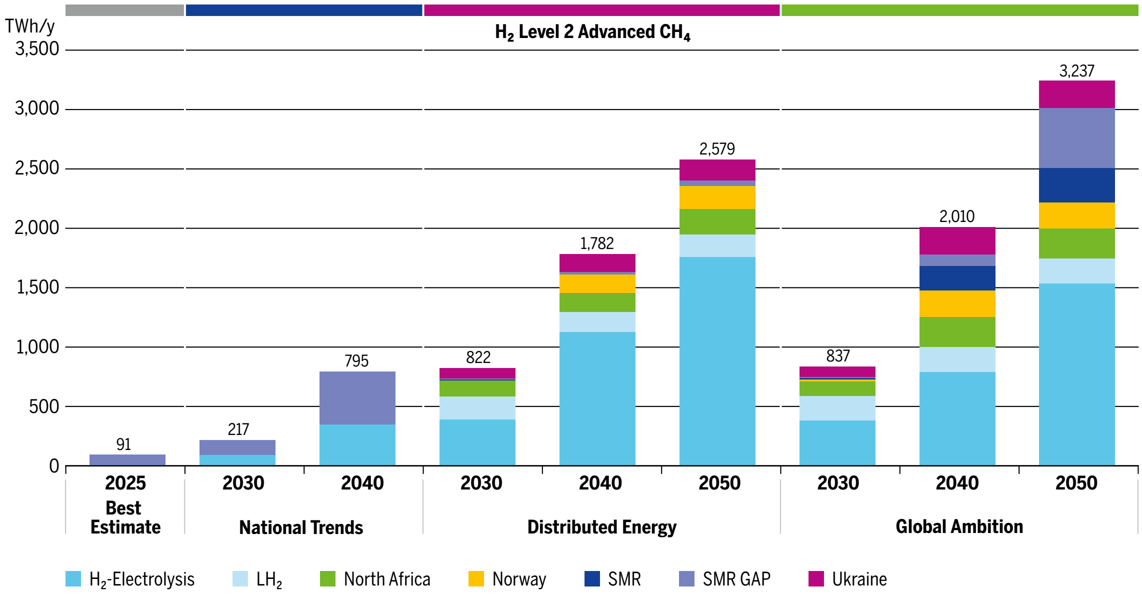


Figure 6.17 H_2 Yearly Supply Results in Advanced CH_4 Infrastructure with H_2 Level 2

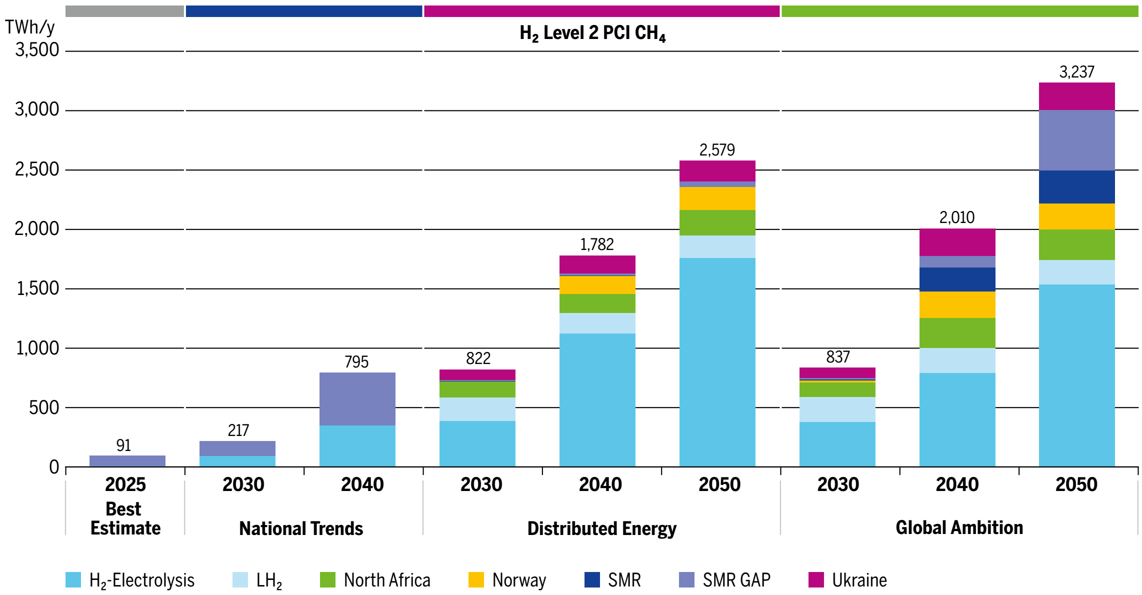


Figure 6.18 H_2 Yearly Supply Results in PCI CH_4 Infrastructure with H_2 Level 2

Picture courtesy of FGSZ

SIMULATION RESULTS

ENTSOG focuses the simulations on network-related demand and supply depending on the data availability. It should be noted that the simulations done for yearly demand and high demand situations (2-week, 2-week dunkelflaute and design case) are independent from each other. The fact that the maximum supply from LNG tanks and underground storages is only allowed for the high demand situations, as described in Annex D, explains the possibility to reduce the curtailment observed in the yearly results.

As for the **hydrogen system** no existing infrastructure level is available yet, and ENTSOG has identified a possible hydrogen network based on the information provided by promoters in their project submission for the TYNDP/PCI process (i. e., H_2 Infrastructure level). Therefore, the System Assessment shows the results that could be reached (for different timestamps) under the hypothesis of a full commissioning of the H_2 infrastructure projects submitted by project promoters but not yet in place. Therefore, each time results show no H_2 demand curtailment (e. g., Distributed Energy, average winter, 2030) these should not be read as an absence of H_2 infrastructure needs for the given scenario. On the contrary, the full availability of the planned infrastructures composing the H_2 Infrastructure level is assumed to avoid the potential demand curtailment.

Furthermore, the results are determined by the **behaviour of the model**, that does not factorise supply commercial agreements, and assumptions on infrastructure developments. Moreover, results are also impacted by the demand and supply figures adopted that, in some specific cases, refer to scenarios that have been defined a few years ago (i. e., National Trends).

It should be noted that the **scenario values for hydrogen** were determined by an expansion model as explained in the TYNDP 2022 Scenario report and its accompanying documents. However, an interlinked model with the electricity grid was also run after the scenarios were built, using the actual H_2 Infrastructure levels as well as the relevant electricity projects instead of the results of the expansion model that had delivered the scenario values. From these new simulations, the curves for hydrogen- and methane-fired power plants were retrieved as well as updated electrolytic hydrogen production values to maintain consistency with the electricity TYNDP. However, the location of the hydrogen production as well as its distribution over the year can also thereby change. This can affect the optimal specifications of the European hydrogen infrastructure.

7 REFERENCE CASE[18]

7.1 YEARLY DEMAND

7.1.1 METHANE RESULTS

7.1.1.1 Existing Methane Infrastructure

There is no risk of methane demand curtailment in any scenario except for Bosnia and Herzegovina. The results show an infrastructure limitation (i. e., bottleneck) between Serbia and Bosnia Herzegovina in all years and scenarios. In 2030 in the National Trends scenario, Germany and Czech Republic show 1 % and 3 % of demand curtailment respectively due to infrastructure limitations with other interconnected countries, not among themselves.

7.1.1.2 Advanced and PCI Infrastructure for methane

The risk of demand curtailment still exists in the PCI infrastructure level for Bosnia and Herzegovina but it is fully mitigated with the Advanced infrastructure level.

7.1.2 HYDROGEN RESULTS

In 2025 there is no hydrogen infrastructure considered in any of the two infrastructure levels (no difference between levels 1 and 2), and some European countries have no demand to satisfy.

7.1.2.1 Existing Methane Infrastructure

In H_2 Infrastructure Level 2, demand curtailment is fully mitigated in all years and scenarios, due to the upgraded hydrogen infrastructure , allowing for higher imports and better cooperation, and to additional hydrogen production using methane. The latter allows for the indirect usage of methane storages to satisfy the seasonal hydrogen demand. In these cases, the crucial role of dedicated hydrogen storages is mitigated. Therefore, only results for the **H_2 Infrastructure Level 1** are described in figure 7.1.

18 All results and maps will be available through the visualization platform, including those with no curtailments

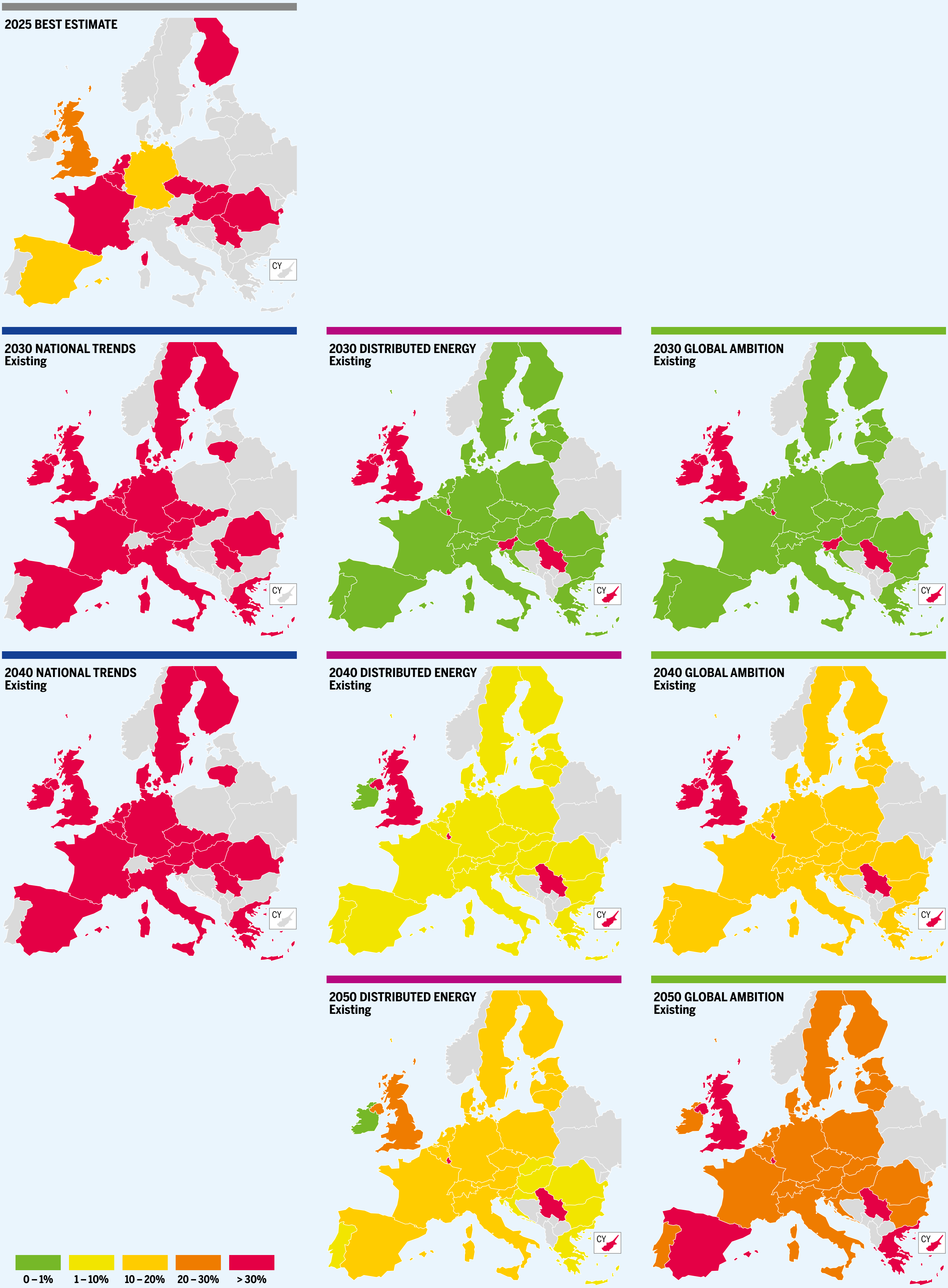


Figure 7.1 Hydrogen Results for Yearly Demand in Existing CH_4 Infrastructure and H_2 Level 1

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

In **Best Estimate** scenario, there is a hydrogen demand curtailment in countries with hydrogen demand. The hydrogen production of these countries does not satisfy their demand and there is no infrastructure for cooperation between countries. The following hydrogen demand curtailment rates could therefore be observed: Spain and Germany (15 %), United Kingdom (29 %), Czech Republic (91 %), Belgium (94 %), Hungary (96 %), Slovenia, Slovakia, The Netherlands (98 %), Latvia, Finland, France, Serbia and Romania (100 %).

2030

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, all countries with hydrogen demand show hydrogen demand curtailment. The hydrogen infrastructure allows cooperation between countries and demand curtailment is mitigated without any infrastructure limitations. Most countries show 63 % hydrogen demand curtailment. Some countries are not interconnected and show different hydrogen demand curtailment values: Slovenia (58 %), United Kingdom (86 %), Ireland (96 %) and Luxembourg (98 %).

In **Distributed Energy** scenario, assuming the commissioning of all the planned H_2 infrastructure there is no risk of hydrogen demand curtailment in most of the countries due to hydrogen imports from Norway, North Africa, Ukraine, and via Liquefied Hydrogen and SMR contribution (40 GWh/d). The following countries show hydrogen demand curtailment due to missing interconnections with neighbouring countries: United Kingdom (46 %), Ireland (33 %), Luxembourg (61 %), Slovenia (86 %), Croatia (1 %) and Serbia (100 %). Their own hydrogen production cannot satisfy their demand.

In **Global Ambition** scenario, assuming the commissioning of all the planned H_2 infrastructure there is no risk of hydrogen demand curtailment in most of the countries due to hydrogen import from Norway, North Africa, Ukraine and via Liquefied Hydrogen and SMR contribution (68 GWh/d). The following countries show hydrogen demand curtailment due to missing interconnections with neighbouring countries: United Kingdom (46 %), Ireland (37 %), Luxembourg (55 %), Slovenia (89 %) and Serbia (100 %). Their own hydrogen production cannot satisfy their demand.

2040

The curtailed demand that occurs for the observed scenarios in 2040 under normal conditions requires further explanation. For this TYNDP, a monthly granularity is used in the ENTSOG System Assessment simulations. Thus, a displayed average curtailment rate for a country can be potentially caused by curtailments of a shorter duration than a full year. The main reason for curtailed demand thereby is the seasonality of hydrogen demand and electrolytic hydrogen production. This seasonality cannot be sufficiently buffered by hydrogen import infrastructure or hydrogen storages. More details are given for the individual scenarios.

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, all countries with hydrogen demand show demand curtailment. The hydrogen infrastructure allows cooperation between most countries and hydrogen demand curtailment is then mitigated in a cooperative manner. Thus, these countries all show 54 % of hydrogen demand curtailment. The Netherlands shows 57 % demand curtailment since Belgium and Germany cannot cooperate further due to infrastructure limitations. Some countries are not interconnected and therefore show different hydrogen demand curtailment values: Slovenia (53 %), United Kingdom (94 %), Ireland (80 %) and Luxembourg (98 %).

In **Distributed Energy** scenario, despite the import of hydrogen and hydrogen production through SMR, most of the countries show 2 % to 5 % hydrogen demand curtailment. Hydrogen import options are only during the winter used at the maximum value allowed by infrastructure limitations. In other seasons, the import is significantly reduced compared to its infrastructure limits due to the preferential production of electrolytic hydrogen within the EU. In winter, the seasonally decreased electrolytic hydrogen production plus the hydrogen imports cannot satisfy the seasonally increased demand. Thus, in most countries the curtailment is observed only in the winter months. This situation could be at least partially mitigated by additional storage capacity since then more hydrogen could be imported along the year. Ireland is not connected with other countries and can satisfy its demand with its own production. Other countries that are not interconnected show different levels of hydrogen demand curtailment: United Kingdom (67 %), Luxembourg (83 %) and Serbia (100 %).

In **Global Ambition** scenario, with less hydrogen production all countries show demand curtailment. Most countries show 12 % of hydrogen demand curtailment. All hydrogen import options are used at a stable value that is as high as allowed by infrastructure limitations. However, the electrolysers cannot produce sufficient additional hydrogen in winter months, when lower electrolytic hydrogen production meets increased hydrogen demand, causing curtailment. This situation could be partially mitigated by additional hydrogen storages. The Baltic states (Lithuania, Latvia and Estonia) show 14 % of hydrogen demand curtailment and cannot cooperate more with Poland and the rest of the European Union's Member States due to an infrastructure limitation between Lithuania and Poland.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, all countries show hydrogen demand curtailment. Only Ireland with its own hydrogen production can satisfy its demand. Most countries show 15 % of hydrogen demand curtailment. The demand is curtailed during autumn and winter since seasonally increased hydrogen demand meets seasonally decreased electrolytic hydrogen production and maxed-out infrastructure that serves hydrogen imports. However, during summer and spring, more hydrogen could be imported if more storage capacity was available. The Eastern countries (Greece, Bulgaria, Slovakia, Croatia, Hungary and Romania show 4 % hydrogen demand curtailment and cannot cooperate more with interconnected countries due to infrastructure limitations. Portugal shows 6 % hydrogen demand curtailment and cannot cooperate more with Spain to mitigate its demand curtailment due to an infrastructure limitation between Portugal and Spain. Some countries that are not interconnected show higher hydrogen demand curtailments: United Kingdom (26 %), Luxembourg (87 %) and Serbia (100 %).

In **Global Ambition** scenario, all countries show hydrogen demand curtailment during the whole year. Ireland with its own hydrogen production shows 22 % hydrogen demand curtailment. The curtailment rate is elevated in winter compared to summer due to the seasonality of hydrogen demand and electrolytic supply while all import routes are used at their technical limit all the year. Most countries show 27 % hydrogen demand curtailment. Greece and Bulgaria show respectively 37 % and 29 % hydrogen demand curtailment. Infrastructure limitations do not allow Romania to mitigate demand curtailment in Bulgaria, while this reason limits Bulgaria to assist Greece. Spain shows 32 % hydrogen demand curtailment and Portugal and France cannot mitigate demand curtailment in Spain due to infrastructure limitations between France and Spain and from Portugal and Spain. It should be noted that the scenarios do not take into account the latest governmental agreements between Portugal, Spain, France, and Germany that envisage the Iberian Peninsula to be an exporter of hydrogen. Some countries that are not interconnected show higher hydrogen demand curtailments: United Kingdom (45 %), Luxembourg (91 %) and Serbia (100 %).

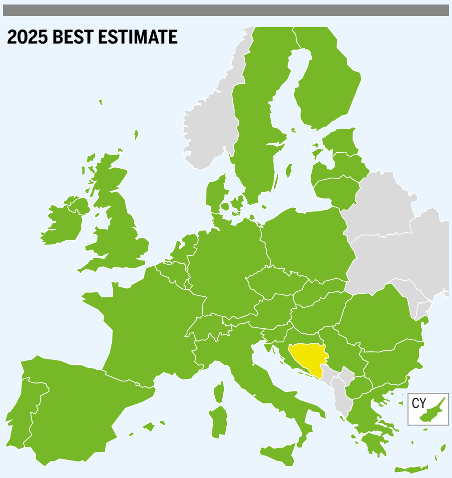
7.1.2.2 Advanced and PCI Infrastructure levels for methane

The situation remains unchanged in all years and demand scenarios compared to the existing methane infrastructure level. Additional flexibility on the methane infrastructure does not allow to produce more hydrogen using methane as hydrogen production using methane is capped to the scenario-based values when modelling the H_2 Infrastructure Level 1.

7.2 2-WEEK COLD SPELL DEMAND

7.2.1 METHANE RESULTS

7.2.1.1 Existing Methane Infrastructure



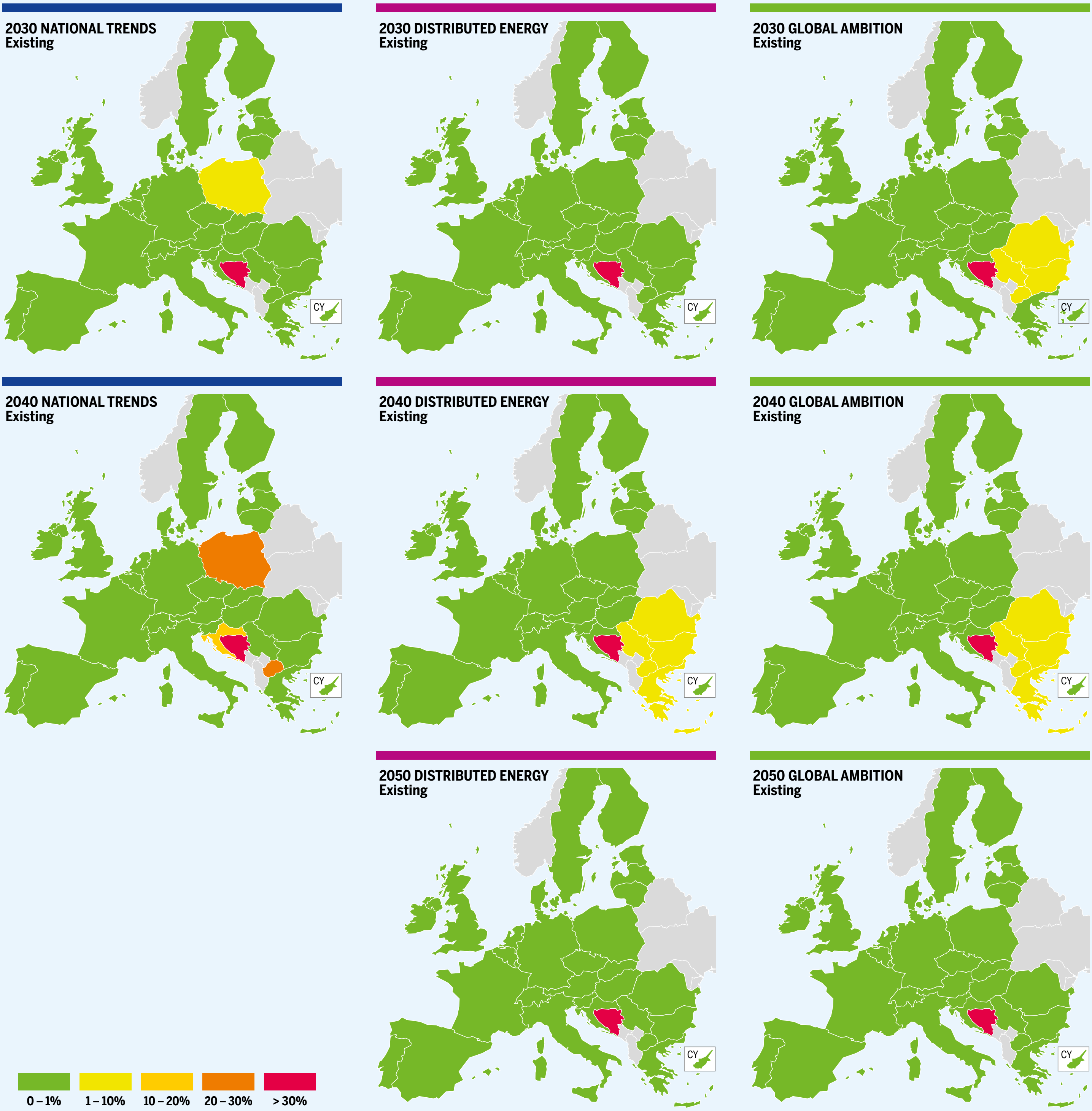


Figure 7.2 Methane Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 1

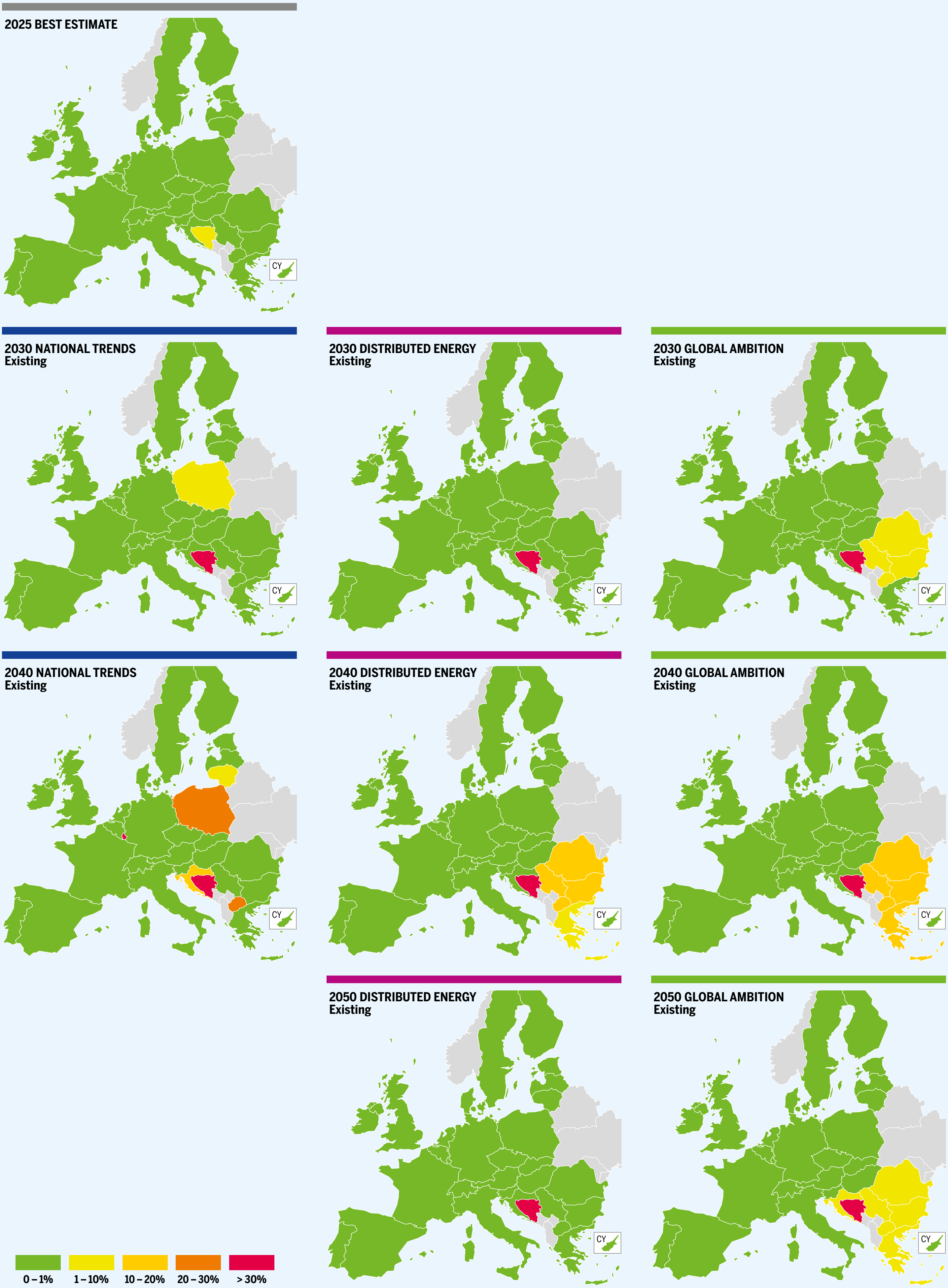


Figure 7.3 Methane Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 2

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

In **Best estimate** scenario, all Member States of the European Union satisfy their methane demand due to the available supply and sufficient interconnection capacities, while Bosnia and Herzegovina cannot satisfy its methane demand due to an infrastructure limitation with Serbia.

H_2 INFRASTRUCTURE LEVEL 2

In **Best Estimate** scenario, there is no difference within H_2 Infrastructure Level 1 and 2.

2030

In all demand scenarios, and both infrastructure levels 1 and 2, Bosnia and Herzegovina shows a methane demand curtailment (54 %).

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, Poland shows 2 % methane demand curtailment due to infrastructure limitations with neighbouring countries.

In **Distributed Energy** scenario, all countries can satisfy their methane demand.

In **Global Ambition** scenario, the Eastern countries Bulgaria, Serbia, North Macedonia and Romania show 1 % methane demand curtailment. Infrastructure limitations do not allow neighbouring countries to cooperate more to mitigate methane demand curtailments.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends and Distributed Energy** scenarios, the situation is the same as for the H_2 Infrastructure Level 1.

In **Global Ambition** scenario, Bulgaria, Serbia, North Macedonia and Romania show 2 % methane demand curtailment. Additional hydrogen production using methane and infrastructure limitations with neighbouring countries increase the methane demand curtailment of 1 % in H_2 Infrastructure Level 1.

2040

In all demand scenarios and both H_2 infrastructure levels, Bosnia and Herzegovina shows a methane demand curtailment (64 %).

H_2 INFRASTRUCTURE LEVEL 1

In the **National Trends** scenario, Poland (21 %), Croatia (14 %) and North Macedonia (21 %) show methane demand curtailment due to infrastructure limitations with neighbouring countries.

In **Distributed Energy** scenario, Bulgaria, Greece, Serbia, North Macedonia, and Romania show 2 % methane demand curtailment. Hydrogen production using methane create methane demand curtailment in these countries and infrastructure limitations do not neighbouring countries to cooperate more to mitigate the methane demand curtailment.

In **Global Ambition** scenario, Bulgaria, Greece, Serbia, North Macedonia, and Romania show 2 % methane demand curtailment. Hydrogen production using methane creates demand curtailment in these countries and infrastructure limitations do not allow neighbouring countries to cooperate more and to mitigate demand curtailment.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, Poland increases its methane demand curtailment by +1 % compared with H_2 Infrastructure Level 1 to 22 % due to additional hydrogen production using methane. The situation remains unchanged for Croatia and North Macedonia. Lithuania shows 2 % methane demand curtailment due to infrastructure limitations with Latvia and additional hydrogen production using methane. Luxembourg shows 21 % methane demand curtailment due to hydrogen production using methane that triggers infrastructure limitations with neighbouring countries Belgium and Germany.

In **Distributed Energy** scenario, Bulgaria, Serbia, North Macedonia, and Romania increase their methane demand curtailment to 12 % due to higher hydrogen production using methane and infrastructure limitations with neighbouring countries. Greece shows only 2 % of methane demand curtailment and cannot cooperate more with Bulgaria due to an infrastructure limitation.

In **Global Ambition** scenario, Bulgaria, Greece, Serbia, North Macedonia, and Romania increase their methane demand curtailment to 16 % due to higher hydrogen production using methane and infrastructure limitations with neighbouring countries.

2050

In all demand scenarios, and both H_2 infrastructure levels, Bosnia and Herzegovina shows methane demand curtailment (64 %).

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy and the Global Ambition** scenarios, all countries can satisfy their methane demand.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, the situation is the same as observed for H_2 Infrastructure Level 1. Thus, all countries can satisfy their methane demand.

In **Global Ambition** scenario, Bulgaria, Greece, Serbia, North Macedonia, and Romania increase their methane demand curtailment to 9 % and Croatia shows 1 % methane demand curtailment due to higher hydrogen production using methane and infrastructure limitations with neighbouring countries.

7.2.1.2 Advanced and PCI Infrastructure levels for methane

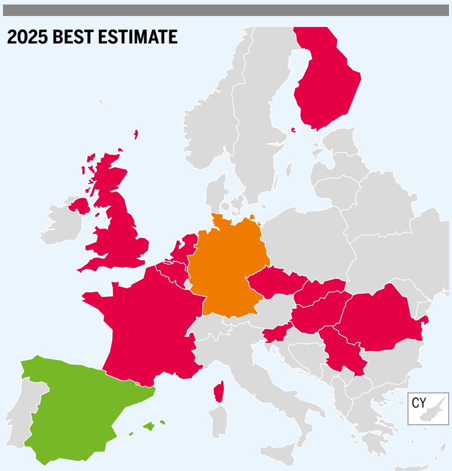
In the Advanced Infrastructure level in comparison with the Existing Methane Infrastructure level, the methane demand curtailment is fully mitigated in all countries except in Poland in 2040 in the National Trends scenario in both hydrogen infrastructure levels. Poland decreases its methane demand curtailment to 9 % due to additional LNG send-out capacities in the Advanced Infrastructure level. Bosnia and Herzegovina fully mitigates its methane demand curtailment due to the new interconnection with Croatia and the Trans Adriatic Pipeline.

When comparing the PCI Infrastructure level with the existing methane infrastructure level, the methane demand curtailment is fully mitigated in all countries except for Bosnia and Herzegovina as well as Poland. In Bosnia and Herzegovina, the situation remains unchanged. Poland faces methane demand curtailment in 2040 in the National Trends scenario in both hydrogen infrastructure levels. This methane demand curtailment is reduced to 9 % due to additional LNG send-out capacities in the PCI Infrastructure level.


Picture courtesy of Teréga

7.2.2 HYDROGEN RESULTS

7.2.2.1 Existing Methane Infrastructure



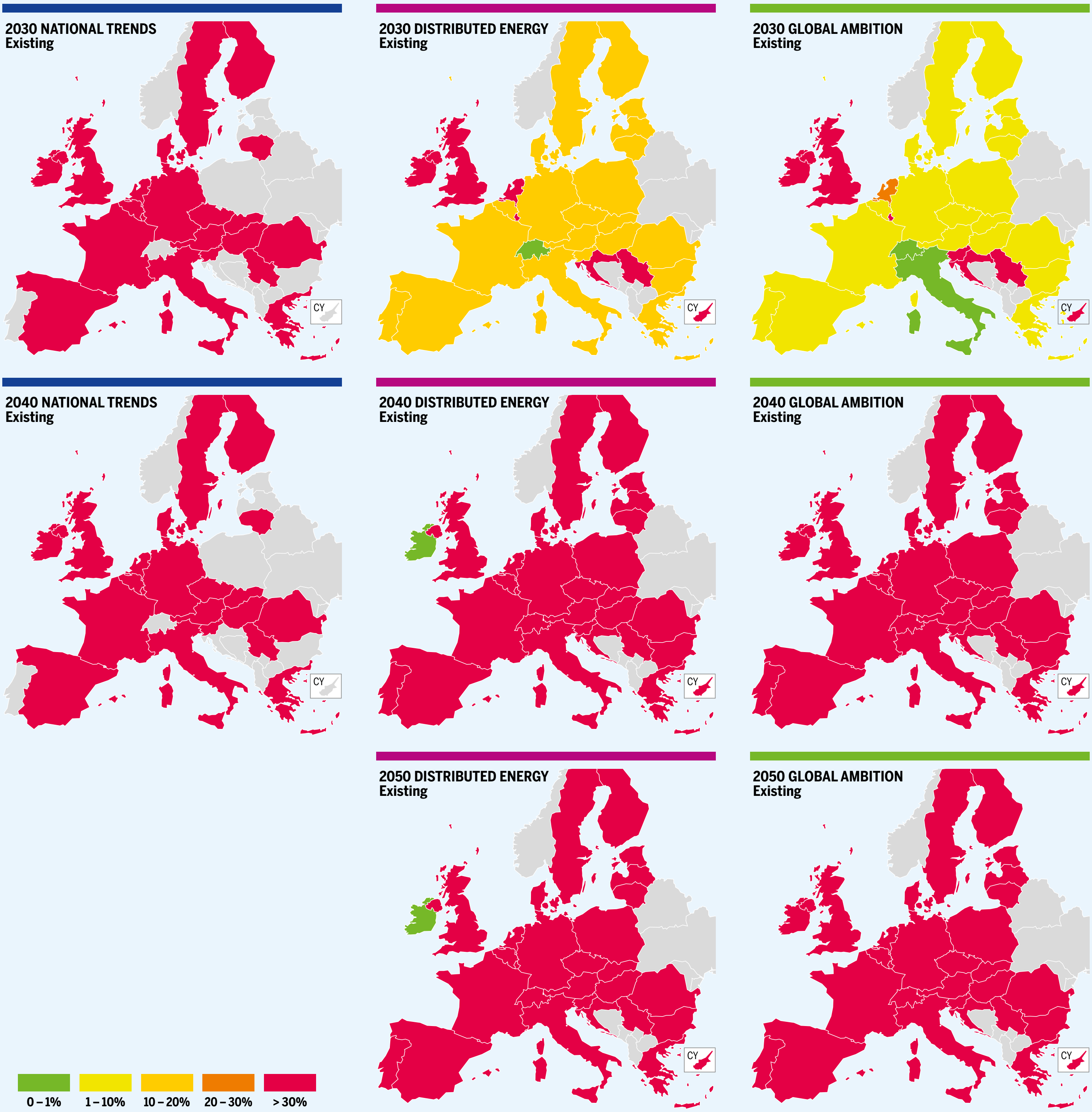


Figure 7.4 Hydrogen Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 1

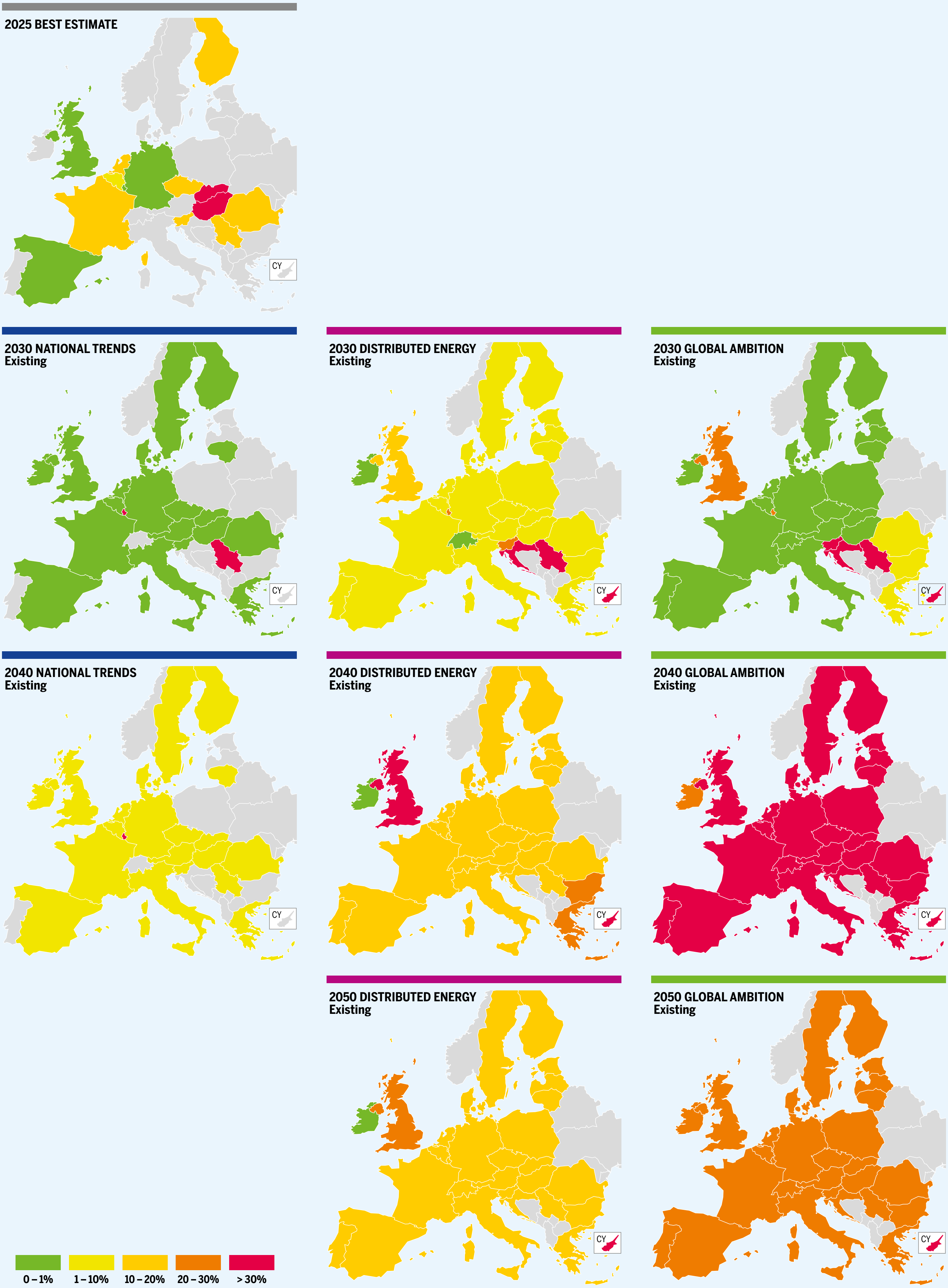


Figure 7.5 Hydrogen Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 2

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

All countries with demand except for Spain show demand curtailment of 22 % to 100 %. Their national production cannot satisfy their demand. Spain satisfies its demand with its own production.

H_2 INFRASTRUCTURE LEVEL 2

Additional hydrogen produced using methane, taking advantage of the methane infrastructure flexibility, mitigates the hydrogen demand curtailment. While it can be fully mitigated in Germany and the United Kingdom, the other countries mitigate partially their hydrogen demand curtailment.

2030

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, all countries with hydrogen demand face a hydrogen demand curtailment. Without any imports and hydrogen production using methane infrastructure, most countries show 72 % hydrogen demand curtailment. Greece shows 57 % hydrogen demand curtailment and cannot cooperate with other countries due to infrastructure limitations. The Netherlands shows 77 % hydrogen demand curtailment and Belgium and Germany cannot cooperate more due to infrastructure limitations. Some countries are not interconnected and can only partially satisfy their demand with their own production, leading to the following hydrogen demand curtailments: Slovenia (65 %), United Kingdom (87 %), Ireland (97 %), Luxembourg (97 %) and Serbia (100 %).

In **Distributed Energy** scenario, all countries show a hydrogen demand curtailment. Most countries show 11 % hydrogen demand curtailment. The Eastern countries Greece, Bulgaria, Romania and Hungary show 17 % hydrogen demand curtailment and countries in the North and West cannot cooperate with them due to infrastructure limitations. The Netherlands shows 31 % hydrogen demand curtailment and Belgium and Germany cannot cooperate more due to infrastructure limitations. Croatia (38 %), Slovenia (89 %), Serbia (100 %), Luxembourg (70 %), United Kingdom (71 %) and Ireland (43 %) are not interconnected with other countries and cannot fully satisfy their hydrogen demand with their own national production.

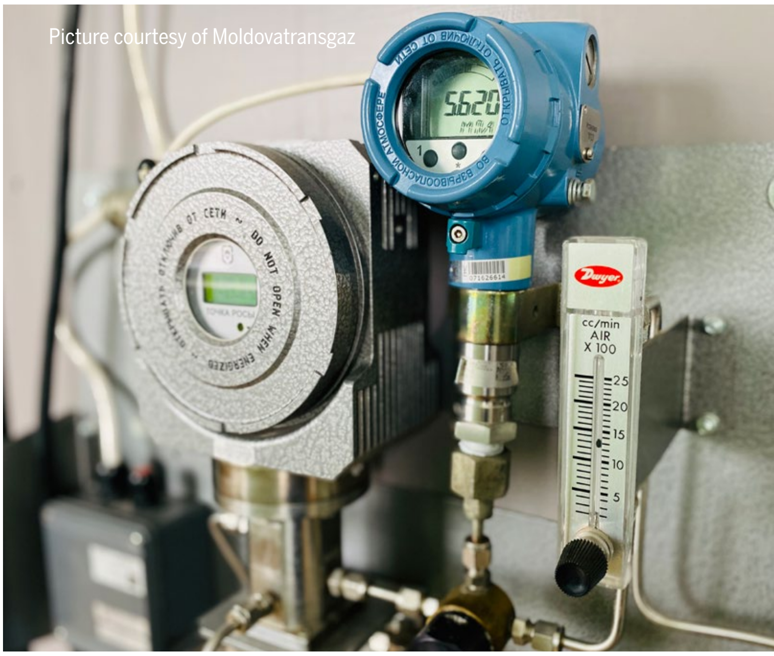
In **Global Ambition** scenario, most of the countries show 2 % hydrogen demand curtailment. Italy shows no hydrogen demand curtailment due to the North African supply, ., but it cannot cooperate more as the infrastructure with Austria is fully used. Infrastructure limitations restrict Italy's cooperation with the connected country Austria.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, due to new interconnections and additional hydrogen production using methane, demand curtailment is fully mitigated in all countries in comparison with the H_2 Infrastructure Level 1. Luxembourg (37 %) and Serbia (47 %) show hydrogen demand curtailments due to missing interconnections and limited access to hydrogen production using methane.

In **Distributed Energy** scenario, due to new interconnections and additional hydrogen production using methane, most of the countries mitigate their demand curtailment to 3 % in comparison with the H_2 Infrastructure Level 1. Ireland fully mitigates its hydrogen demand curtailment. The Eastern countries Greece, Bulgaria, Romania and Hungary mitigate their hydrogen demand curtailment to 9 %. The United Kingdom (19 %), Luxembourg (15 %), Slovenia (29 %), Croatia (41 %) and Serbia (41 %) partially mitigate their hydrogen demand curtailment.

In **Global Ambition** scenario, most countries fully mitigate their hydrogen demand curtailment. Romania, Greece, Bulgaria and Hungary mitigate their demand hydrogen curtailment to 1 %. The United Kingdom (27 %), Luxembourg (17 %), Slovenia (32 %), Croatia (40 %) and Serbia (41 %) partially mitigate their hydrogen demand curtailment.



Picture courtesy of Moldovatransgaz

2040

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, all countries with hydrogen demand show demand curtailment. Without any supply and hydrogen production using methane infrastructure, most countries show 57 % of hydrogen demand curtailment. The Netherlands shows 89 % hydrogen demand curtailment and Belgium and Germany cannot cooperate more due to infrastructure limitations. Countries that are not interconnected show higher demand curtailments: Ireland (85 %), United Kingdom (95 %), Luxembourg (97 %) and Serbia (100 %).

In **Distributed Energy** scenario, all countries show a hydrogen demand curtailment. Most countries show 34 % hydrogen demand curtailment. Countries not interconnected show higher demand curtailments: Serbia (100 %), Luxembourg (87 %) and United Kingdom (83 %). Ireland satisfies its hydrogen demand due to sufficient national hydrogen production.

In **Global Ambition** scenario, all countries show a hydrogen demand curtailment. Most countries show 50 % hydrogen demand curtailment. Countries not interconnected show higher demand curtailments: Serbia (100 %), Luxembourg (91 %), Ireland (65 %) and United Kingdom (85 %).

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, due to new interconnections and additional hydrogen production using methane, most of the countries mitigate their hydrogen demand curtailment to 1 % in comparison with the H_2 Infrastructure Level 1. Only Luxembourg shows 21 % hydrogen demand curtailment due to missing interconnections and limited access to hydrogen production using methane.

In the **Distributed Energy** scenario, most of the countries mitigate their hydrogen demand curtailment to 19 % in comparison with the H_2 Infrastructure Level 1. The Eastern countries Serbia, Croatia, Romania, Hungary and Slovakia show 16 % hydrogen demand curtailment and cannot cooperate with other countries due to infrastructure limitations. Greece and Bulgaria show 28 % hydrogen demand curtailment and Romania cannot cooperate more with Bulgaria due to an infrastructure limitation. Ireland is the only country that can fully mitigate its demand curtailment. The United Kingdom shows 32 % hydrogen demand curtailment.

In **Global Ambition** scenario, all countries mitigate their hydrogen demand curtailment in comparison with the H_2 Infrastructure Level 1. Most of the countries mitigate their hydrogen demand curtailment to 32 %. Ireland mitigates its hydrogen demand curtailment to 22 % and the United Kingdom to 35 %.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most countries show 43 % hydrogen demand curtailment. The Eastern countries Greece, Bulgaria, Slovakia, Hungary, Croatia and Romania show 32 % hydrogen demand curtailment and cannot cooperate more with interconnected countries in the North due to infrastructure limitations. Ireland can satisfy its demand with its own production and countries not interconnected show higher demand curtailments: Serbia (100 %), Luxembourg (90 %) and United Kingdom (57 %).

In the **Global Ambition** scenario, all countries show hydrogen demand curtailment. Most countries show 59 % hydrogen demand curtailment. Ireland shows 51 % hydrogen demand curtailment and cannot satisfy its demand with its own production. Greece shows 65 % hydrogen demand curtailment, and a bottleneck does not allow Bulgaria to cooperate more to mitigate further the demand curtailment in Greece. Some countries not interconnected show higher demand curtailments: Serbia (100 %), Luxembourg (94 %) and United Kingdom (68 %).

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, due to new interconnections and additional hydrogen production using methane, Ireland fully mitigates its hydrogen demand curtailment and the other countries mitigate their hydrogen demand curtailment to 18 % in comparison with the H_2 Infrastructure Level 1. The Eastern countries Greece, Bulgaria, Serbia, Slovakia, Croatia, Romania and Hungary mitigate their hydrogen demand curtailment to 15 %. The United Kingdom mitigates its hydrogen demand curtailment to 27 % and Belgium and Ireland cannot cooperate more with United Kingdom due to infrastructure limitations.

In **Global Ambition** scenario, due to new interconnections and additional hydrogen production using methane, all countries mitigate their demand curtailment in comparison with the H_2 Infrastructure Level 1. Most countries show 21 % of hydrogen demand curtailment. Greece, Bulgaria, and Romania mitigate their hydrogen demand curtailment to 25 %.

Picture courtesy of GRTgaz

7.2.2.2 Advanced and PCI Infrastructure levels for methane

The Advanced and PCI Infrastructure levels for methane do not show any different hydrogen curtailment rates in comparison with the Existing Methane Infrastructure level. The hydrogen infrastructure is limited to how much methane can be used to produce hydrogen and the Advanced and PCI Infrastructure levels do not add any additional hydrogen production possibilities.

7.3 2-WEEK DUNKELFLAUTE DEMAND

The 2-Week Dunkelflaute country demands are generally very similar to the 2-Week Cold Spell demand values. Hydrogen demand is the same for Best Estimate and National Trends scenarios and it is also the same in the year 2030 of Distributed Energy and Global Ambition scenarios. Regarding Distributed Energy and Global Ambition scenarios in 2040 and 2050, only Italy, The Netherlands, Romania and United Kingdom show higher values in 2-Week Dunkelflaute.

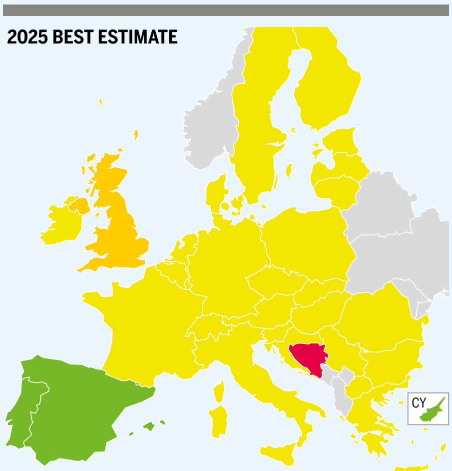
Regarding the methane demand values, only Bulgaria, Czech Republic, Germany, Croatia and Italy present slight differences when comparing demand of 2-Week Dunkelflaute with 2-Week Cold in Best Estimate and National trends scenarios. In Distributed Energy and Global Ambition scenarios just Spain, France, Greece, Italy, The Netherlands, Portugal, Romania and United Kingdom present higher methane demand in 2-Week Dunkelflaute.

Consequently, the curtailment rate results in 2-Week Dunkelflaute and in 2-Week Cold Spell are exactly the same for most of the countries. The countries with higher demand in 2-Week Dunkelflaute are only increasing their demand curtailment rate in 1 or 2 % maximum.

7.4 PEAK DEMAND

7.4.1 METHANE RESULTS

7.4.1.1 Existing Methane Infrastructure



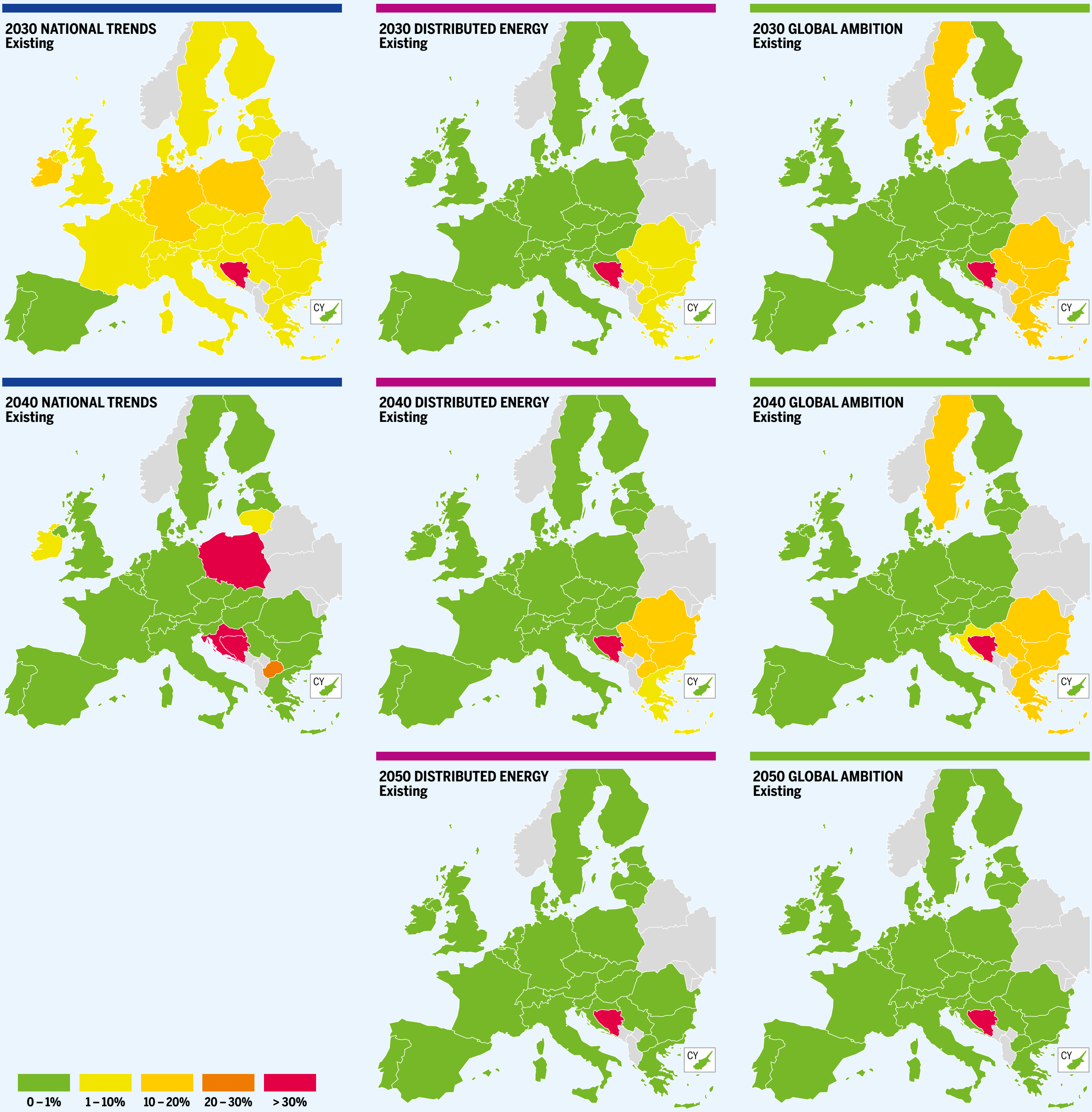


Figure 7.6 Methane Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 1

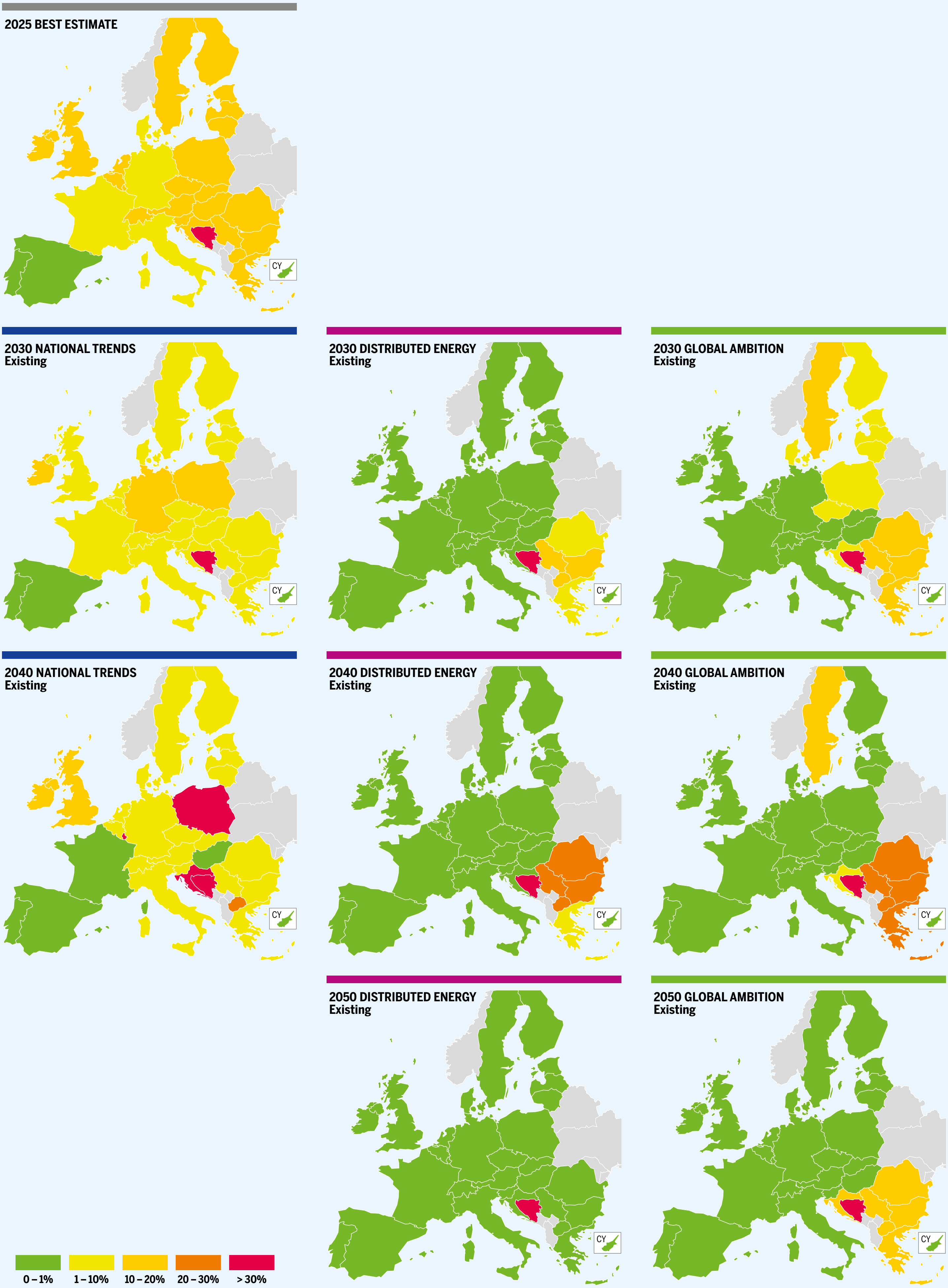


Figure 7.7 Methane Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 2

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

Most countries show 8 % to 9 % methane demand curtailment. Supply cannot satisfy demand and infrastructure allows countries to cooperate to mitigate demand curtailment in a cooperative manner. The United Kingdom (10 %), Ireland (9 %) and Bosnia and Herzegovina (61 %) show more methane demand curtailment due to infrastructure limitations with neighbouring countries. Spain and Portugal do not show any demand curtailment due to supply flexibility (LNG). They cannot cooperate more with France due to infrastructure limitations.

H_2 INFRASTRUCTURE LEVEL 2

Methane demand curtailment increases by 1 % to 2 %, while its stable in Bosnia and Herzegovina, due to hydrogen production using methane.

2030

In both H_2 infrastructure levels and all scenarios, Bosnia and Herzegovina shows 79 % methane demand curtailment due to an infrastructure limitation with Serbia.

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, most of the countries show a methane demand curtailment. Infrastructure limitations do not allow them to fully cooperate to mitigate the methane demand curtailment to reach the same level across Europe. Spain and Portugal do not show any methane demand curtailment due to their supply flexibility (LNG). Most of the countries show 3 % to 4 % methane demand curtailment. United Kingdom, Belgium and The Netherlands show 6 % methane demand curtailment and France cannot cooperate more due to infrastructure limitations to mitigate demand curtailment in Belgium. Ireland shows 13 % methane demand curtailment and the United Kingdom cannot cooperate more with Ireland to mitigate demand curtailment due to infrastructure limitations. Germany and Poland show respectively 10 % and 14 % methane demand curtailment and countries interconnected cannot cooperate more with them to mitigate their demand curtailment due to infrastructure limitations.

In **Distributed Energy** scenario, most countries can satisfy their demand. Only the Eastern countries Romania, Serbia, Bulgaria, North Macedonia and Greece show 7 % methane demand curtailment. Infrastructure limitations do not allow other countries to increase their cooperation to mitigate the methane demand curtailment in the mentioned countries.

In **Global Ambition** scenario, most countries can satisfy their demand. The Eastern countries Romania, Serbia, Bulgaria, North Macedonia and Greece show 17 % methane demand curtailment. Infrastructure limitations do not allow other countries to increase their cooperation to mitigate the methane demand curtailment in the mentioned countries. Sweden shows 17 % methane demand curtailment due to a very high estimation of the methane peak demand and an infrastructure limitation with Denmark.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, most countries with low demand curtailments show additional demand curtailment of 1 % due to additional hydrogen production using methane in comparison with the H_2 Infrastructure Level 1.

In the **Distributed Energy** scenario, countries in the East increase their methane demand curtailment to 9 % to 10 % due to additional hydrogen production using methane in comparison with the H_2 Infrastructure Level 1.

In **Global Ambition** scenario, Eastern curtailed countries in H_2 Infrastructure Level 1 show additional methane demand curtailment of 1 % due to additional hydrogen production using methane. Poland, Denmark, Czech Republic, Slovakia, Lithuania, Latvia, Estonia and Finland show methane demand curtailments of 1 % to 2 %. Sweden decreases its methane demand curtailment to 10 % due to a new hydrogen interconnection from Finland which leads to a decreased production of hydrogen using methane.

2040

In both H_2 infrastructure levels and all scenarios, Bosnia and Herzegovina shows 84 % methane demand curtailment due to an infrastructure limitation with Serbia.

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, several countries show a methane demand curtailment. Ireland (6 %), Croatia (30 %), and North Macedonia (21 %) show methane demand curtailment due to infrastructure limitations with neighbouring countries. In Poland, infrastructure limitations from neighbouring countries limit cooperation. Poland shows 31 % methane demand curtailment. Lithuania shows 5 % methane demand curtailment due to an infrastructure limitation with Latvia.

In **Distributed Energy** scenario, most countries can satisfy their demand. The Eastern countries Romania, Serbia, Bulgaria, and North Macedonia show 11 % demand curtailment. Infrastructure limitations do not allow other countries to increase their cooperation to mitigate their methane demand curtailment. Greece shows 9 % methane demand curtailment and cannot cooperate more with Bulgaria due to an infrastructure limitation.

In **Global Ambition** scenario, most of the countries can satisfy their demand. The Eastern countries Romania, Serbia, Bulgaria, North Macedonia and Greece shows 12 % methane demand curtailment. Infrastructure limitations do not allow other countries to increase their cooperation to mitigate their methane demand curtailment. Croatia shows 8 % methane demand curtailment and infrastructure limitations do not allow interconnected countries to cooperate more with Croatia to mitigate its demand curtailment. Sweden shows 11 % curtailment rate due to a very high projection of the methane peak demand and a bottleneck with Denmark.

H_2 INFRASTRUCTURE LEVEL 2

All changes described in this section are in comparison with the H_2 Infrastructure Level 1.

In **National Trends** scenario, with additional hydrogen production using methane and repurposed infrastructures, most of the countries show 5 % to 6 % methane demand curtailment. Luxembourg shows 36 % methane demand curtailment due to hydrogen production using methane that triggers infrastructure limitations with neighbouring countries Belgium and Germany. The United Kingdom and Ireland show 10 % methane demand curtailment and Belgium and The Netherlands cannot cooperate more to mitigate the methane demand curtailment due to infrastructure limitations with the United Kingdom.

In **Distributed Energy** scenario, the Eastern countries Romania, Serbia, Bulgaria and North Macedonia increase their methane demand curtailment to 24 % due to additional hydrogen production using methane.

In **Global Ambition** scenario, the Eastern countries Romania, Serbia, Bulgaria and North Macedonia increase their methane demand curtailment to 27 % due to additional hydrogen production using methane.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** and **Global Ambition** scenarios, all countries can satisfy their demand except for Bosnia and Herzegovina with 84 % methane demand curtailment due to an infrastructure bottleneck with Serbia.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, all countries can satisfy their demand.

In **Global Ambition** scenario, the Eastern countries Romania, Serbia, Bulgaria and Greece show 18 % demand curtailment and Croatia shows 13 % due to infrastructure limitations with countries in the West and additional hydrogen production using methane.

7.4.1.2 Advanced Methane Infrastructure

The Advanced Infrastructure level for methane improves the situation in all scenarios and years and for all countries.

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

In **Best Estimate** scenario, most countries fully mitigate their methane demand curtailment. Ireland and the United Kingdom mitigate their methane demand curtailment to 5 %.

H_2 INFRASTRUCTURE LEVEL 2

In **Best Estimate** scenario, most countries show 1 % methane demand curtailment due to additional hydrogen production using methane.

2030

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, all countries fully mitigate their demand curtailment except for Ireland. The situation remains unchanged for Ireland in comparison with the Existing Methane Infrastructure level due to an infrastructure limitation with the United Kingdom.

In **Distributed Energy** scenario, all countries fully mitigate their methane demand curtailment.

In **Global Ambition** scenario, all countries fully mitigate demand curtailment except for Sweden where the situation remains unchanged compared to the Existing Methane Infrastructure.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, the methane results remains unchanged in comparison with the H_2 Infrastructure Level 1.

In **Distributed Energy** scenario, the methane results remains unchanged in comparison with the H_2 Infrastructure Level 1.

In **Global Ambition** scenario, Sweden mitigates its methane demand curtailment to 10 % due to a new hydrogen interconnection with Finland which allows Sweden to decrease its hydrogen production using methane.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, all countries fully mitigate their methane demand curtailment except Ireland (6 %) and Poland (19 %) only partially mitigating their demand curtailment.

In **Distributed Energy** scenario, all countries fully mitigate their methane demand curtailment.

In **Global Ambition** scenario, all countries fully mitigate their methane demand curtailment except Sweden. Sweden shows 11 % methane demand curtailment as for the Existing Methane Infrastructure level due to a very high methane peak demand.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, due to additional hydrogen production using methane, Ireland and the United Kingdom increase their methane demand curtailment to 10 %. Poland also increases its methane demand curtailment to 20 %, i. e., 1 % more than for the H_2 Infrastructure Level 1. Luxembourg shows 36 % methane demand curtailment due to hydrogen production using methane that triggers infrastructure limitations with neighbouring countries Belgium and Germany as for the Existing Methane Infrastructure level.

In **Distributed Energy** scenario, there is no methane demand curtailment as for the H_2 Infrastructure Level 1.

In **Global Ambition** scenario, the Eastern countries Romania, Serbia, Bulgaria and Greece increase their methane demand curtailment to 27 % due to additional hydrogen production using methane and limited connections with the West.

2050

In both H_2 Infrastructure levels, in all scenarios, methane demand curtailment is fully mitigated in 2050.

7.4.1.3 PCI Methane Infrastructure level

The situation remains unchanged for Bosnia and Herzegovina in all scenarios and years compared to the Existing Methane Infrastructure level.

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

In **Best Estimate** scenario, the methane demand curtailment is mitigated to 7 % in all curtailed countries in the Existing Methane Infrastructure level.

H_2 INFRASTRUCTURE LEVEL 2

In **Best Estimate** scenario, the situation remains unchanged in comparison with the Existing Methane Infrastructure level.

2030

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, several countries fully mitigate or partially mitigate their methane demand curtailment. Belgium, The Netherlands, Sweden, Denmark and Switzerland mitigate their methane demand curtailment to 1 %. Germany mitigates its methane demand curtailment to 4 % and Czech Republic and Poland mitigate their methane demand curtailment to 6 % and 7 % respectively. The United Kingdom mitigates its methane demand curtailment to 2 %.

In **Distributed Energy** scenario, the methane demand curtailment is fully mitigated.

In **Global Ambition** scenario, the methane demand curtailment is fully mitigated except in Serbia and North Macedonia that show 1 % methane demand curtailment. For Sweden the situation remains unchangedi n comparison with existing.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, the methane demand curtailment is similar to the one for the Existing Methane Infrastructure level with 2 % to 7 % methane demand curtailment due to hydrogen production using methane.

In the **Distributed Energy** scenario, the situation is unchanged.

In the **Global Ambition** scenario, countries showing methane demand curtailment increase their methane demand curtailment by 1 % due to hydrogen production using methane.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, Ireland and North Macedonia do not improve their methane demand curtailment. Poland, Lithuania and Croatia mitigate their methane curtailment rate to respectively 21 %, 0 % and 13 %. Slovenia cooperates with Croatia and shows 13 % methane curtailment rate.

In **Distributed Energy** scenario, demand curtailment is fully mitigated in all countries.

In **Global Ambition** scenario, most of the countries fully mitigate their methane demand curtailment. Sweden, Serbia and North Macedonia mitigate their methane curtailment rate to 10 %, 1 % and 1 %.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario**,** only a part of the countries with curtailed methane demand fully mitigate their methane demand curtailment. Other countries decrease their methane demand curtailment to 1 % due to additional flexibility in the PCI infrastructure level.

In **Distributed Energy** scenario, there is no change compared to H_2 Infrastructure Level 1.

In **Global Ambition** scenario, there is no change compared to H_2 Infrastructure Level 1.

2050

H_2 INFRASTRUCTURE LEVEL 1

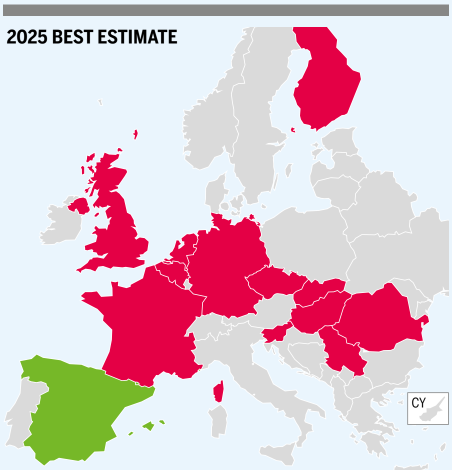
In **Distributed Energy** scenario and in **Global Ambition** scenario, methane demand curtailment is fully mitigated in all countries.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario and in **Global Ambition** scenario, there is no change compared to H_2 Infrastructure Level 1, i. e., the methane demand curtailment is fully mitigated in all countries.

7.4.2 HYDROGEN RESULTS

7.4.2.1 Existing Methane Infrastructure level



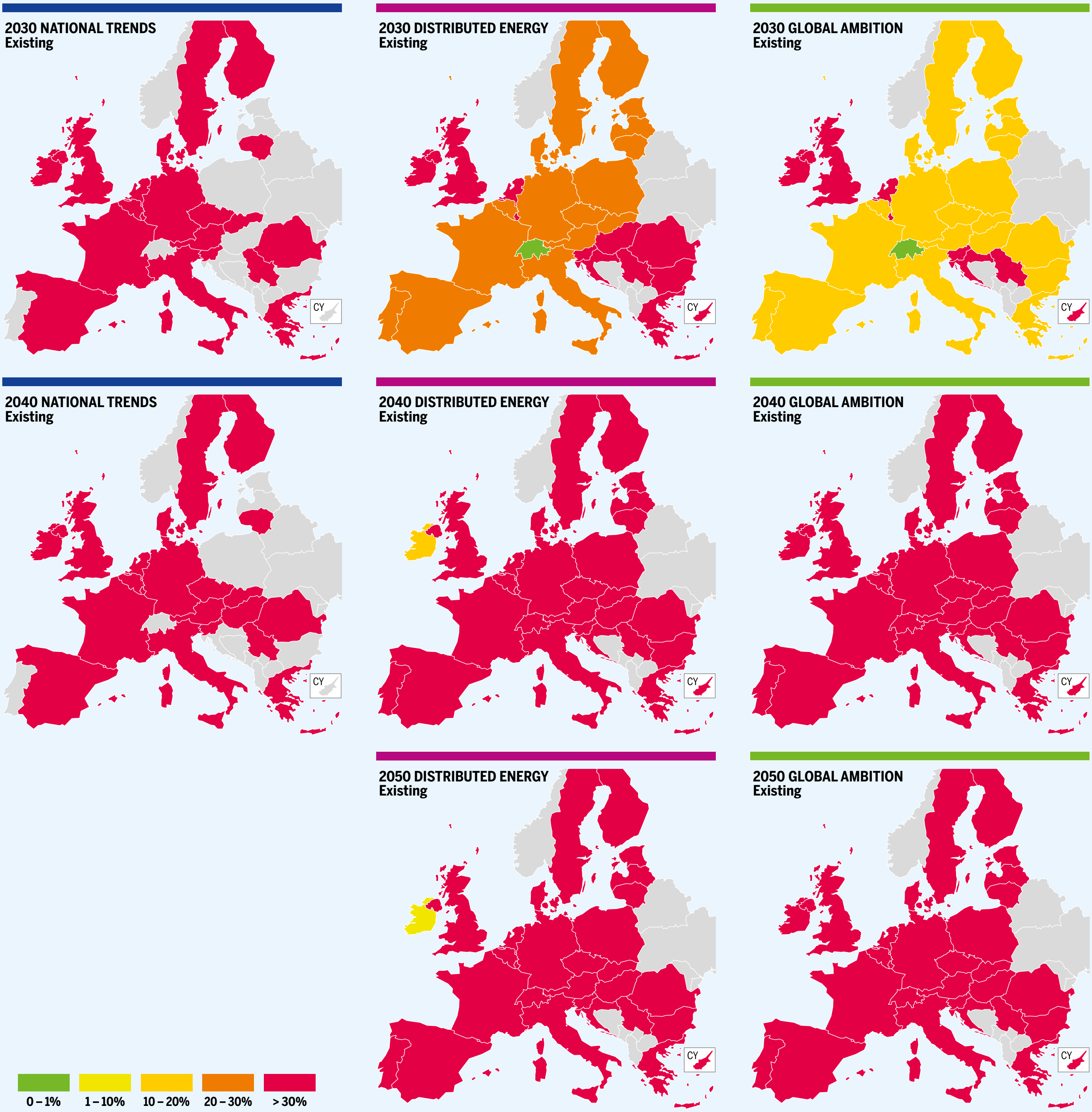


Figure 7.8 Hydrogen Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 1

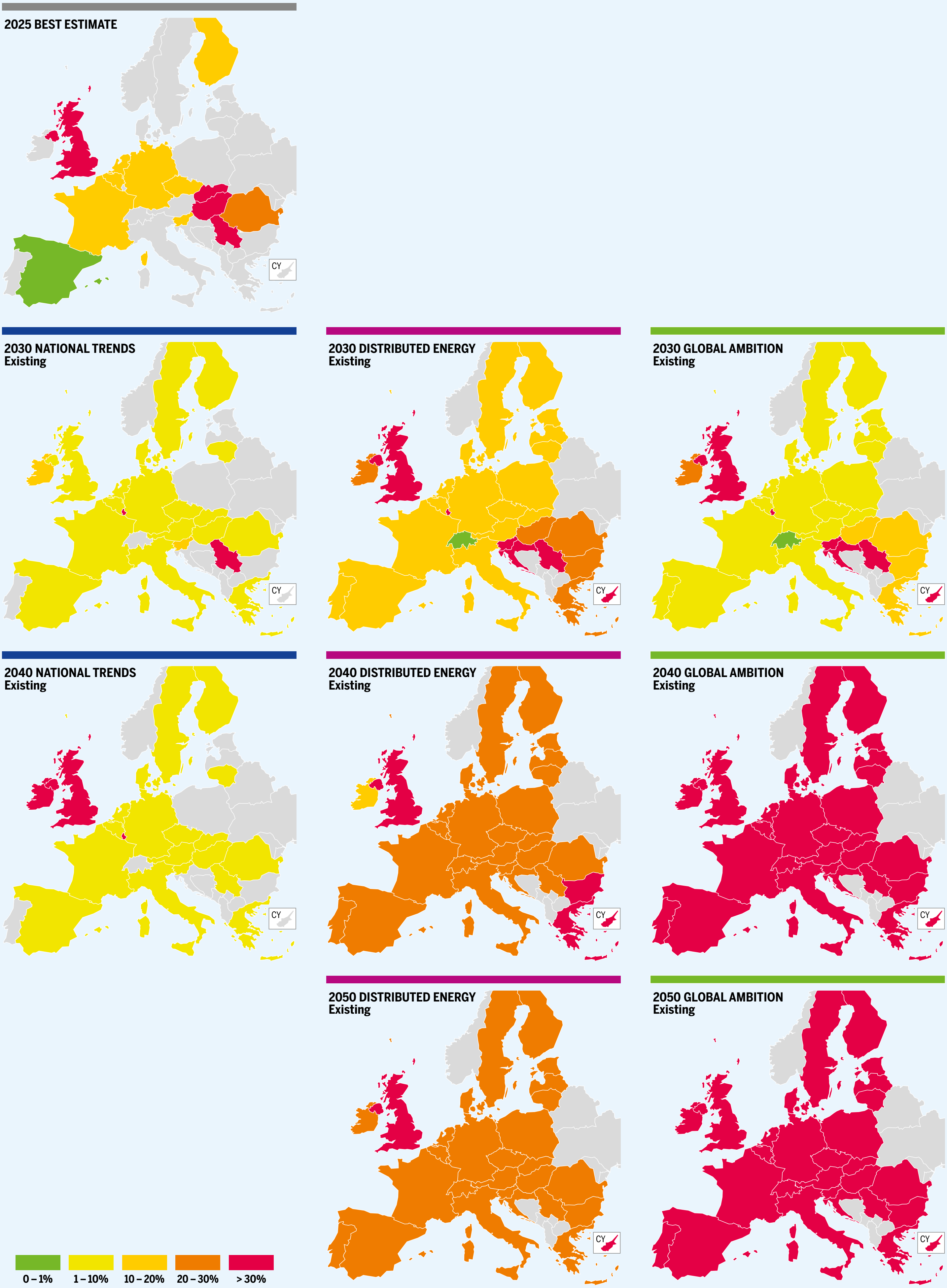


Figure 7.9 Hydrogen Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 2

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

In **Best Estimate** scenario, all countries with hydrogen demand are partially curtailed. Without any hydrogen infrastructure, countries must satisfy demand with national production which is not sufficient and cause hydrogen curtailment rates: Germany (33 %), United Kingdom (66 %), Belgium (90 %), Czech Republic (93 %), Hungary (97 %), Slovakia (98 %), Slovenia (98 %) and Serbia, France, Latvia, The Netherlands, Romania and Finland (all 100 %).

H_2 INFRASTRUCTURE LEVEL 2

In **Best Estimate** scenario, due to additional hydrogen production using methane, all countries mitigate their demand curtailment to levels between 10 % and 48 %.

2030

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, most countries with hydrogen demand show 61 % of hydrogen curtailment rate. Greece with 49 % hydrogen curtailment rate benefits from more hydrogen production that it cannot share. The Netherlands shows 77 % hydrogen curtailment rate and Belgium and Germany cannot cooperate more to mitigate The Netherlands' demand curtailment due to infrastructure limitations. Without any interconnections, some countries show higher hydrogen curtailment rates: Slovenia (86 %), United Kingdom (91 %), Ireland (98 %) Luxembourg (97 %) and Serbia (100 %) cannot satisfy their hydrogen demand with their own hydrogen production.

In **Distributed Energy** scenario, most of the countries show 25 % of hydrogen curtailment rate. The Netherlands (41 %) and Croatia, Hungary, Romania, Bulgaria and Greece (all 31 %) suffer from infrastructure limitations with neighbouring countries. Without any interconnections, some countries show higher hydrogen curtailment rates: Luxembourg (74 %), Slovenia (91 %), Croatia (49 %), Serbia (100 %), United Kingdom (78 %) and Ireland (62 %) cannot satisfy their hydrogen demand with their own hydrogen production.

In **Global Ambition** scenario, most of the countries show 16 % hydrogen curtailment rate. The Netherlands shows 41 % demand curtailment due to infrastructure limitations with neighbouring countries. Without any interconnections, some countries show higher hydrogen curtailment rates: Croatia (45 %), Luxembourg (71 %), Slovenia (94 %), Serbia (100 %), United Kingdom (76 %) and Ireland (62 %) cannot satisfy their hydrogen demand with their own hydrogen production.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, all countries mitigate their demand curtailment compared to H_2 Infrastructure Level 1 due to additional hydrogen production using methane and methane infrastructure flexibility. Most of the countries mitigate their hydrogen curtailment to 5 %. Some countries are not interconnected but can still mitigate their hydrogen curtailment rate: United Kingdom (6 %), Ireland (13 %), Slovenia (19 %), Serbia (47 %) and Luxembourg (49 %).

In **Distributed Energy** scenario, due to additional interconnections and increased capacities, demand curtailment is mitigated to 14 % for most of the countries compared to H_2 Infrastructure Level 1. The Eastern countries Romania, Bulgaria and Greece mitigate their hydrogen curtailment rate to 24 % due to infrastructure limitations with neighbouring countries. Croatia (49 %), Serbia (49 %), Slovenia (42 %), Luxembourg (27 %), Ireland (25 %) and the United Kingdom (36 %) are not interconnected with neighbouring countries but can mitigate the hydrogen curtailment rate by producing additional hydrogen from available methane.

In **Global Ambition** scenario, most of the countries mitigate their hydrogen curtailment rate to 7 %. 17 % are observed in Eastern countries and 45 % in Croatia, Serbia and Slovenia. Ireland (20 %) and United Kingdom (40 %) mitigate their hydrogen curtailment rate. Due to additional hydrogen production using methane, countries not interconnected can mitigate their hydrogen curtailment rate.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, results are similar to 2030. Most of the countries show 53 % hydrogen curtailment rate. The Netherlands shows 89 % hydrogen curtailment rate and Belgium and Germany cannot cooperate more with The Netherlands due to infrastructure limitations. Ireland (93 %), the United Kingdom (97 %), Luxembourg (97 %) and Serbia (100 %) are not interconnected with other countries and cannot satisfy their hydrogen demand with their own hydrogen production.

In **Distributed Energy** scenario, most of the countries show 43 % hydrogen curtailment rate. Cooperation is at the maximum without any infrastructure limitations. Luxembourg (88 %), United Kingdom (87 %) and Serbia (100 %) cannot satisfy their hydrogen demand with their own hydrogen production and are not interconnected with neighbouring countries. Ireland with its high hydrogen production shows only 14 % hydrogen curtailment rate.

In **Global ambition** scenario, most of the countries show 60 % of hydrogen demand curtailment. Cooperation is at the maximum without any infrastructure limitations. Luxembourg (93 %), United Kingdom (90 %), Ireland (81 %) and Serbia (100 %) cannot satisfy their hydrogen demand with their own hydrogen production and are not interconnected with neighbouring countries.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, all countries mitigate their demand curtailment. Most of the countries mitigate their demand curtailment to 5 %. Luxembourg shows 35 % demand curtailment and Belgium cannot cooperate more due to a bottleneck. United Kingdom and Ireland show 38 % demand curtailment due infrastructure limitation with Belgium.

In **Distributed Energy** scenario, most of the countries show 24 % demand curtailment. Bulgaria and Greece show 35 % demand curtailment and Romania cannot cooperate more with Bulgaria to mitigate demand curtailment in Bulgaria and Greece due to infrastructure limitations. Ireland with high hydrogen production shows only 16 % demand curtailment. United Kingdom shows 54 % demand curtailment and Belgium and Ireland cannot cooperate more with United Kingdom due to infrastructure limitations (bottlenecks).

In **Global Ambition** scenario, most of the countries show 40 % demand curtailment. Ireland and United Kingdom mitigate their demand curtailment to 52 % with additional hydrogen production using methane and interconnection with Belgium.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show 50 % demand curtailment. Eastern countries (Hungary, Romania, Croatia, Greece and Slovakia) show 42 % demand curtailment and cannot cooperate more with other countries due to infrastructure limitations. Ireland shows only 8 % demand curtailment due to high hydrogen production. Portugal shows only 40 % demand curtailment due to high hydrogen production and cannot cooperate with Spain due to a bottleneck. United Kingdom (68 %), Luxembourg (90 %) and Serbia (100 %) are curtailed due to no interconnection with neighbouring countries and limited hydrogen production.

In **Global Ambition** scenario, most of the countries show 66 % demand curtailment. Hydrogen infrastructure does not show infrastructure limitation and cooperation is at the maximum between countries. Ireland (69 %), United Kingdom (79 %), Serbia (100 %) and Luxembourg (95 %) are curtailed due to lack of interconnection with other countries and with limited hydrogen production.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, demand curtailment is mitigated to 23 % – 24 % in most of the countries. United Kingdom shows 44 % demand curtailment and Belgium and Ireland cannot cooperate more due to infrastructure limitations.

In **Global Ambition** scenario, demand curtailment is mitigated to 31 % for most of the countries. United Kingdom and Ireland show 46 % demand curtailment and Belgium cannot cooperate more due to a bottleneck. Greece and Bulgaria show 35 % demand curtailment and Romania cannot cooperate more with them to mitigate their demand curtailment due to a bottleneck with Bulgaria.

7.4.2.2 Advanced and PCI Methane Infrastructure

Advanced and PCI methane infrastructure levels do not show any difference with existing infrastructure. Hydrogen infrastructure is limited in the use of methane to produce hydrogen and the Advanced or PCI infrastructure levels do not add any additional hydrogen production.

8 RUSSIA METHANE SUPPLY DISRUPTION

This chapter considers the disruption of all gas imports from Russia affecting all the routes to the EU, including direct routes to Germany, Baltic states and Finland, and all the transits though Belarus, Ukraine and Turkey. Only Russian flows to Serbia and North Macedonia are considered.

8.1 YEARLY DEMAND

As a consequence of the minimisation of Russian gas in the Reference case, Distributed Energy and Global Ambition scenarios show no need for Russian gas in 2030 and 2040, for this reason the results in these cases remain unchanged compared to Reference case. The infrastructure assessment is limited to Best Estimate and National Trends scenarios in 2030 and 2040.

8.1.1 METHANE RESULTS

In contrast to Reference case results, with no disruptions, without Russian gas the simulations show many countries are exposed to methane demand curtailment for average winters in Best Estimate and National Trends scenarios, in both H_2 infrastructure levels, but no impact in Distributed Energy and Global Ambition. These two scenarios only show minor differences compared to reference case results in a few cases of in 2050.

Picture courtesy of Reganosa

8.1.1.1 Existing Methane Infrastructure level

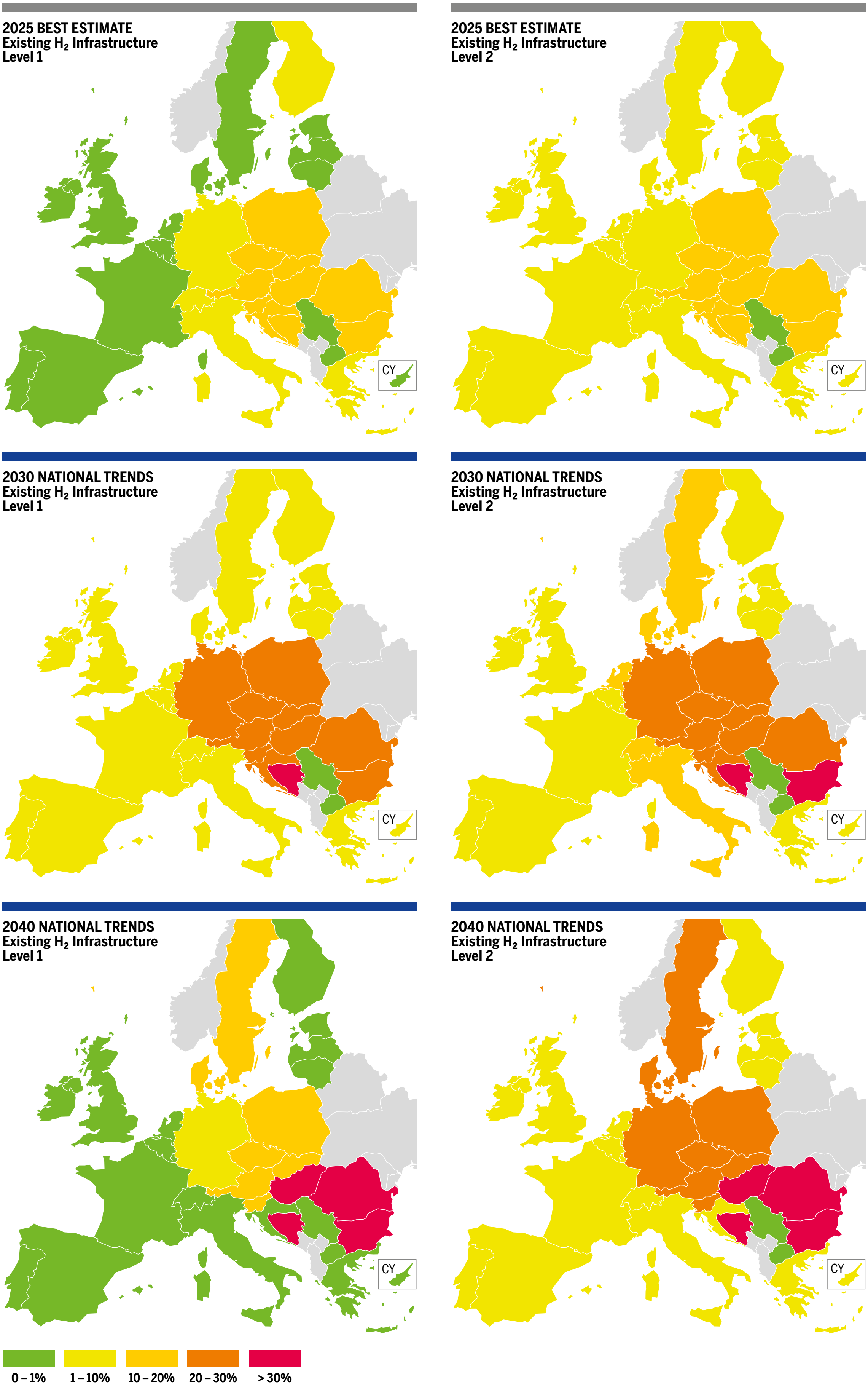


Figure 8.1 RU CH_4 Supply Disruption – Methane Results for Yearly Demand in Existing CH_4 Infrastructure and H_2 Levels 1 and 2

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

Without Russian gas in 2025 Best Estimate Scenario many countries show risk of demand curtailment. The higher values are observed in Austria, Bulgaria, Czech Republic, Croatia, Hungary, Poland, Romania, Slovenia and Slovakia with a potential curtailment of 11 %. Germany and Switzerland show 8 %, Italy 7 %, Finland 6 % and Greece only 2 %.

Two significant groups of bottlenecks are noted from west to east: the first starts from The Netherlands, Belgium and France to eastern neighbouring countries and the second one comprises Germany, Switzerland and Italy, also to the east. Three more bottlenecks are observed from Greece to Bulgaria, Lithuania to Poland and Estonia to Finland.

H_2 INFRASTRUCTURE LEVEL 2

If more methane is used to produce more hydrogen, then the curtailment in the methane side increases to 2–3 % in all Europe, reducing some of the bottlenecks. One of the two main infrastructure limitations remain, this is the one from Germany, Switzerland and Italy to the east. Bottlenecks from Greece to Bulgaria and from Lithuania to Poland also continue.

Picture courtesy of GAZ-SYSTEM

2030 – National Trends

H_2 INFRASTRUCTURE LEVEL 1

Demand curtailment occurs in all Europe. The biggest curtailments occur in Austria, Bulgaria, Czech Republic, Croatia, Hungary, Poland, Romania, Slovenia and Slovakia with a 29 % rate. Germany shows 20 %, Sweden 10 %, Denmark 9 %, Switzerland 9 %, Italy 6 %, Greece 5 % and all the rest 3–4 %.

Therefore, bottlenecks are observed from The Netherlands, Belgium, France, Switzerland and Italy to their eastern neighbouring countries and also from Denmark to Germany and from Germany to the east. Other bottlenecks are observed from Greece to Bulgaria and Lithuania to Poland.

H_2 INFRASTRUCTURE LEVEL 2

When allowing more hydrogen production with methane, Bulgaria, Hungary and Romania increase their CH_4 curtailment to 30 %, Germany to 21 %, Sweden to 11 %, Denmark to 10 %, Switzerland to 10 %, Italy to 10 %, and all the rest to 8-9 %. Bottlenecks remain.

2040 – National Trends

H_2 INFRASTRUCTURE LEVEL 1

In 2040 National Trends under H_2 Level 1 without Russian gas a 41 % demand curtailment is observed in Bulgaria, Hungary, and Romania. Austria, Czech Republic, Denmark, Croatia, Poland, Sweden, Slovenia and Slovakia present a 16 % curtailment rate.

Bottlenecks are observed from The Netherlands, Belgium, France, Switzerland and Italy to their eastern neighbouring countries and from Germany to Denmark and also to the east.

Other bottlenecks are observed are from Greece to Bulgaria, Lithuania to Poland and also from central Europe to Hungary.

H_2 INFRASTRUCTURE LEVEL 2

If more hydrogen production from methane is allowed, then Germany raises its curtailment rate to 10 % and all the other countries in Europe show new curtailments of 3–4 %.

8.1.1.2 Advanced and PCI Methane Infrastructure

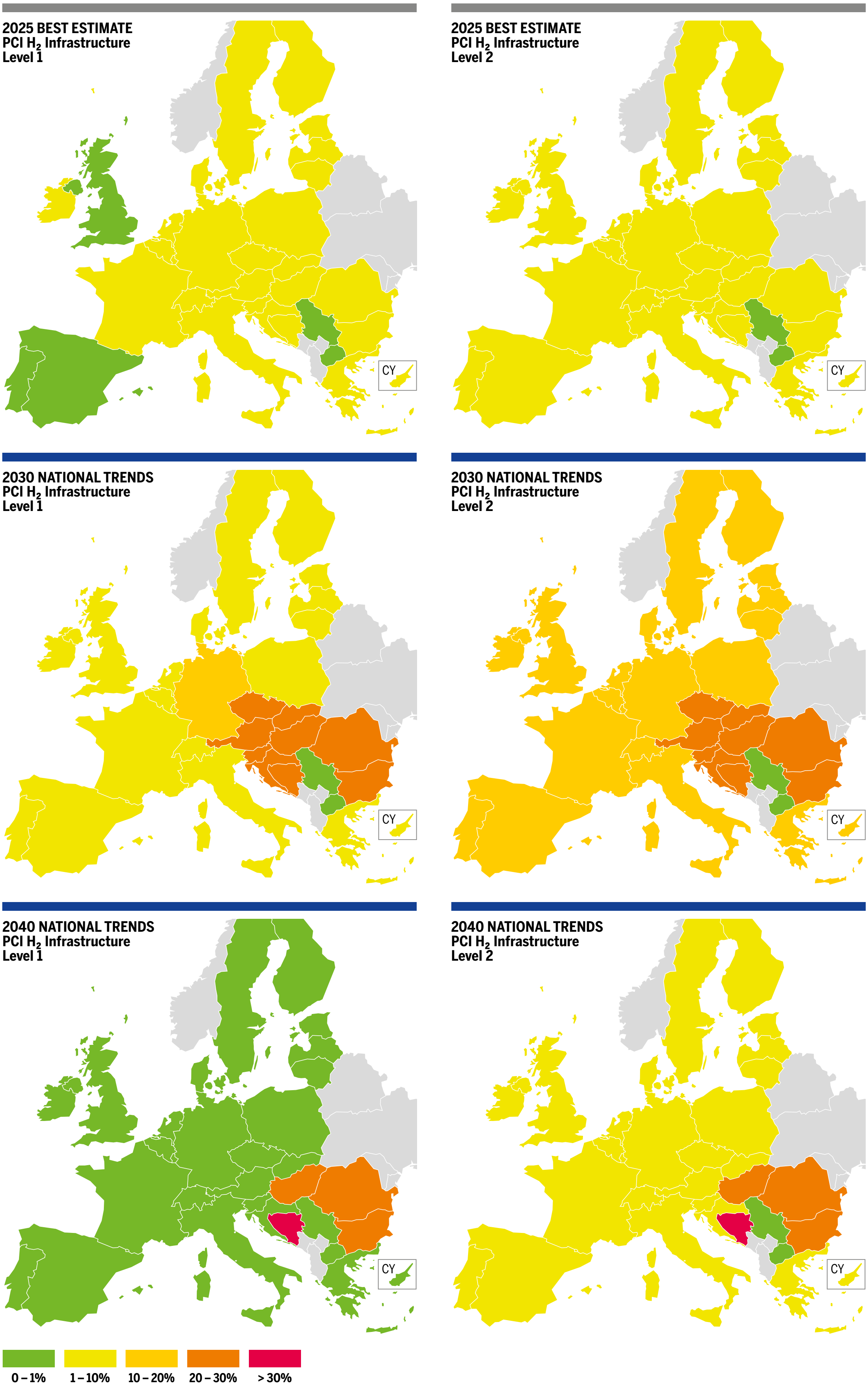


Figure 8.2 RU CH_4 Supply Disruption – Methane Results for Yearly Demand in PCI & Advanced CH_4 Infrastructure and H_2 Level 1 and 2

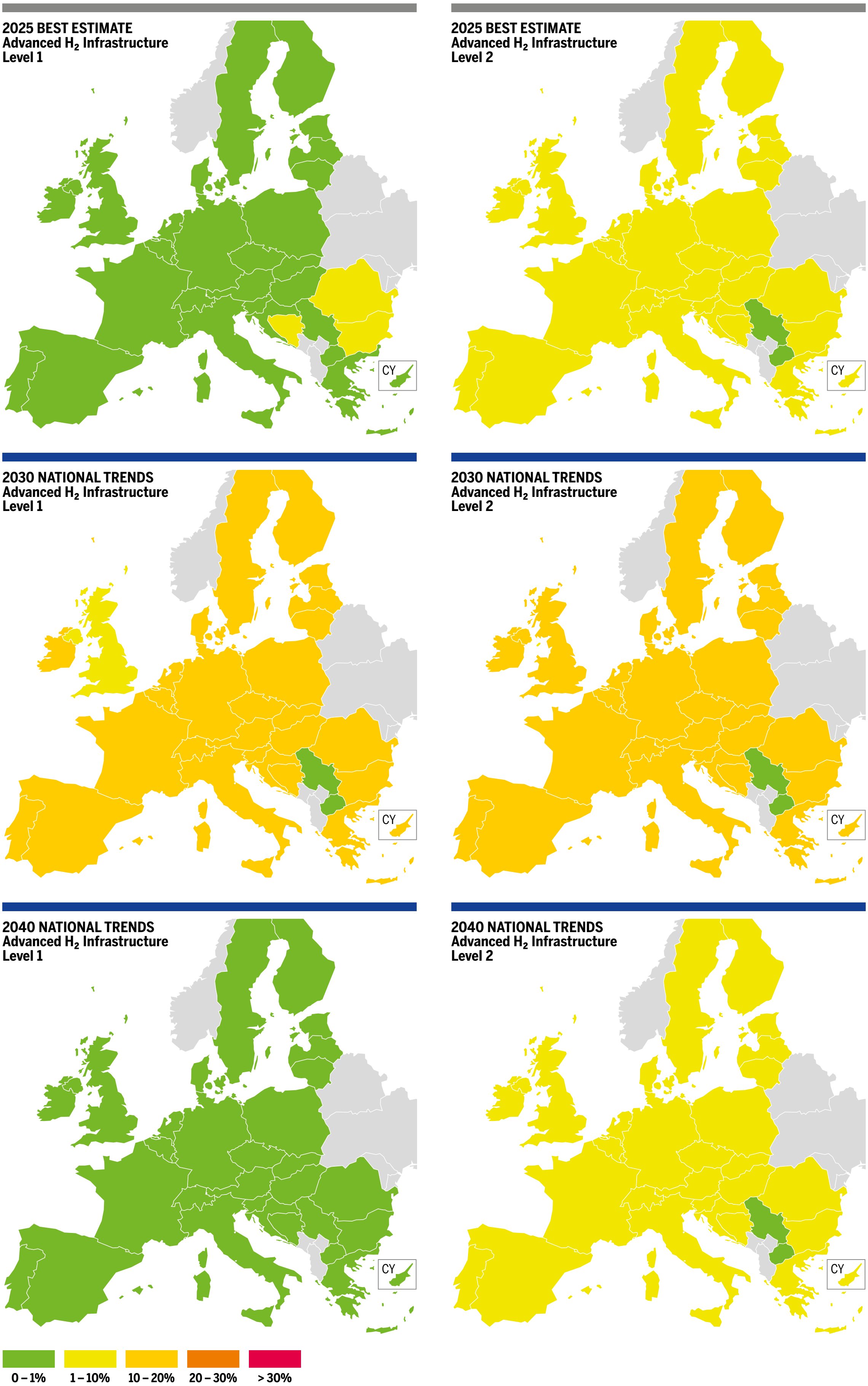


Figure 8.3 RU CH_4 Supply Disruption – Methane Results for Yearly Demand in PCI & Advanced CH_4 Infrastructure and H_2 Level 1 and 2

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

PCI infrastructure reduces demand curtailment observed in Existing infrastructure from 11 % to 5 % in Austria, Bulgaria, Czech Republic, Croatia, Hungary, Poland, Romania, Slovenia and Slovakia. Germany and Finland reduce curtailment to 4 %, Italy and Switzerland to 3 % and all the rest to 1 % or less (in Spain and United Kingdom).

Infrastructure limitations are reduced but still occur in **PCI infrastructure**, in similar places to the ones described in Existing infrastructure, first from The Netherlands, Belgium and France to the east and second from Germany, Switzerland and Italy, also to the east. The bottlenecks from Greece to Bulgaria, Lithuania to Poland and Estonia to Finland also remain.

Advanced infrastructure reduces demand curtailment to 0–1 % and mitigates all bottlenecks.

H_2 INFRASTRUCTURE LEVEL 2

When combining **PCI infrastructure** and H_2 Level 2 demand curtailment increases slightly in all countries and results show a range of 3–6 % curtailment with only one bottleneck remaining between Greece and Bulgaria, all the other countries are able to reduce their difference with neighbours to less than 1 %.

In the case of **Advanced infrastructure**, H_2 Level 2 shows a demand curtailment range in all Europe of 2–3 % and no bottlenecks at all.

2030 – National Trends scenario

H_2 INFRASTRUCTURE LEVEL 1

National trends demand in 2030 is curtailed everywhere even with **PCI infrastructure**. Results show a 21 % curtailment in Austria, Bulgaria, Czech Republic, Croatia, Hungary, Romania, Slovenia and Slovakia. Germany stands alone with a 15 % demand curtailment and all the rest share an 8 % curtailment. In this case a new bottleneck appears from Poland to the south.

Advanced infrastructure shows a demand curtailment range in 2030 of 10–11 % for H_2 Level 1 and no infrastructure limitations.

H_2 INFRASTRUCTURE LEVEL 2

PCI infrastructure shows a higher demand curtailment with H_2 Level 2 for Germany, increasing from 15 to 17 % and also the rest of Europe increasing from 8 to 11 – 12 %.

In 2030 **Advanced infrastructure** H_2 Level 2 shows a demand curtailment range in all Europe of 13–14 % without any bottlenecks.

2040 – National Trends scenario

H_2 INFRASTRUCTURE LEVEL 1

PCI infrastructure in 2040 only presents 3 countries with a 25–26 % range of methane demand curtailment, Bulgaria, Hungary and Romania with infrastructure limitations to Hungary and Bulgaria.

Advanced infrastructure shows no demand curtailment with H_2 Level 1.

H_2 INFRASTRUCTURE LEVEL 2

PCI infrastructure shows the same results than in Level 1 plus an additional demand curtailment of 6 % across Europe.

In 2040 **Advanced infrastructure** H_2 Level 2 shows a demand curtailment range in all Europe of 6–7 % without any bottlenecks.

8.1.2 HYDROGEN RESULTS

Results for hydrogen in H_2 Level 1 show the same demand curtailment in all scenarios and all CH_4 levels (Existing, Advanced and PCI) than in Reference case. Results in H_2 Level 2 are different and, in this case, they also present a small Hydrogen demand curtailment in Best Estimate and National Trends for all CH_4 levels. No curtailments occur with H_2 Level 2 in Distributed Energy and Global Ambition scenarios.

8.1.2.1 Existing Methane Infrastructure

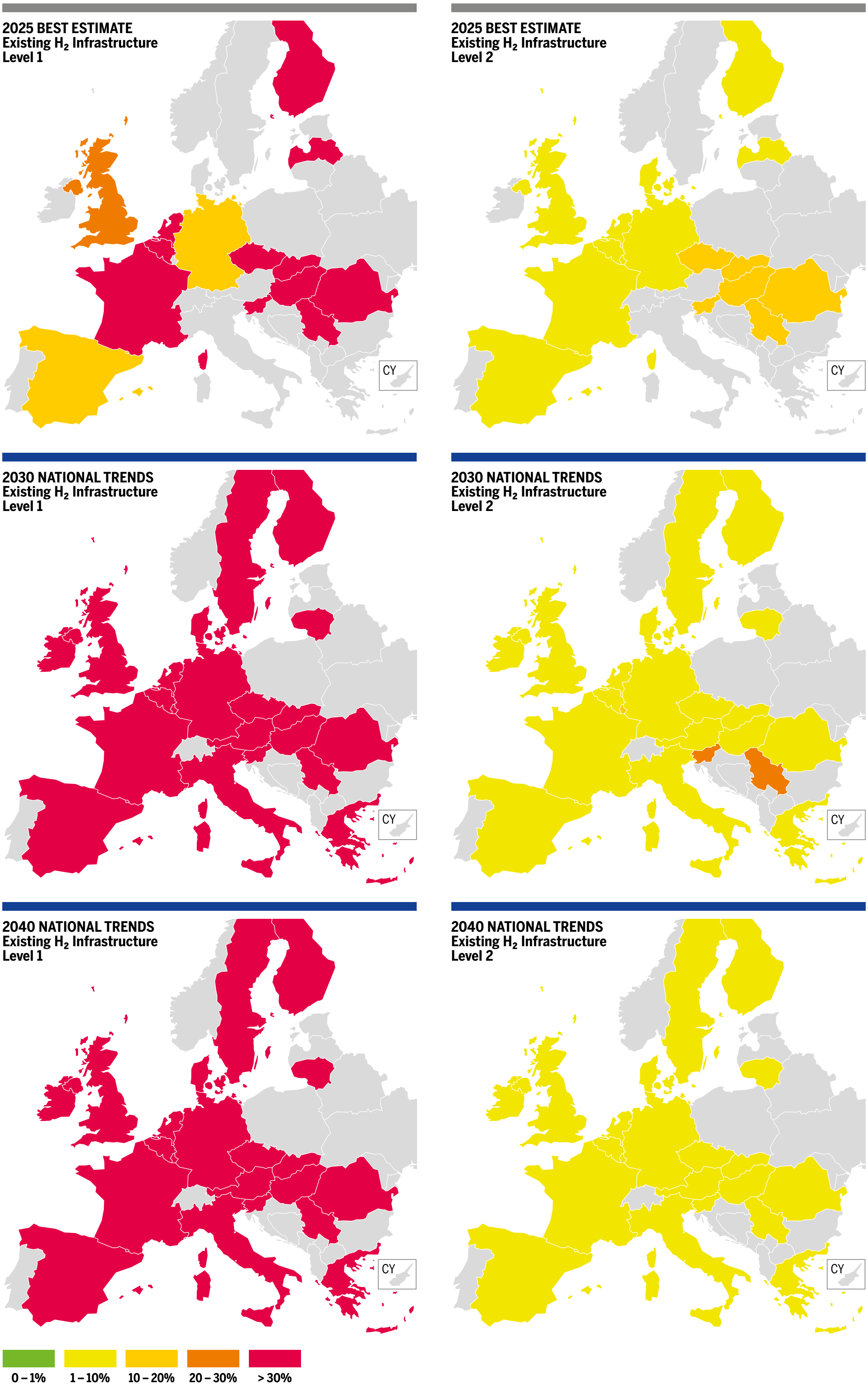


Figure 8.4 RU CH_4 Supply Disruption – Hydrogen Results for Yearly Demand in Existing CH_4 Infrastructure and H_2 Level 1 and 2

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 2

In **Best Estimate** scenario, all the countries with hydrogen demand values are curtailed. Czech Republic, Hungary, Romania, Serbia, Slovenia and Slovakia reach 13 % of curtailment, all the other countries show 6 % or less. Hydrogen production is not enough to satisfy demand, as in 2025 there is no H_2 infrastructure between countries where are no bottelnecks.

2030

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario all countries with hydrogen demand show demand curtailment. The hydrogen infrastructure for 2030 allows countries with H_2 interconnections to share a 9 % of demand curtailment. Only Serbia and Slovenia reach 29 %. No bottlenecks are observed.

2040

H_2 INFRASTRUCTURE LEVEL 2

In 2040 all countries show a 3 % demand curtailment in National Trends scenario.

Picture courtesy of Gas Connect Austria

8.1.2.2 Advanced and PCI Methane Infrastructure

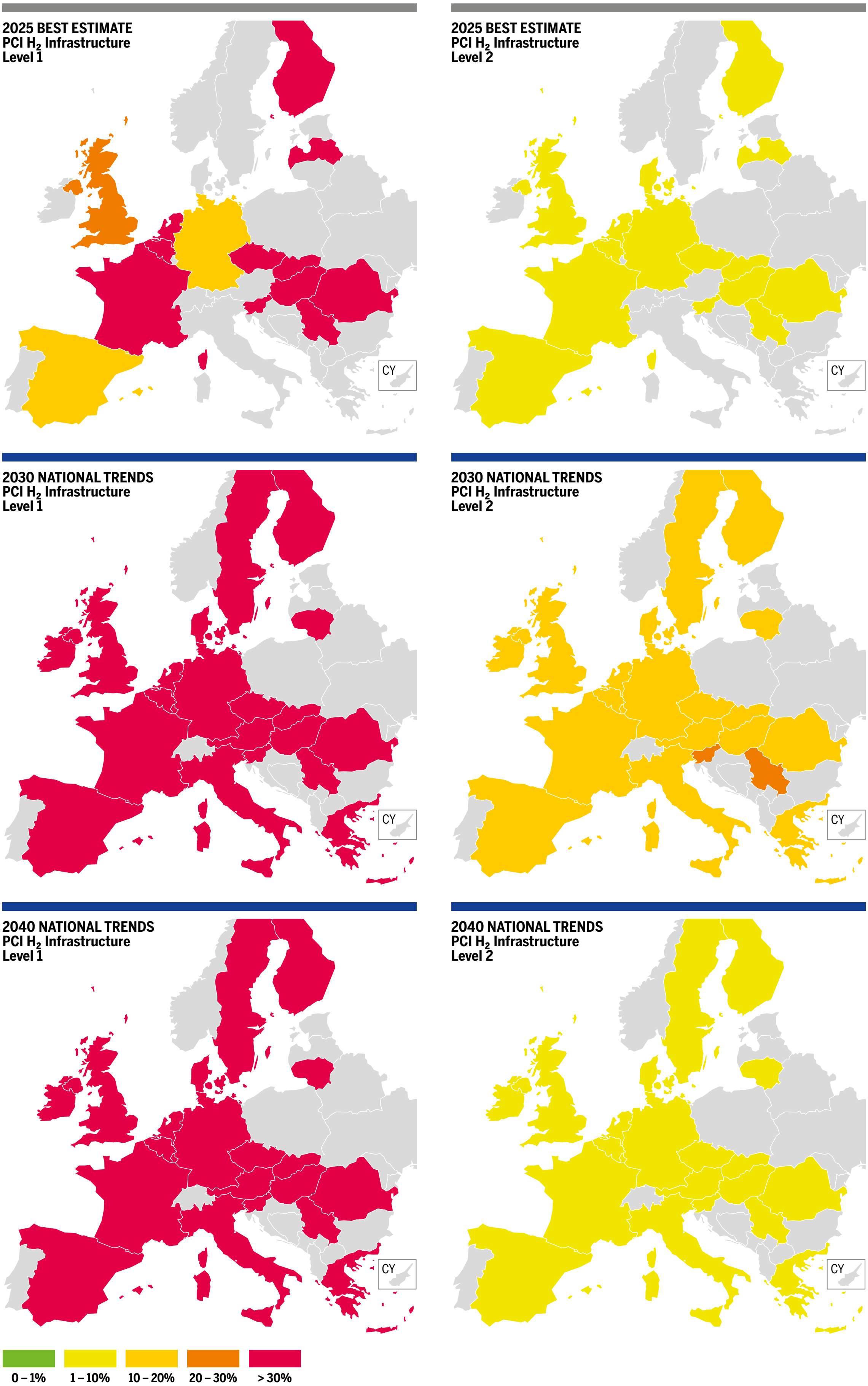


Figure 8.5 RU CH_4 Supply Disruption – Hydrogen Results for Yearly Demand in PCI & Advanced CH_4 Infrastructure and H_2 Level 1 + 2

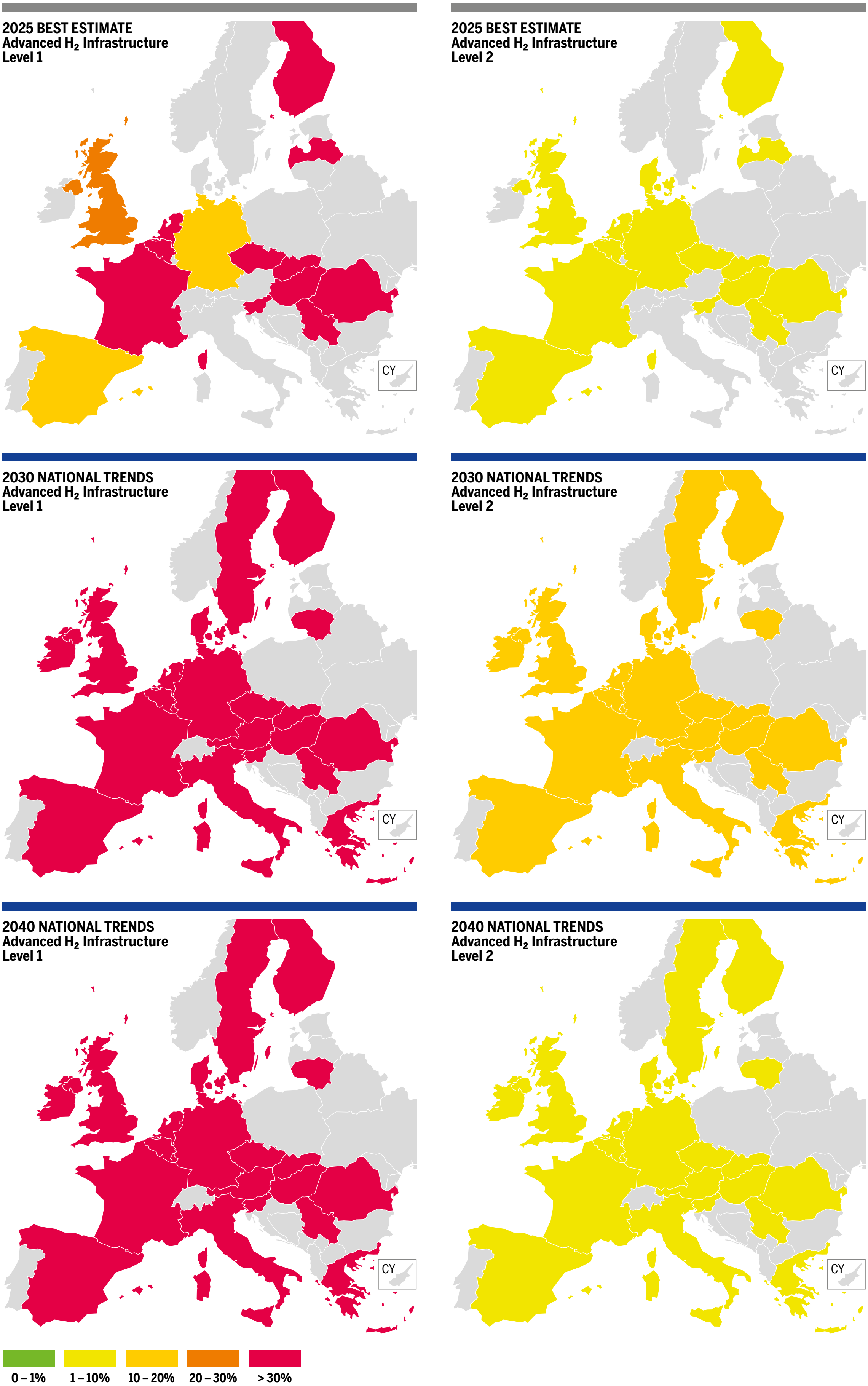


Figure 8.6 RU CH_4 Supply Disruption – Hydrogen Results for Yearly Demand in PCI & Advanced CH_4 Infrastructure and H_2 Level 1 + 2

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 2

PCI Infrastructure also shows that all the countries with hydrogen demand are curtailed. Belgium, Czech Republic, Finland, France, Latvia, The Netherlands, Hungary, Romania, Serbia, Slovenia and Slovakia keep a 7–8 % of curtailment. United Kingdom, Germany and Spain only 3–4 %.

Advanced Infrastructure in 2025 would already help to slightly reduce curtailment by 1–2 % in all the countries considering H_2 Level 2 allows hydrogen production with hydrogen.

2030

H_2 INFRASTRUCTURE LEVEL 2

PCI Infrastructure results show countries with hydrogen infrastructure in 2030 share a 11 % demand curtailment. Luxemburg reaches 12 %, Serbia 21 % and Slovenia 20 %.

Advanced Infrastructure in 2030 allows all the countries with demand to share a 13 % hydrogen curtailment.

2040

H_2 INFRASTRUCTURE LEVEL 2

PCI Infrastructure results show that all countries with hydrogen demand have a 5–6 % curtailment without any bottlenecks.

Advanced Infrastructure in 2040 allows all the countries with demand to share a 6 % hydrogen curtailment without infrastructure limitations.


Picture courtesy of TAP

8.2 2-WEEK COLD SPELL DEMAND

8.2.1 METHANE RESULTS

Bosnia and Herzegovina always shows the same methane demand curtailment than in the Reference Case.

8.2.1.1 Existing Methane Infrastructure

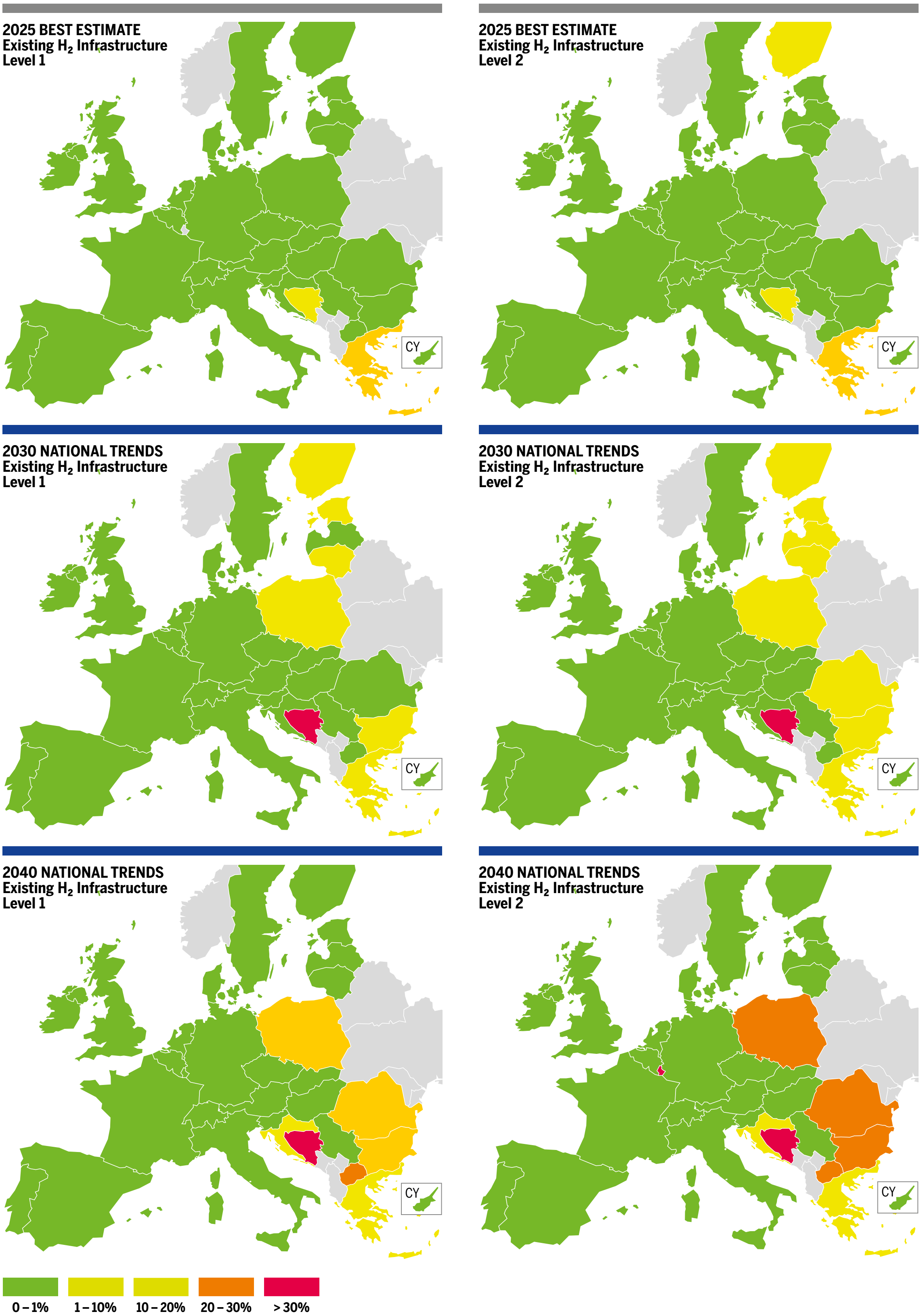


Figure 8.7 RU CH_4 Supply Disruption – Methane Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 1 and 2

2025 – Best Estimate scenario

H_2 INFRASTRUCTURE LEVEL 1

Only Greece shows an additional 14 % of demand curtailment due to infrastructure limitations.

H_2 INFRASTRUCTURE LEVEL 2

In No Russia H_2 Level 2 also Finland presents a 7 % extra demand curtailment.

2030

H_2 INFRASTRUCTURE LEVEL 1

In 2030 Greece shows an extra 5 % curtailment rate due to infrastructure limitations. All the other countries are having 1 % or less curtailment.

H_2 INFRASTRUCTURE LEVEL 2

In addition to Reference, H_2 Level 2 shows an additional demand curtailment of 4 % in Bulgaria, Estonia, Finland, Lithuania, Latvia and Romania.

2040

H_2 INFRASTRUCTURE LEVEL 1

In this case 2 week demand plus infrastructure limitations cause a demand curtailment of 18 % in Poland, 14 % in Bulgaria and Romania and 6 % in Greece and Croatia.

H_2 INFRASTRUCTURE LEVEL 2

Demand curtailment increase to 23 % in Poland, 22 % in Bulgaria and Romania and stays in 6 % for Greece and Croatia. Luxemburg shows the same 21 % curtailment in H_2 Level 2 than in the Reference case.

Picture courtesy of GAZ-SYSTEM

8.2.1.2 Advanced and PCI Methane Infrastructure

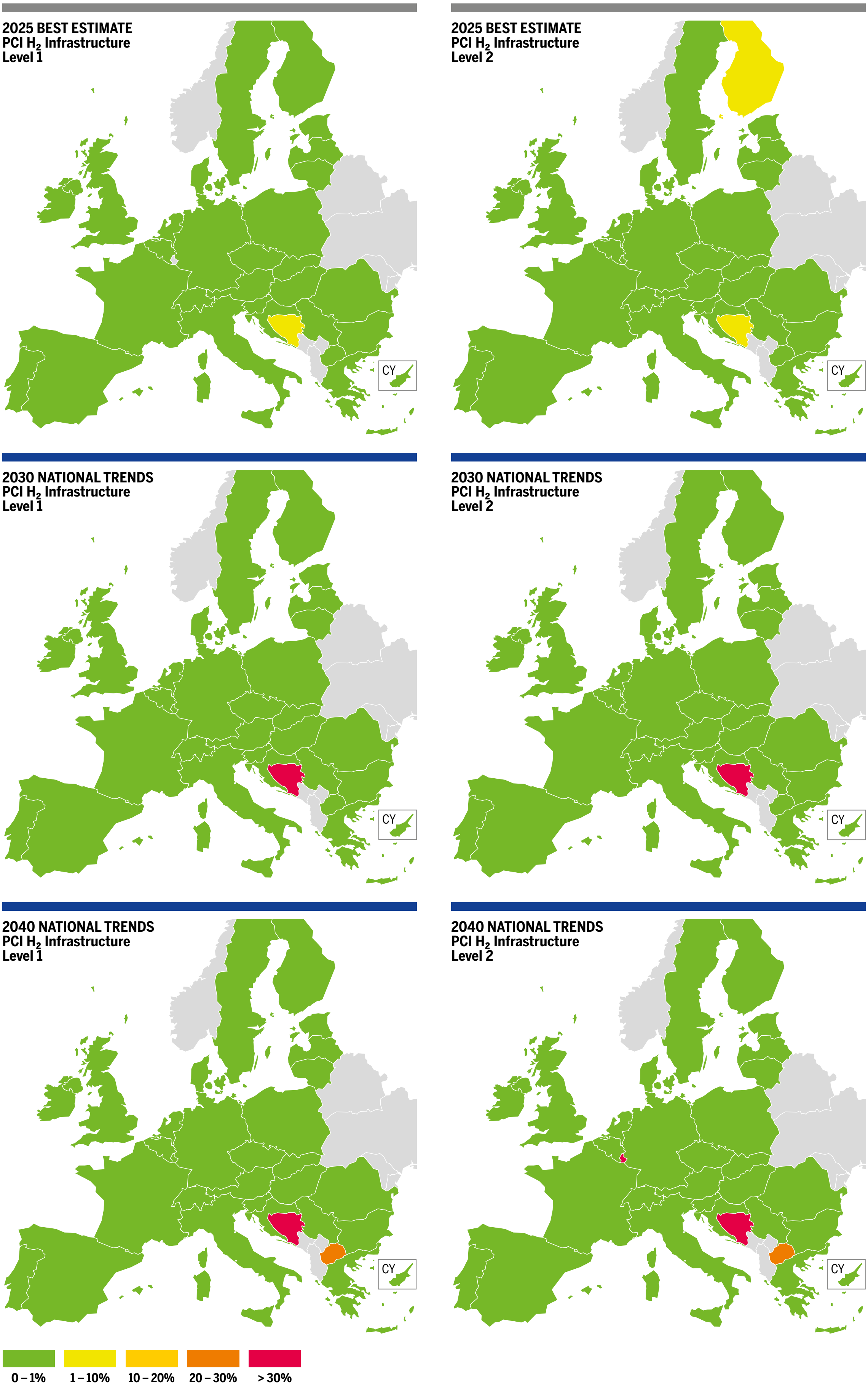


Figure 8.8a RU CH_4 Supply Disruption – Methane Results for 2W Demand in PCI & Advanced CH_4 Infrastructure and H_2 Level 1 and 2

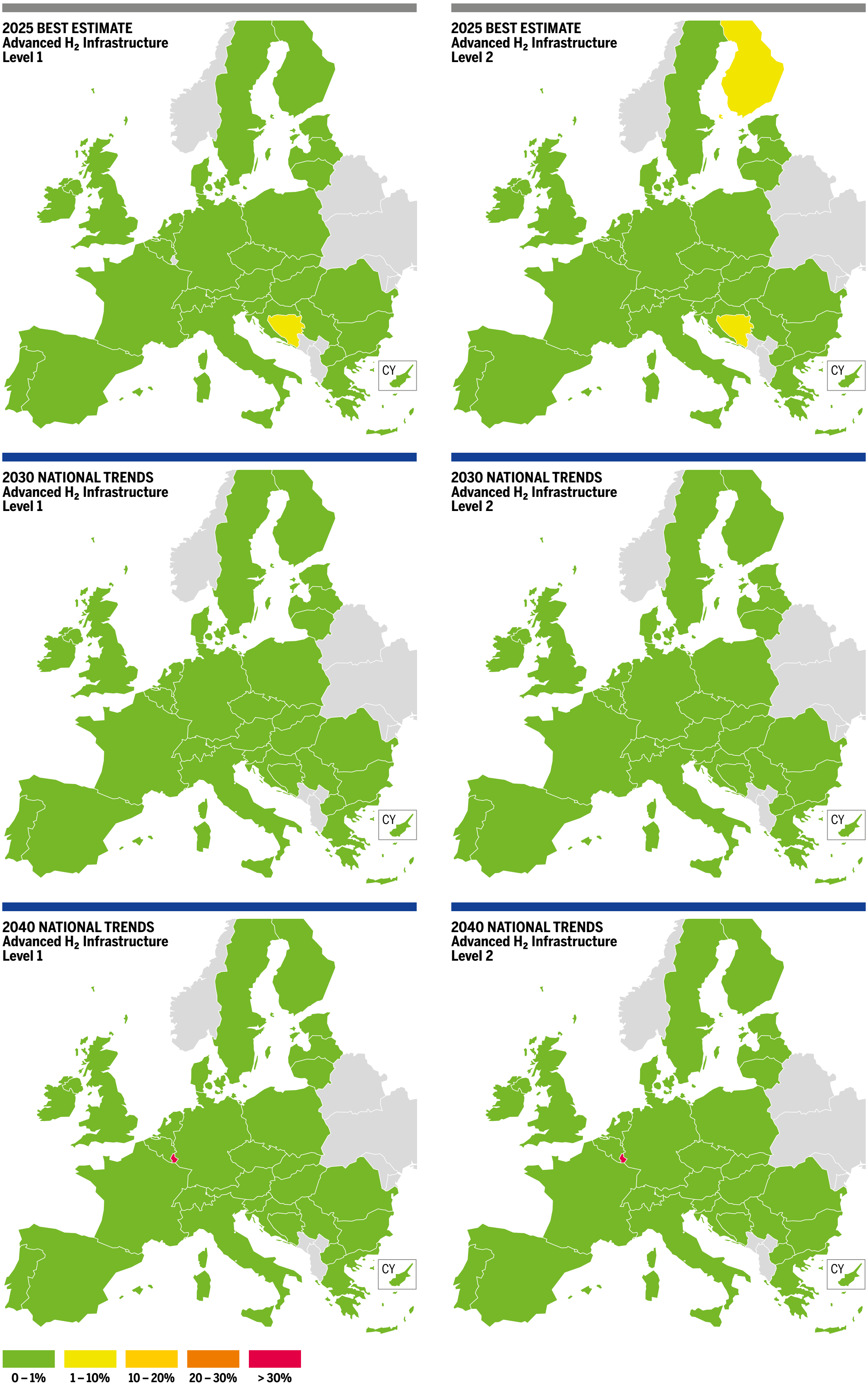


Figure 8.8b RU CH_4 Supply Disruption – Methane Results for 2W Demand in PCI & Advanced CH_4 Infrastructure and H_2 Level 1 and 2

The situation improves in the east with both Advanced and PCI Infrastructure compared to Existing. Poland is even mitigating the curtailment rate observed in the Reference case due to the 50 % of storage level and the enhanced capacities from west to east used in the No Russian gas simulation.

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

With **PCI and Advanced infrastructure** levels results are the same as the Reference case, Bosnia and Herzegovina shows the same risk of demand curtailment.

H_2 INFRASTRUCTURE LEVEL 2

Finland shows an additional curtailment of 7 % under the H_2 Level 2 in both PCI and Advanced.

2030

H_2 INFRASTRUCTURE LEVEL 1

In 2030, PCI and Advanced infrastructure results are the same as those of Reference case.

H_2 INFRASTRUCTURE LEVEL 2

In 2030, PCI and Advanced infrastructure results are the same as those of Reference case.

2040

H_2 INFRASTRUCTURE LEVEL 1

Only Macedonia shows 21 % demand curtailment in PCI infrastructure and only Luxemburg shows 23 % demand curtailment in Advanced.

H_2 INFRASTRUCTURE LEVEL 2

Additional to Macedonia, in PCI with H_2 Level 2 also Luxemburg shows 21 % of demand curtailment. Advanced infrastructure remains unchanged.


Picture courtesy of GASCADE

8.2.2 HYDROGEN RESULTS

8.2.2.1 Existing Methane Infrastructure

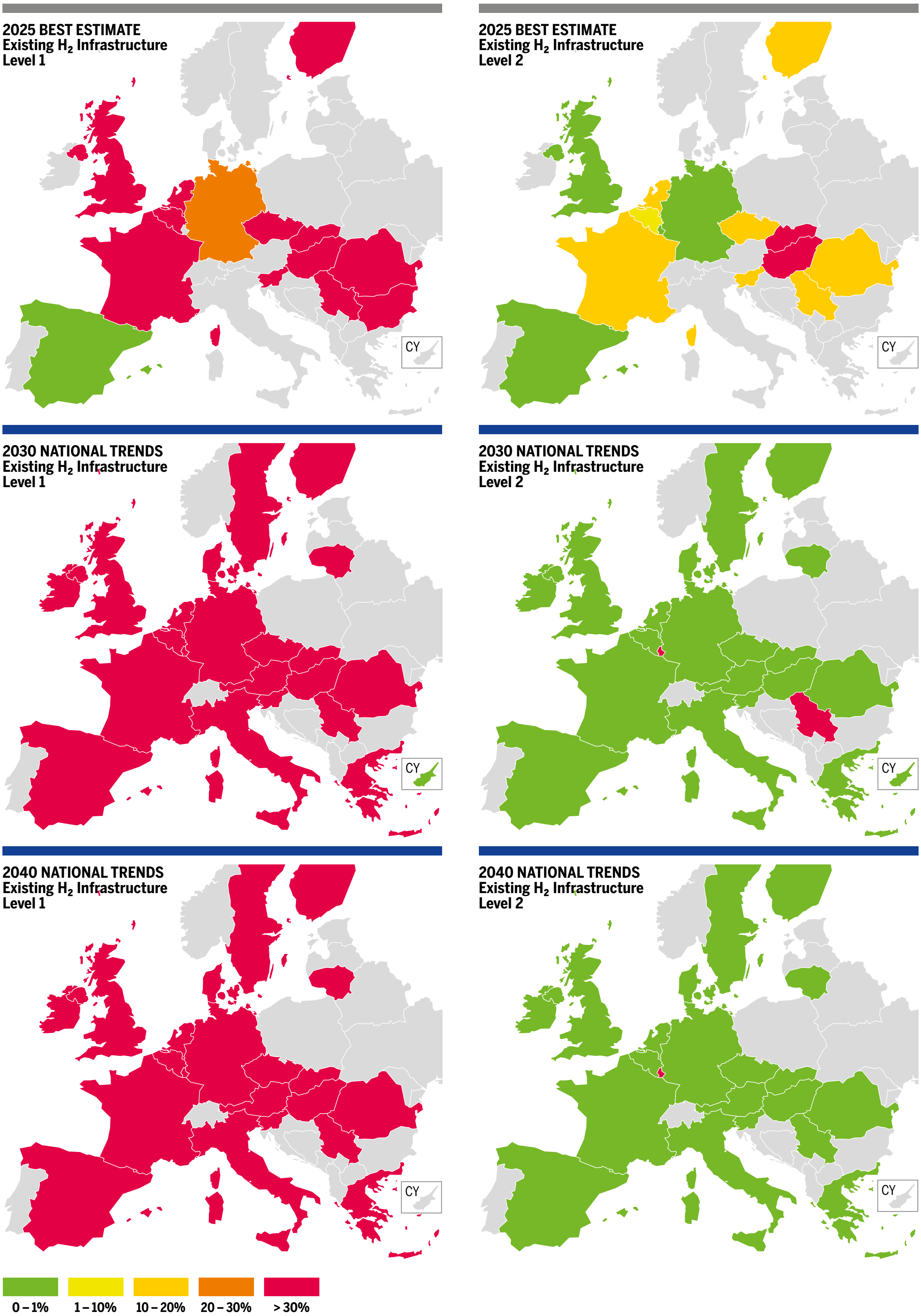


Figure 8.9 RU CH_4 Supply Disruption – Hydrogen Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 1 and 2

With **Existing infrastructure H_2 Level 1 and Level 2** all hydrogen demand curtailment results remain unchanged compared to the ones described in Reference case for 2 week cold spell demand in methane existing infrastructure.

8.2.2.2 Advanced and PCI Methane Infrastructure

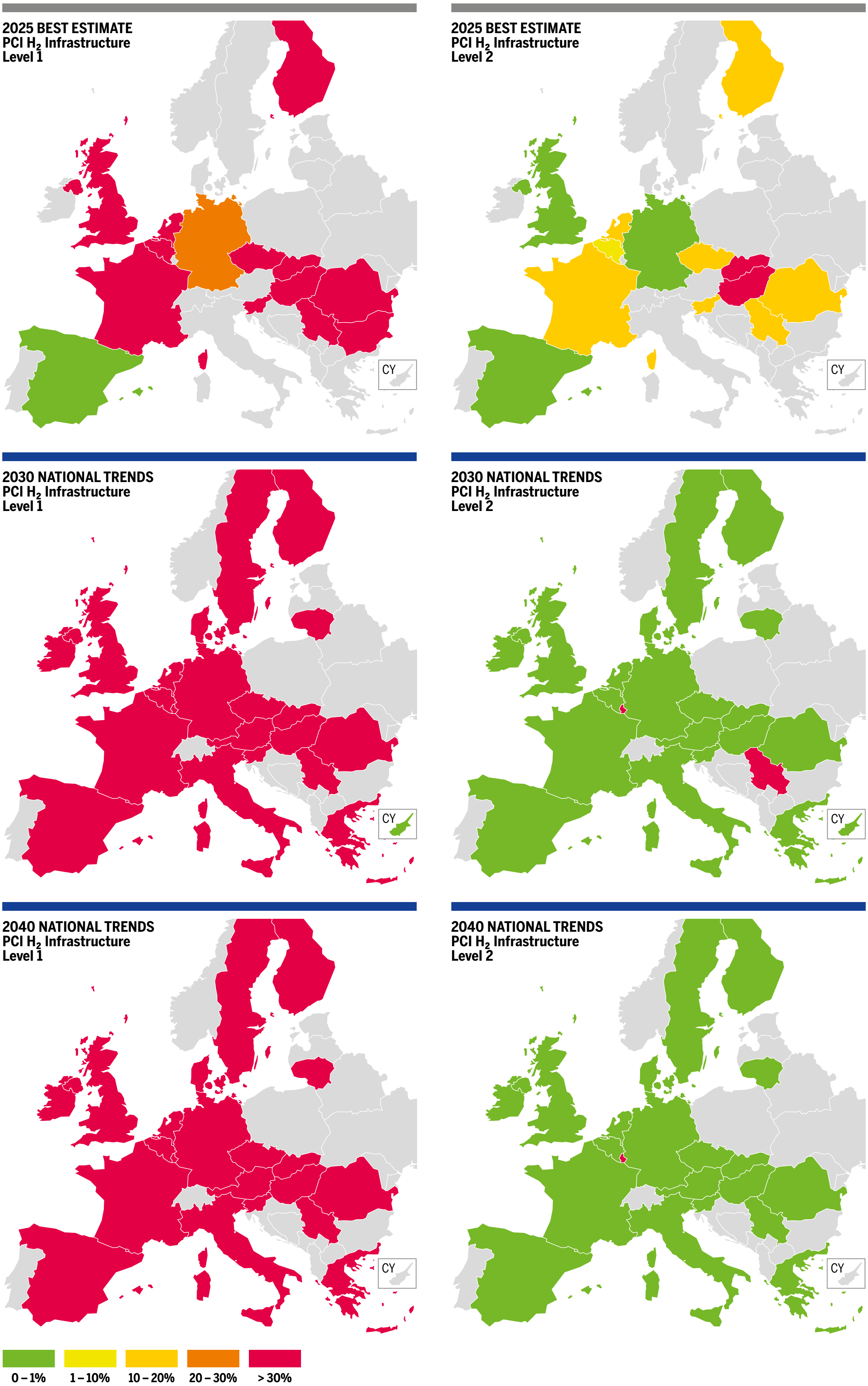


Figure 8.10a Hydrogen Results for 2W Demand in PCI & Advanced CH_4 Infrastructure and H_2 Level 1 and 2

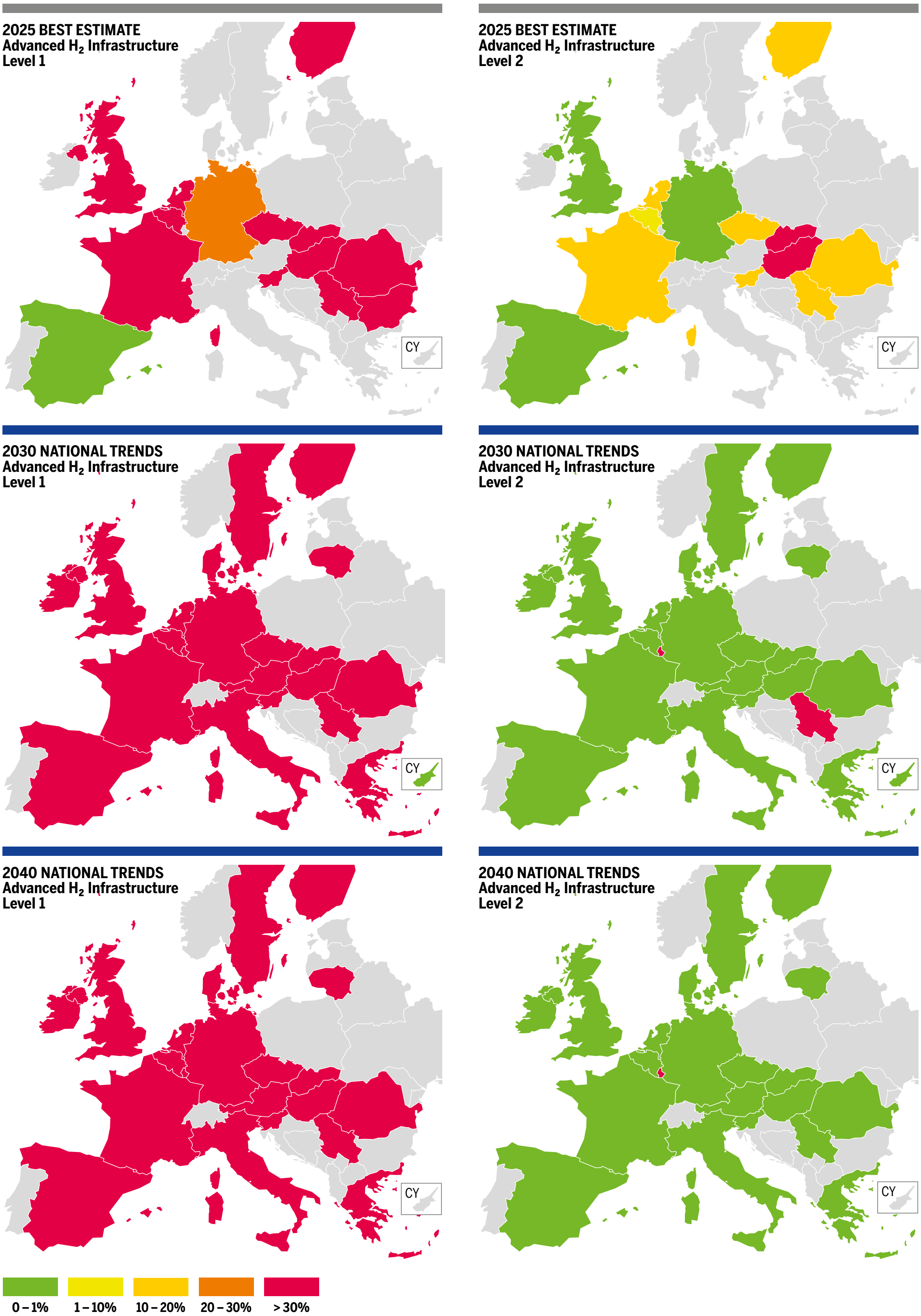


Figure 8.10b Hydrogen Results for 2W Demand in PCI & Advanced CH_4 Infrastructure and H_2 Level 1 and 2

Both **CH_4 PCI and CH_4 Advanced infrastructure** together with H_2 levels 1 and 2 show that curtailment results remain unchanged compared to 2 week cold spell demand described in the Reference case.

8.3 2-WEEK DUNKELFLAUTE DEMAND

The 2-Week Dunkelflaute country demands are generally very similar to the 2-Week Cold Spell demand values. Hydrogen demand is the same for Best Estimate and National Trends scenarios and it is also the same in the year 2030 of Distributed Energy and Global Ambition scenarios. Regarding Distributed Energy and Global Ambition scenarios in 2040 and 2050, only Italy, The Netherlands, Romania and United Kingdom show higher values in 2-Week Dunkelflaute.

Regarding the methane demand values, only Bulgaria, Czech Republic, Germany, Croatia and Italy present slight differences when comparing demand of 2-Week Dunkelflaute with 2-Week Cold in Best Estimate and National trends scenarios. In Distributed Energy and Global Ambition scenarios just Spain, France, Greece, Italy, The Netherlands, Portugal, Romania and United Kingdom present higher methane demand in 2-Week Dunkelflaute.

Consequently, the curtailment rate results in 2-Week Dunkelflaute and in 2-Week Cold Spell are exactly the same for most of the countries. The countries with higher demand in 2-Week Dunkelflaute are only increasing their demand curtailment rate in 1 or 2 % maximum.


Picture courtesy of Plinovodi

8.4 PEAK DEMAND

8.4.1 METHANE RESULTS

8.4.1.1 Existing Methane Infrastructure

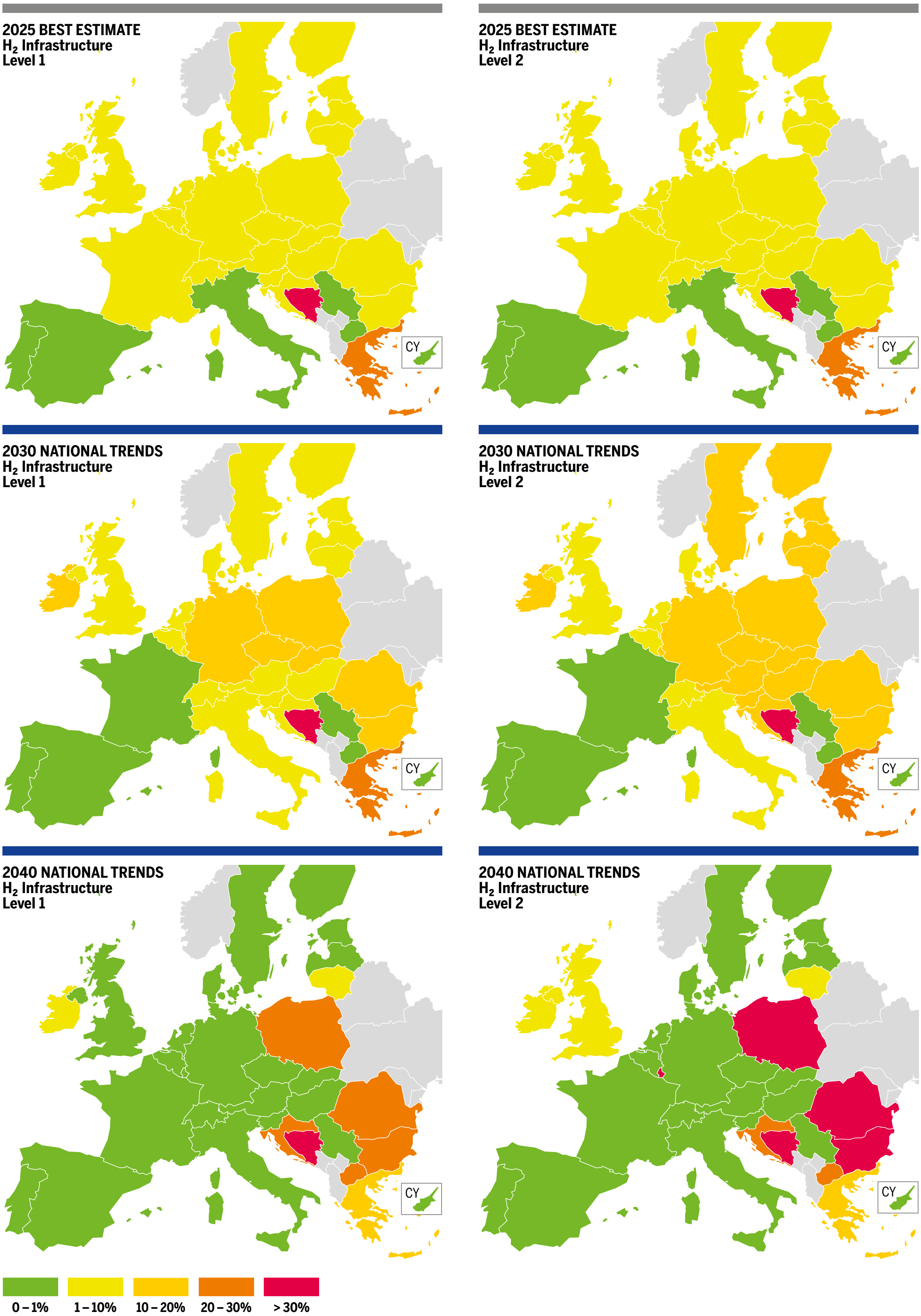


Figure 8.11 RU CH_4 Supply Disruption – Methane Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 1 and 2

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

For No Russia in Best Estimate scenario all the countries with curtailed demand in the Reference case show 2–3 % extra curtailment and Greece jumps from 7 to 28 % due to infrastructure limitations.

H_2 INFRASTRUCTURE LEVEL 2

In H_2 Level 2 all the countries with curtailed demand in the Reference case show 2-3 % extra curtailment, Greece behaves equal to H_2 Level 1 and additionally Austria shows a demand curtailment of 10 %.

2030

H_2 INFRASTRUCTURE LEVEL 1

In 2030 Greece shows 28 % demand curtailment again. There are also many countries showing demand curtailment, Bulgaria, Czech Republic, Germany, Ireland, Poland, Romania and Slovakia with 11-13 % and with 8-9 % those are Austria, Belgium, Denmark, Estonia, Finland, Croatia, Hungary, Latonia, Luxemburg, Latvia, The Netherlands, Sweden, Slovenia and United Kingdom.

H_2 INFRASTRUCTURE LEVEL 2

Compared to H_2 Level 1, Level 2 shows an additional demand curtailment of 4 % in, Estonia, Finland, Lithuania, Latvia and Romania and 1 % change or less in the rest of the countries with curtailment.

2040

H_2 INFRASTRUCTURE LEVEL 1

In National Trends 2040 without Russian gas only Bulgaria and Romania are showing new demand curtailment of 26 % and Greece of 18 %.

H_2 INFRASTRUCTURE LEVEL 2

In H_2 Level 2 shows new curtailments of 36 % in Luxemburg and 6 % in UK and other countries increasing to 32–33 % (Bulgaria, Poland and Romania).


Picture courtesy of GRTgaz

8.4.1.2 Advanced and PCI Methane Infrastructure

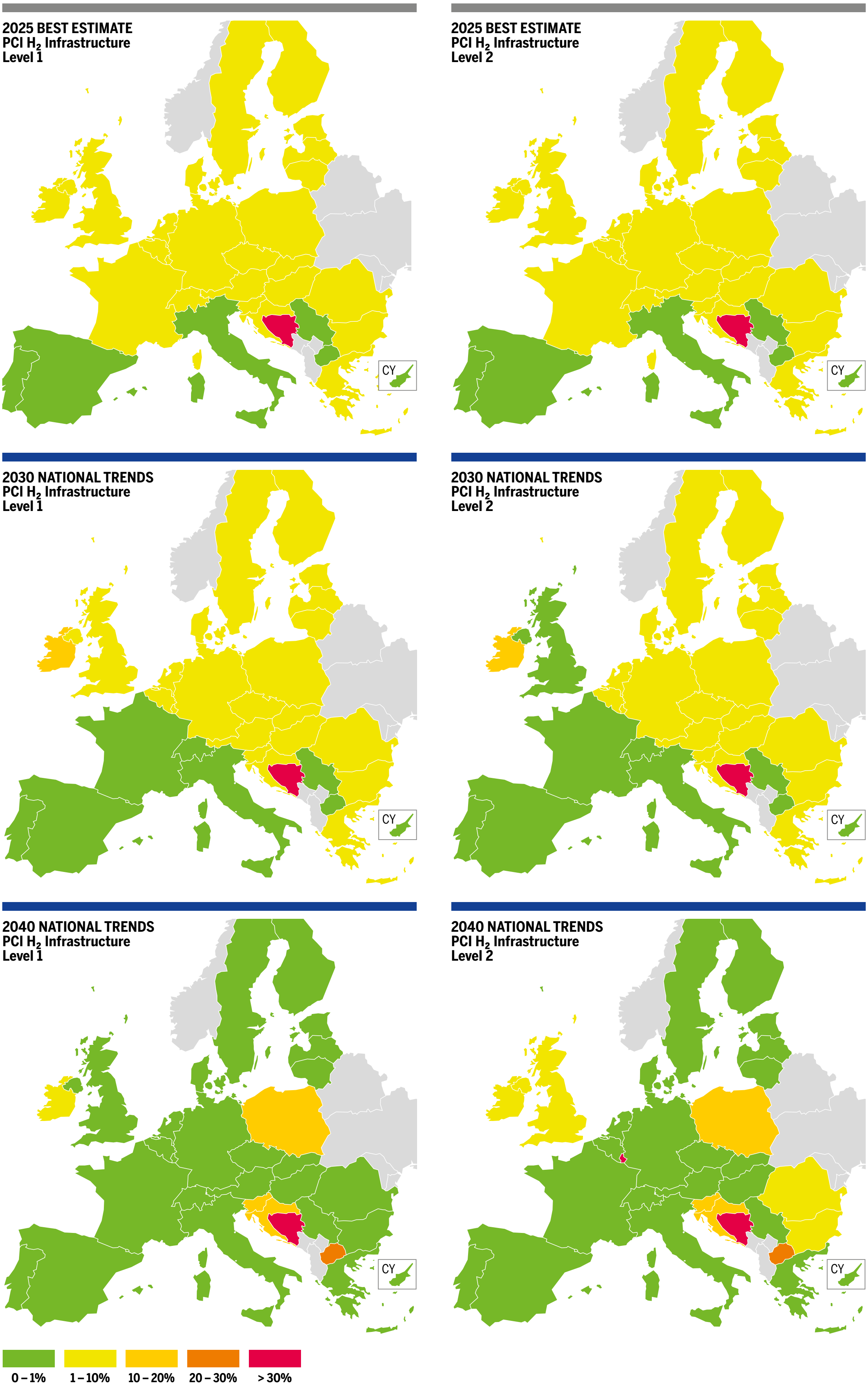


Figure 8.12a RU CH_4 Supply Disruption – Methane Results for Peak Demand in PCI & Advanced CH_4 Infrastructure and H_2 Level 1 and 2

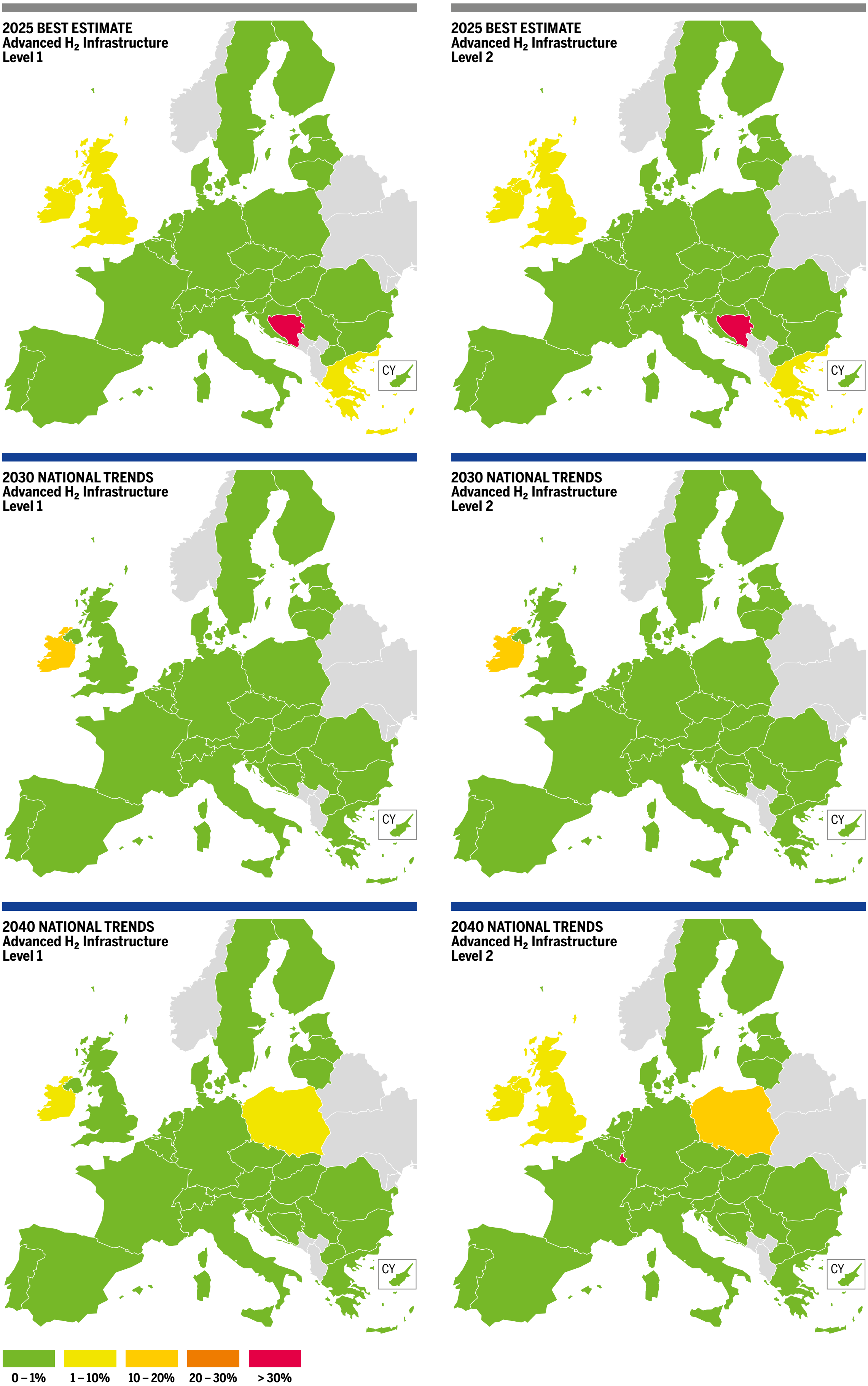


Figure 8.12b RU CH_4 Supply Disruption – Methane Results for Peak Demand in PCI & Advanced CH_4 Infrastructure and H_2 Level 1 and 2

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

PCI infrastructure allows all the countries with curtailment to reduce the figures to 3–4 %, except for Greece with 10 %.

With Advanced infrastructure only Greece shows an extra 3 % demand curtailment compared to the Reference case, much less than the 28 % reached with Existing infrastructure.

H_2 INFRASTRUCTURE LEVEL 2

PCI infrastructure with H_2 Level 2 increases demand curtailment in all countries by only 1 %, Greece remains with 10 %. Same result to H_2 Level 1 in Advance.

2030

H_2 INFRASTRUCTURE LEVEL 1

PCI infrastructure in 2030 shows many countries with a new 3 % of demand curtailment: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, Greece, Croatia, Hungary, Latonia, Luxemburg, Latvia, The Netherlands, Sweden, Slovenia, and Romania compared to Refence case results.

Poland and UK change their result to a 4 % of demand curtailment.

Advanced infrastructure shows exactly the same results as the ones from Reference case.

H_2 INFRASTRUCTURE LEVEL 2

PCI with H_2 Level 2 shows an additional demand curtailment of 4 % in Bulgaria, Estonia, Finland, Lithuania, Latvia and Romania.

Advanced infrastructure shows exactly the same results as the ones from Reference case.

2040

H_2 INFRASTRUCTURE LEVEL 1

In Advance infrastructure only Poland shows a different demand curtailment raising from 9 % in Reference to 17 % in No Russia.

H_2 INFRASTRUCTURE LEVEL 2

In both PCI and Advanced Infrastructure there are new curtailments of 36 % in Luxemburg and 6 % in UK compared to Level 1.

Picture courtesy of REN

8.4.2 HYDROGEN RESULTS

8.4.2.1 Existing Methane Infrastructure

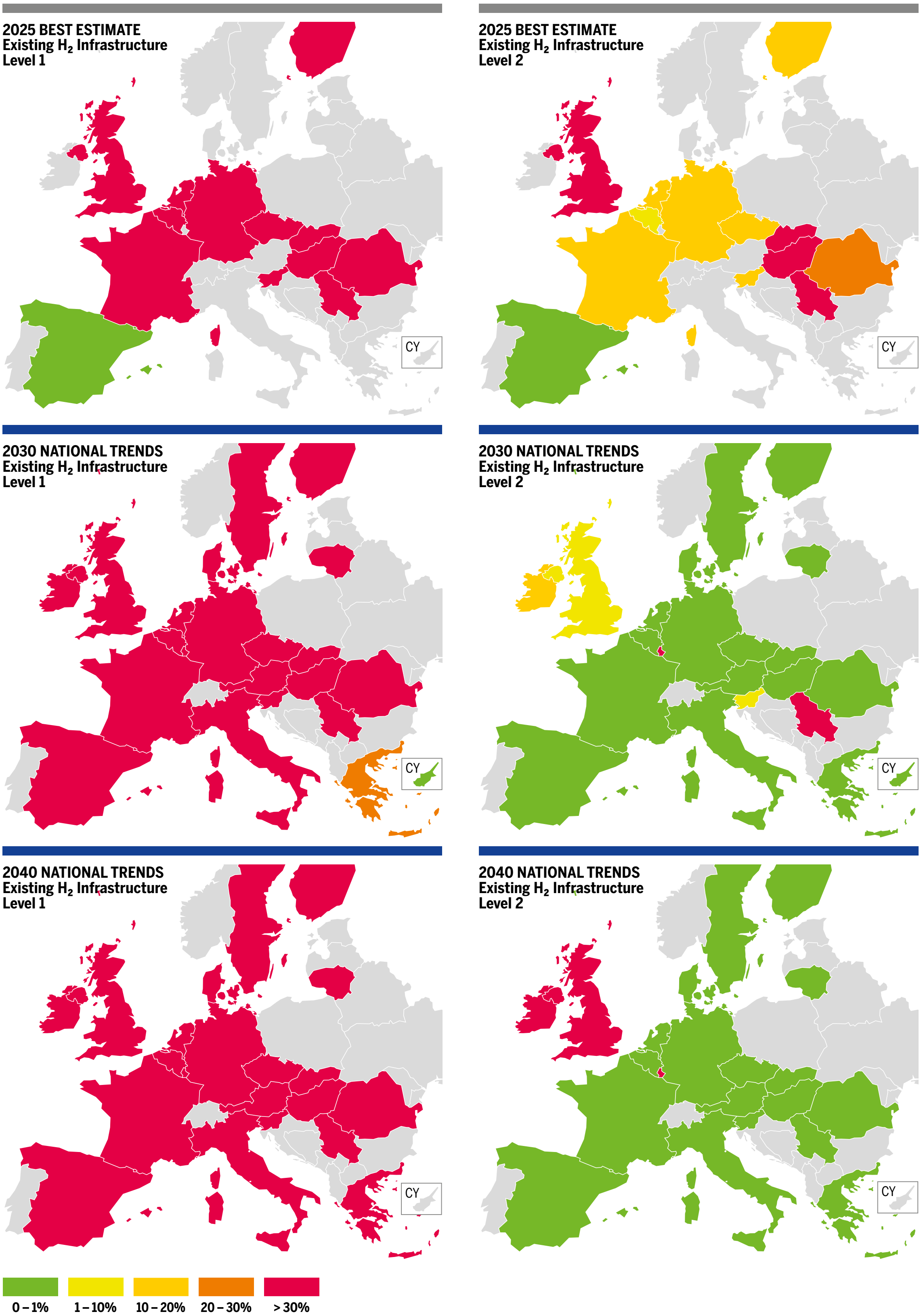


Figure 8.13 RU CH_4 Supply Disruption – Hydrogen Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 1 and 2

CH_4 Existing infrastructure results show that H_2 demand curtailment remains unchanged compared to the Reference case results in all years of both H_2 levels 1.

8.4.2.2 Advanced and PCI Methane Infrastructure

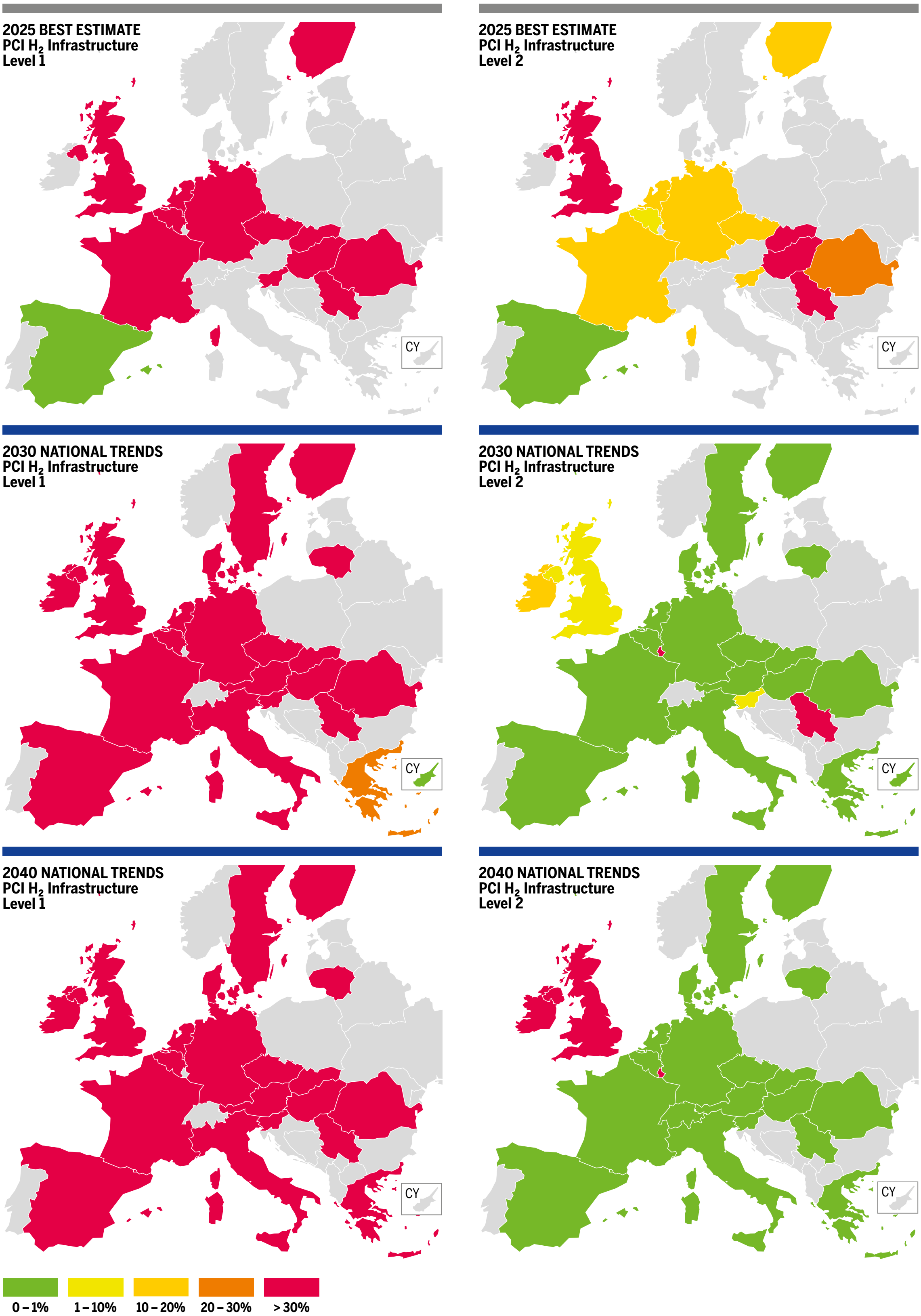


Figure 8.14a RU CH_4 Supply Disruption – Methane Results for Peak Demand in PCI & Advanced CH_4 Infrastructure and H_2 Level 1 and 2

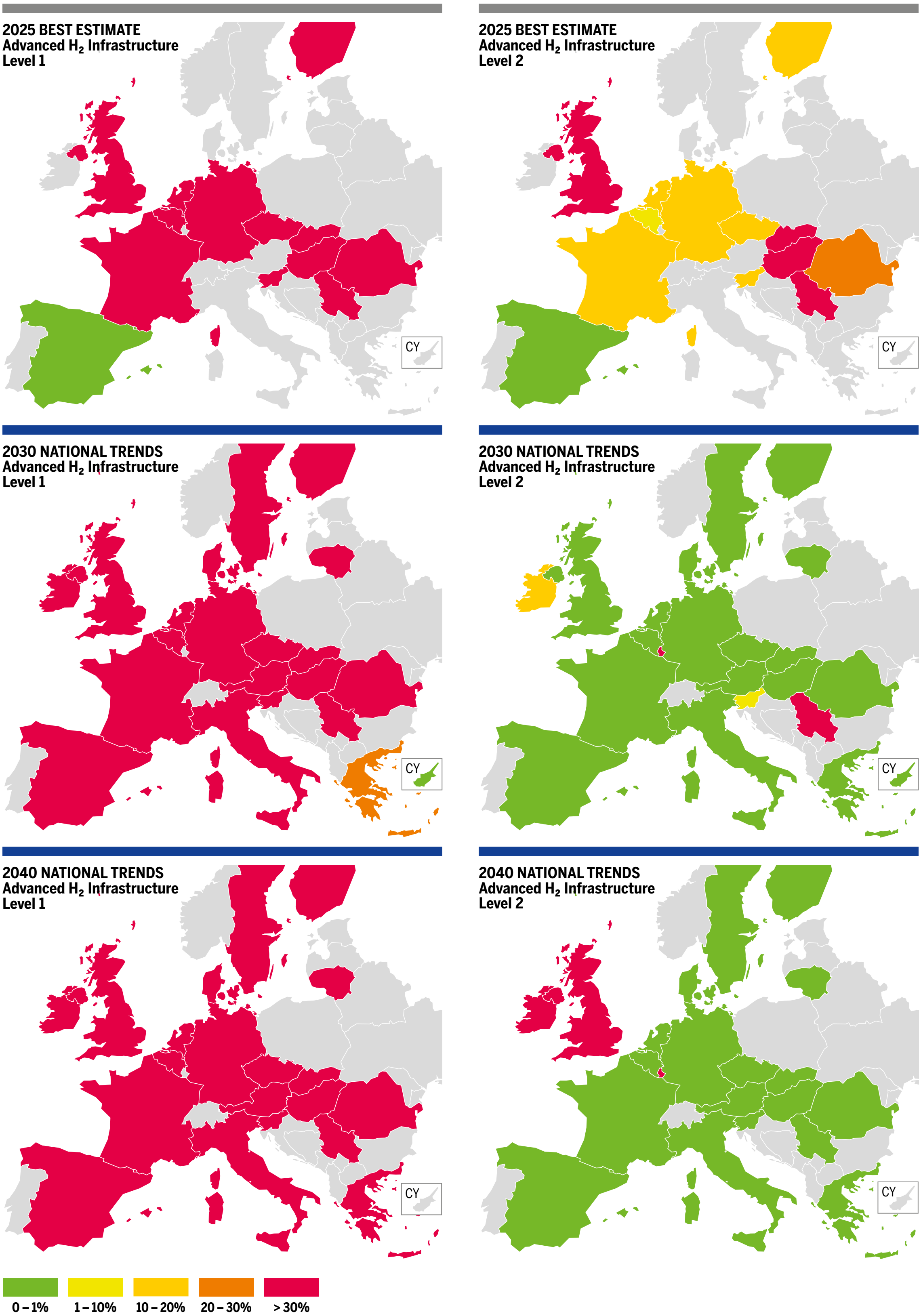


Figure 8.14b RU CH_4 Supply Disruption – Methane Results for Peak Demand in PCI & Advanced CH_4 Infrastructure and H_2 Level 1 and 2

PCI and Advanced infrastructure show in both H_2 levels that curtailment results remain unchanged compared to the ones for peak demand in the Reference case.

9 NORTH AFRICA HYDROGEN SUPPLY DISRUPTION

9.1 YEARLY DEMAND

North Africa Hydrogen supply disruption does not impact simulations results in 2025 Best Estimate and in National Trends demand scenarios (2030 and 2040); in those scenarios, there is no hydrogen import potential and methane demand curtailment is not impacted compared to the Reference Case. The infrastructure assessment is limited to Distributed Energy and Global Ambition demand scenarios in 2030, 2040 and 2050.

9.1.1 METHANE RESULTS

9.1.1.1 Existing

North Africa hydrogen supply disruption impact only one demand scenario and one year. In 2040, in Global Ambition scenario, Hungary, Romania, Serbia, Bulgaria and North Macedonia show 2 % demand curtailment using the maximum SMR supply potential. Neighbouring countries cannot cooperate due to infrastructure limitations and do not mitigate demand curtailment.

9.1.1.2 Advanced and PCI Methane

Demand curtailment is fully mitigated in advanced and PCI infrastructure level.

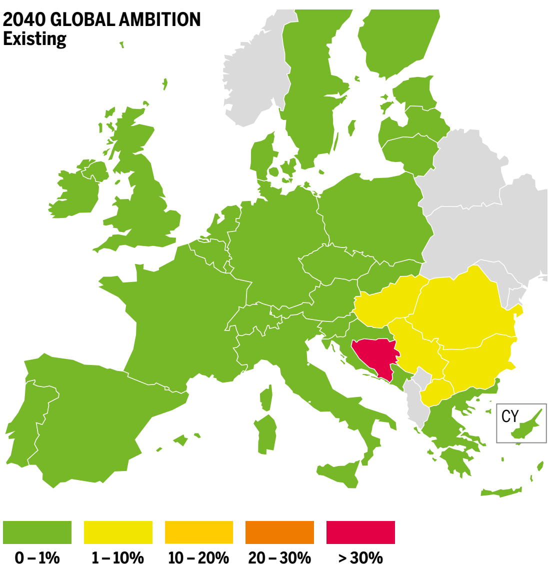


Figure 9.1 NA H_2 Supply Disruption – Methane Results for Yearly Demand in Existing CH_4 with H_2 Level 1

9.1.2 HYDROGEN RESULTS

9.1.2.1 Existing Hydrogen

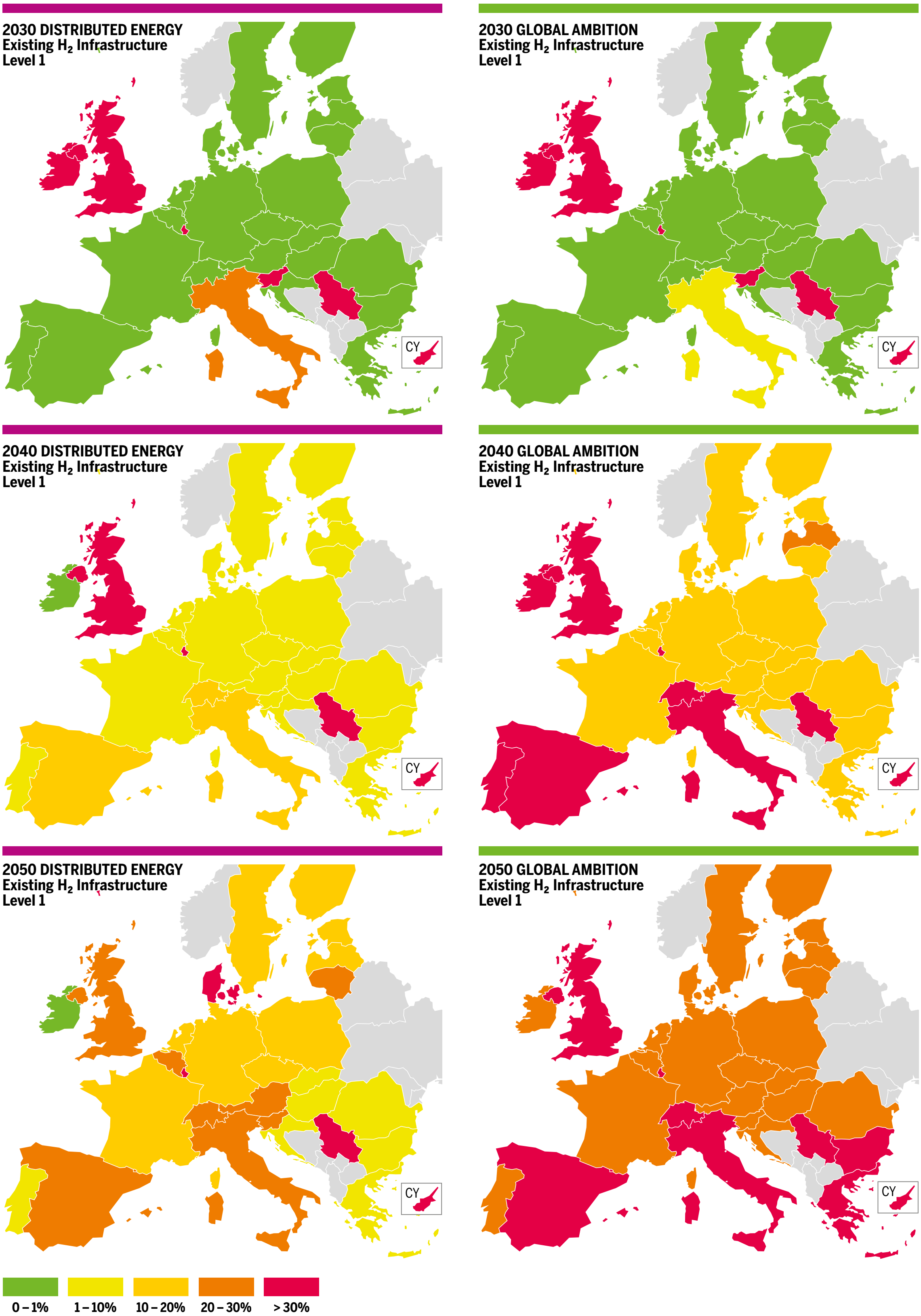


Figure 9.2a NA H_2 Supply Disruption – Hydrogen Results for Yearly Demand in Existing CH_4 Infrastructure and H_2 Level 1

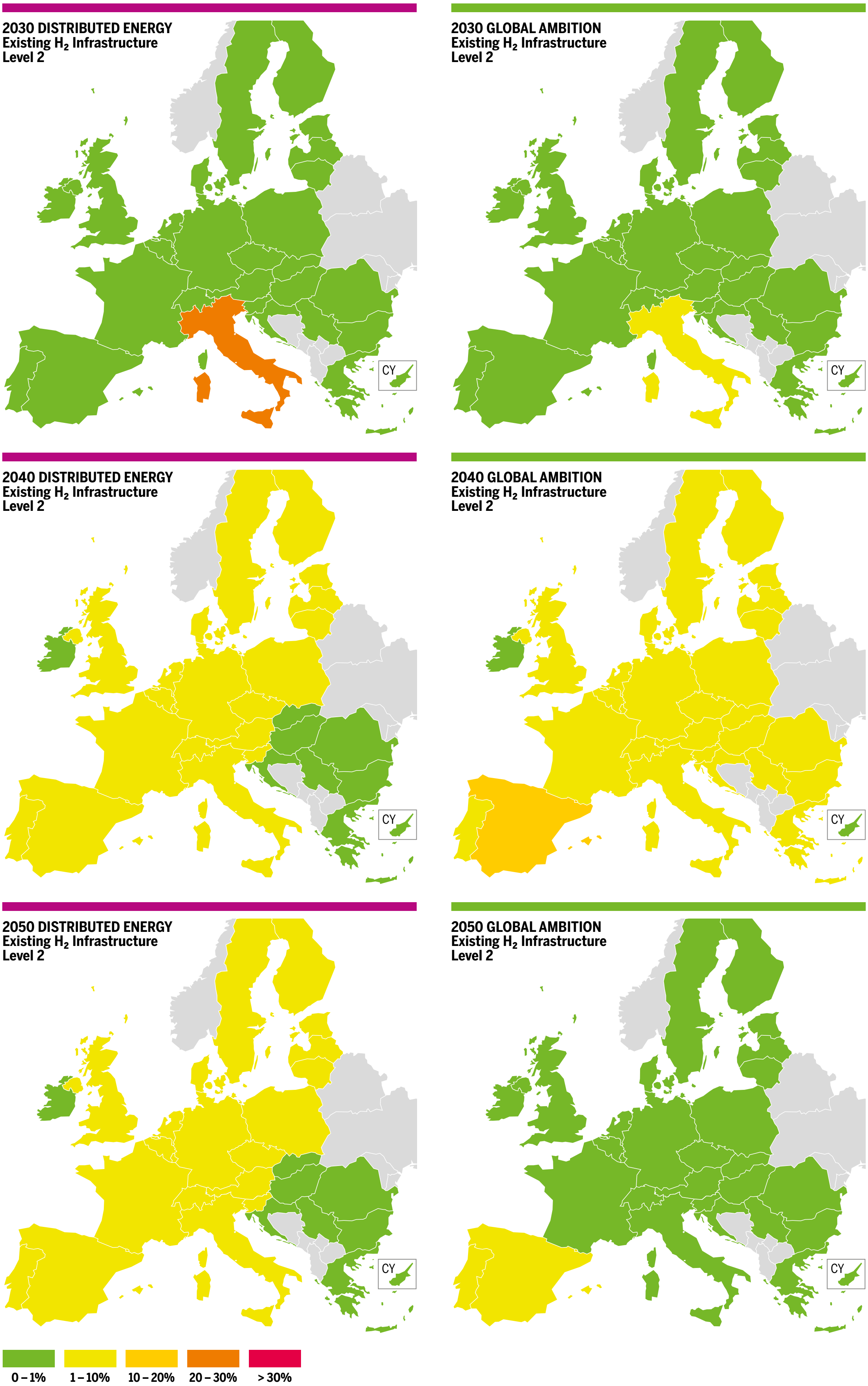


Figure 9.2b NA H_2 Supply Disruption – Hydrogen Results for Yearly Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

In both scenarios (**Distributed Energy and Global Ambition**), Italy is curtailed respectively to 29 % and 2 %. Hydrogen bottleneck does not allow Austria to cooperate more with Italy. Ireland, United Kingdom, Slovenia and Serbia, without any interconnections with other countries they cannot satisfy their demand with their own hydrogen production.

H_2 INFRASTRUCTURE LEVEL 2

Italy is curtailed (23 % in **Distributed Energy** scenario and 2 % in **Global Ambition** scenario) and hydrogen infrastructures limitations do not allow Austria to cooperate more with Italy. Other countries already curtailed in Infrastructure Level 1 can now satisfy their demand with interconnections with neighbouring countries and cooperation.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show demand curtailment (8 % to 9 %) with a good cooperation between countries. Countries on the east side (Croatia, Hungary, Romania, Bulgaria and Greece) with more supply show limited curtailment (3 % to 5 %) but cannot cooperate more with other countries due to infrastructure limitations. Italy (13 %), Spain (12 %) and Portugal (10 %) show higher demand curtailment compared to other countries due to bottlenecks with neighbouring countries (Austria and Slovenia for Italy and France, Portugal with Spain). United Kingdom (84 %), Luxembourg (84 %) and Serbia (100 %) without any interconnection with neighbouring countries they cannot satisfy their demand with own production.

In **Global Ambition** scenario, most of the countries show demand curtailment (18 % to 19 %). Countries on the east side (Croatia, Hungary, Romania, Bulgaria and Greece) with more supply limit their curtailment to 14 % to 15 % and cannot cooperate more with other countries due to infrastructure limitations. Italy (31 %), Spain and Portugal (32 %) show higher demand curtailment compared to other countries due to bottlenecks with neighbouring countries (Austria and Slovenia for Italy and France with Spain). The other countries show demand curtailment: Ireland(50 %), United Kingdom (71 %) and Serbia (100 %) without any interconnections with other countries do not satisfy their demand with their own production.

H_2 INFRASTRUCTURE LEVEL 2

All countries mitigate demand curtailment. In **Distributed Energy** scenario, most of the countries reach 3 % demand curtailment and countries on the east side (Croatia, Hungary, Romania, Bulgaria and Greece) with more supply show no curtailment but cannot cooperate more with other countries due to infrastructure limitations. In Global Ambition scenario, most of the countries show 4 % demand curtailment. Countries on the east side (Hungary, Romania, Bulgaria and Greece) with more supply limit their curtailment to 1 % and cannot cooperate more with other countries due to bottlenecks. Spain and Portugal show respectively 12 % and 10 % demand curtailment. France and Portugal cannot cooperate more with Spain due to infrastructure limitations between France, Portugal and Spain.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show demand curtailment (19 % to 20 %). Countries on the east side (Croatia, Hungary, Bulgaria and Greece) with more supply limit their curtailment to 3 to 4 % and cannot cooperate more with other countries due to infrastructure limitation. Italy (30 %) and Spain (23 %) show higher demand curtailment compared to other countries due to infrastructure limitations with neighbouring countries (Austria and Slovenia for Italy and France and Portugal with Spain). Portugal shows only 9 % demand curtailment and cannot cooperate with Spain due to infrastructure limitation (bottleneck). The other countries are curtailed: United Kingdom (26 %), Luxembourg (87 %), and Serbia (100 %), without any interconnections with other countries do not satisfy their demand with their own production.

In **Global Ambition** scenario, most of the countries show demand curtailment (28 %). Italy shows 48 % demand curtailment, and interconnected countries, Austria, Slovenia and Spain cannot cooperate more due to infrastructure limitations. Greece shows 39 % demand curtailment due to infrastructure limitation with Bulgaria. Bulgaria shows 30 % demand curtailment due to infrastructure limitation with Romania. Spain shows 37 % demand curtailment due to infrastructure limitations with France and Portugal with respectively 26 % and 30 % demand curtailment. The other countries: Ireland (27 %), United Kingdom (49 %), Luxembourg (91 %) and Serbia (100 %), without any interconnections with other countries cannot satisfy their demand with their own hydrogen production.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, Ireland, Eastern countries (Croatia, Hungary, Slovakia, Romania, Bulgaria, Serbia and Greece) fully mitigate their demand curtailment. The rest of the countries show 5 % demand curtailment except for Portugal with 3 %. Eastern countries cannot cooperate with other countries due to bottlenecks and Portugal cannot help to mitigate Spain's demand curtailment due to infrastructure limitations between Portugal and Spain.

Demand curtailment is fully mitigated in **Global Ambition** scenario. Only Spain (5 %) and Portugal (4 %) show demand curtailment and France cannot cooperate more with Spain due to a bottleneck between France and Spain and between Portugal and Spain.

9.1.2.2 Advanced and PCI Infrastructure

Simulations results show no difference in Advanced and PCI infrastructure level.

9.2 2-WEEK COLD SPELL DEMAND

9.2.1 METHANE RESULTS

9.2.1.1 Existing

Demand curtailment results are similar to the curtailment rates in the reference case. The North Africa Hydrogen disruption does not impact the methane simulation results.

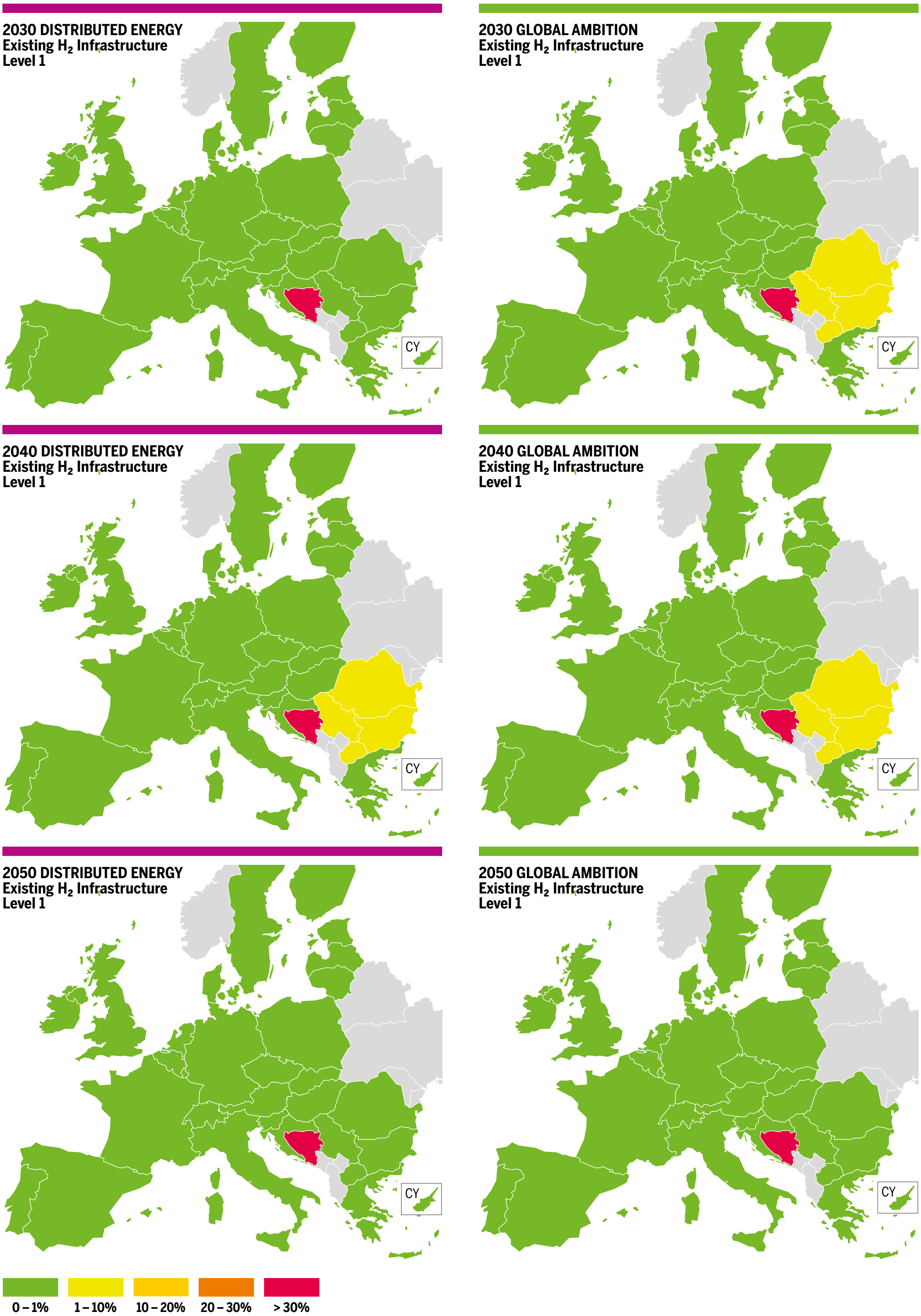


Figure 9.3a NA H_2 Supply Disruption – Methane Results for Yearly Demand in Existing CH_4 Infrastructure and H_2 Level 1

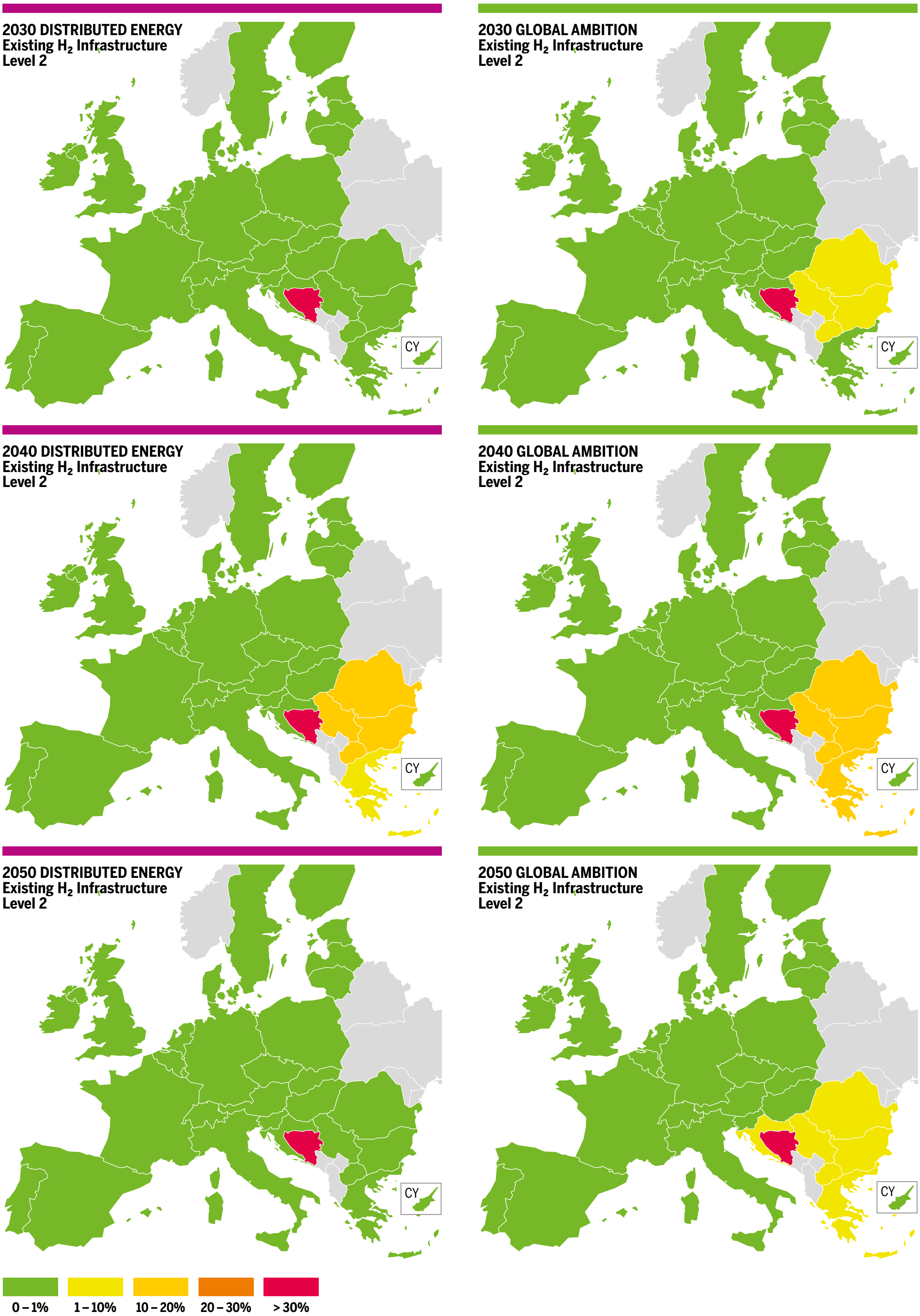


Figure 9.3b NA H_2 Supply Disruption – Methane Results for Yearly Demand in Existing CH_4 Infrastructure and H_2 Level 2

9.2.1.2 Advanced and PCI Methane

Demand curtailment is fully mitigated as in Reference case. The North Africa Hydrogen disruption does not impact the methane simulation results.

9.2.2 HYDROGEN RESULTS

9.2.2.1 Existing Hydrogen

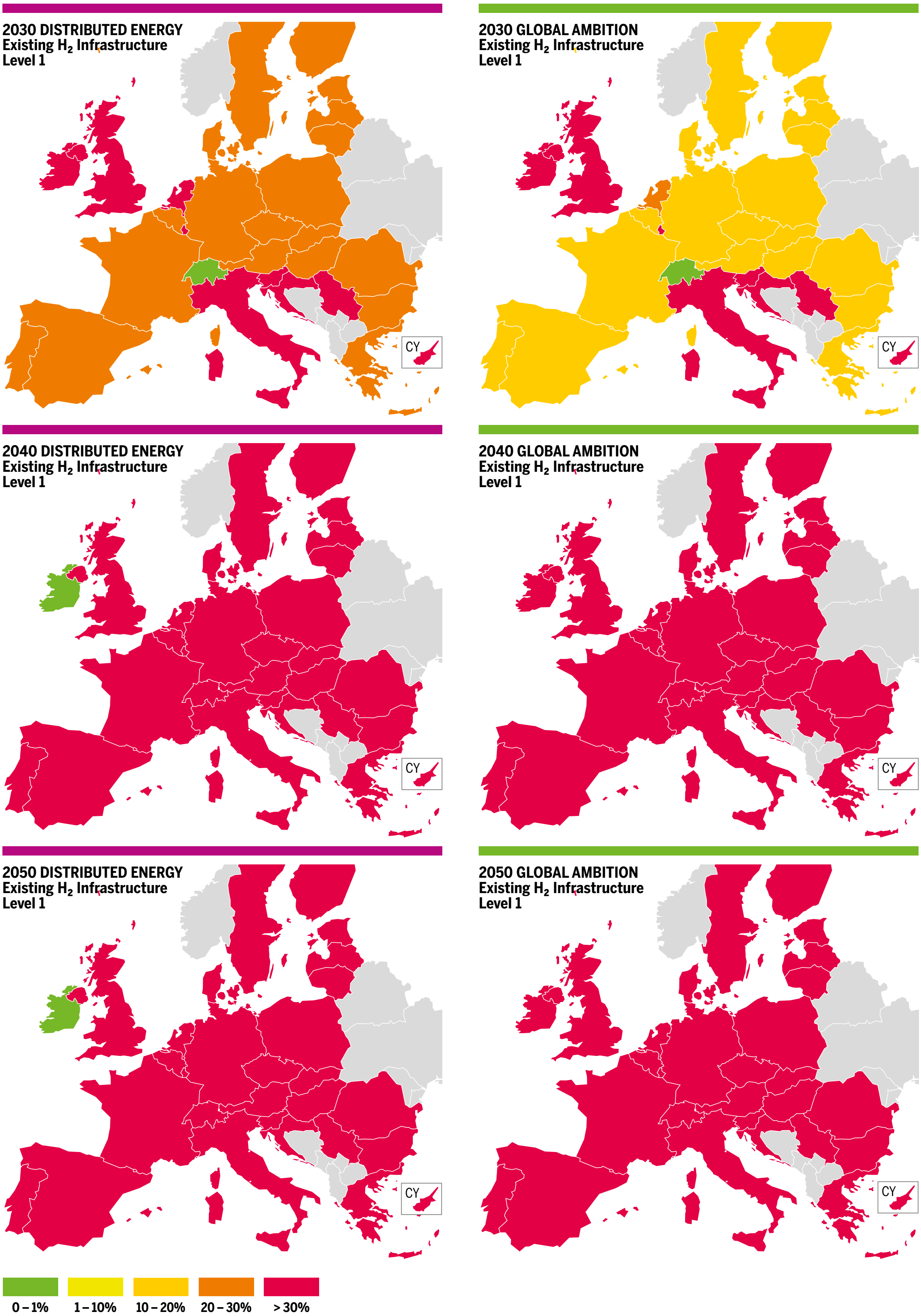


Figure 9.4a NA H_2 Supply Disruption – Hydrogen Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 1

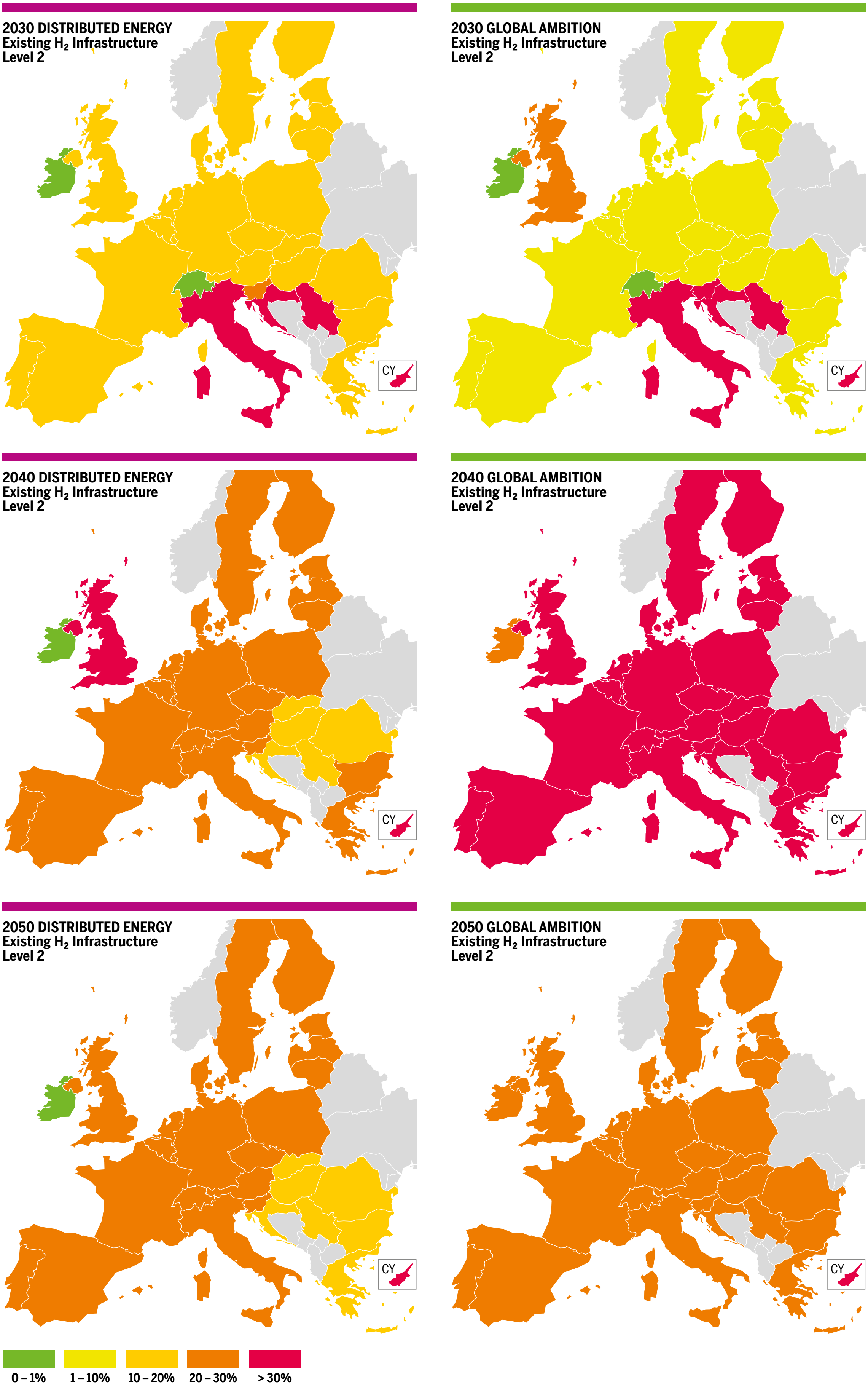


Figure 9.4b NA H_2 Supply Disruption – Hydrogen Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, Ireland (43 %), United Kingdom (71 %), Luxembourg (70 %), Croatia (38 %), Slovenia (89 %) and Serbia (100 %) are not interconnected and show demand curtailment. Their own production cannot satisfy their demand. Italy (49 %) without North Africa supply cannot satisfy its demand and a bottleneck does not allow Austria to cooperate more with Italy. The Netherlands shows 31 % demand curtailment. Belgium and Germany cannot cooperate more due to infrastructure limitations. The other countries show 22 % demand curtailment and infrastructure show no bottlenecks and allow a good cooperation.

In **Global Ambition** scenario, Ireland (46 %), United Kingdom (69 %), Luxembourg (66 %), Croatia (32 %), Slovenia (92 %) and Serbia (100 %) are not interconnected and show demand curtailment. Their own production cannot satisfy their demand. Italy (36 %) without North Africa supply cannot satisfy its demand and infrastructure limitations do not allow Austria to cooperate more with Italy. The Netherlands shows 23 % demand curtailment. Belgium and Germany cannot cooperate more due to bottlenecks. The other countries show 13 % demand curtailment and infrastructure show no bottlenecks and allow a good cooperation.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, Italy show 48 % demand curtailment and Austria cannot cooperate more due to mitigate demand curtailment in Italy. Ireland fully mitigates its demand curtailment with the use of storage and additional hydrogen production with the use of methane. Serbia (41 %), Slovenia (29 %), UK (19 %) and Luxembourg (15 %) mitigate their demand curtailment as the rest of the countries (11 %). With terminal in United Kingdom, the use of storages, new interconnections and additional hydrogen production with the use of methane, those countries mitigate their demand curtailment.

In **Global Ambition** scenario, simulations show similar results with lower demand curtailment due to lower demand values. The rest of the countries reach 3 % and are closed to satisfy their demand.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, United Kingdom (83 %), Luxembourg (87 %) and Serbia (100 %) are not interconnected and show demand curtailment. Their own production cannot satisfy their demand. Italy (42 %) and Switzerland (42 %) without North Africa supply cannot satisfy its demand and infrastructure limitations (bottlenecks) with Austria and Slovenia does not allow Austria and Slovenia to cooperate more with Italy. The other countries show 39 % demand curtailment and infrastructure show no bottlenecks and allow a good cooperation. Portugal and Spain show 41 % demand curtailment and France cannot cooperate more with Spain due to infrastructure limitation (bottleneck).

In the **Global Ambition** scenario, situation is similar with higher demand curtailment. United Kingdom (85 %), Luxembourg (91 %) and Serbia (100 %) are not interconnected and show demand curtailment. Their own production cannot satisfy their demand. Italy (63 %) and Switzerland (63 %) without North Africa supply cannot satisfy its demand and infrastructure limitations with Austria and Slovenia do not allow Austria and Slovenia to cooperate more with Italy. The other countries show 52 % demand curtailment and infrastructure show no bottlenecks and allow a good cooperation. Portugal and Spain show 62 % demand curtailment and France cannot cooperate more with Spain due to a infrastructure limitation.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, Italy shows 30 % demand curtailment and Spain, Austria and Slovenia cannot cooperate more to mitigate demand curtailment in Italy due to infrastructure limitations. Ireland fully mitigates its demand curtailment with the use of storage and additional hydrogen production with methane. United Kingdom shows 32 % curtailment rate and bottlenecks do not allow interconnected countries (Belgium, Ireland) to mitigate demand curtailment. Most of the rest of the countries show 29 % demand curtailment. Slovakia, Hungary, Croatia, Serbia and Romania, with 16 % demand curtailment, cannot cooperate with those countries due to bottlenecks as they cannot cooperate with Bulgaria and Greece with 28 % demand curtailment due to infrastructure limitation with Romania and Serbia.

In **Global Ambition** scenario, most of the countries show 39 % demand curtailment and we can observe a good cooperation between all countries due to high demand curtailment. Only Ireland has lower demand curtailment (22 %) and cannot cooperate with United Kingdom to mitigate its demand curtailment due to a bottleneck between Ireland and United Kingdom.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, Luxembourg and United Kingdom show respectively 90 % and 57 % demand curtailment (no interconnection with neighbouring countries). Italy and Switzerland show 51 % demand curtailment due to North Africa supply disruption and Austria cannot cooperate more with Italy to mitigate demand curtailment. Spain shows 51 % demand curtailment and cooperate at its maximum and France (46 %) and Portugal (32 %) cannot cooperate more due to infrastructure limitations. Eastern countries (Slovakia, Hungary, Romania, Bulgaria and Greece) show 32 % demand curtailment and cannot cooperate with other countries with 46 % demand curtailment due to bottlenecks.

In **Global Ambition** scenario, Luxembourg, Ireland and United Kingdom show respectively 94 %, 51 % and 68 % demand curtailment. Without any interconnection with other countries, they cannot satisfy their demand with their own production. Italy, Switzerland, Portugal and Spain show 69 % demand curtailment due to supply disruption from North Africa and infrastructure limitation from Austria and Slovenia to Italy and from France to Spain. Greece shows 65 % demand curtailment and Bulgaria cannot cooperate more with Greece due to a bottleneck between Bulgaria and Greece. Other countries show 58 % demand curtailment.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, United Kingdom shows 27 % demand curtailment and Ireland fully mitigates its demand curtailment and cannot cooperate more with United Kingdom due to an infrastructure limitation between Ireland and United Kingdom. Eastern countries (Slovakia, Serbia, Croatia, Hungary, Romania, Bulgaria and Greece) show only 15 % demand curtailment and cannot cooperate with other countries with 25 % demand curtailment due to bottlenecks.

In **Global Ambition** scenario, all countries show 25 % demand curtailment. Only Ireland shows 21 % demand curtailment and cannot cooperate more with United Kingdom due to abottleneck with United Kingdom.

9.2.2.2 Advanced and PCI Hydrogen

Advanced and PCI methane infrastructure levels does not show any difference with Existing infrastructure level. Hydrogen infrastructure is limited in the use of methane to produce hydrogen and the Advanced or PCI infrastructure levels does not add any additional hydrogen.

9.3 2-WEEK DUNKELFLAUTE DEMAND

The 2-Week Dunkelflaute country demands are generally very similar to the 2-Week Cold Spell demand values. Hydrogen demand is the same for Best Estimate and National Trends scenarios and it is also the same in the year 2030 of Distributed Energy and Global Ambition scenarios. Regarding Distributed Energy and Global Ambition scenarios in 2040 and 2050, only Italy, The Netherlands, Romania and United Kingdom show higher values in 2-Week Dunkelflaute.

Regarding the methane demand values, only Bulgaria, Czech Republic, Germany, Croatia and Italy present slight differences when comparing demand of 2-Week Dunkelflaute with 2-Week Cold in Best Estimate and National trends scenarios. In Distributed Energy and Global Ambition scenarios just Spain, France, Greece, Italy, The Netherlands, Portugal, Romania and United Kingdom present higher methane demand in 2-Week Dunkelflaute.

Consequently, the curtailment rate results in 2-Week Dunkelflaute and in 2-Week Cold Spell are exactly the same for most of the countries. The countries with higher demand in 2-Week Dunkelflaute are only increasing their demand curtailment rate in 1 or 2 % maximum.

9.4 PEAK DEMAND

Simulations results are similar to 2-Week Cold Spell simulations results but with higher demand curtailment values due to higher demand values.

9.4.1 METHANE RESULTS

9.4.1.1 Existing

North Africa supply disruption does not impact the methane side. Demand curtailment are demand curtailment in Reference case.

9.4.1.2 Advanced and PCI Methane

Demand curtailment is fully mitigated in all countries.

9.4.2 HYDROGEN RESULTS

9.4.2.1 Existing

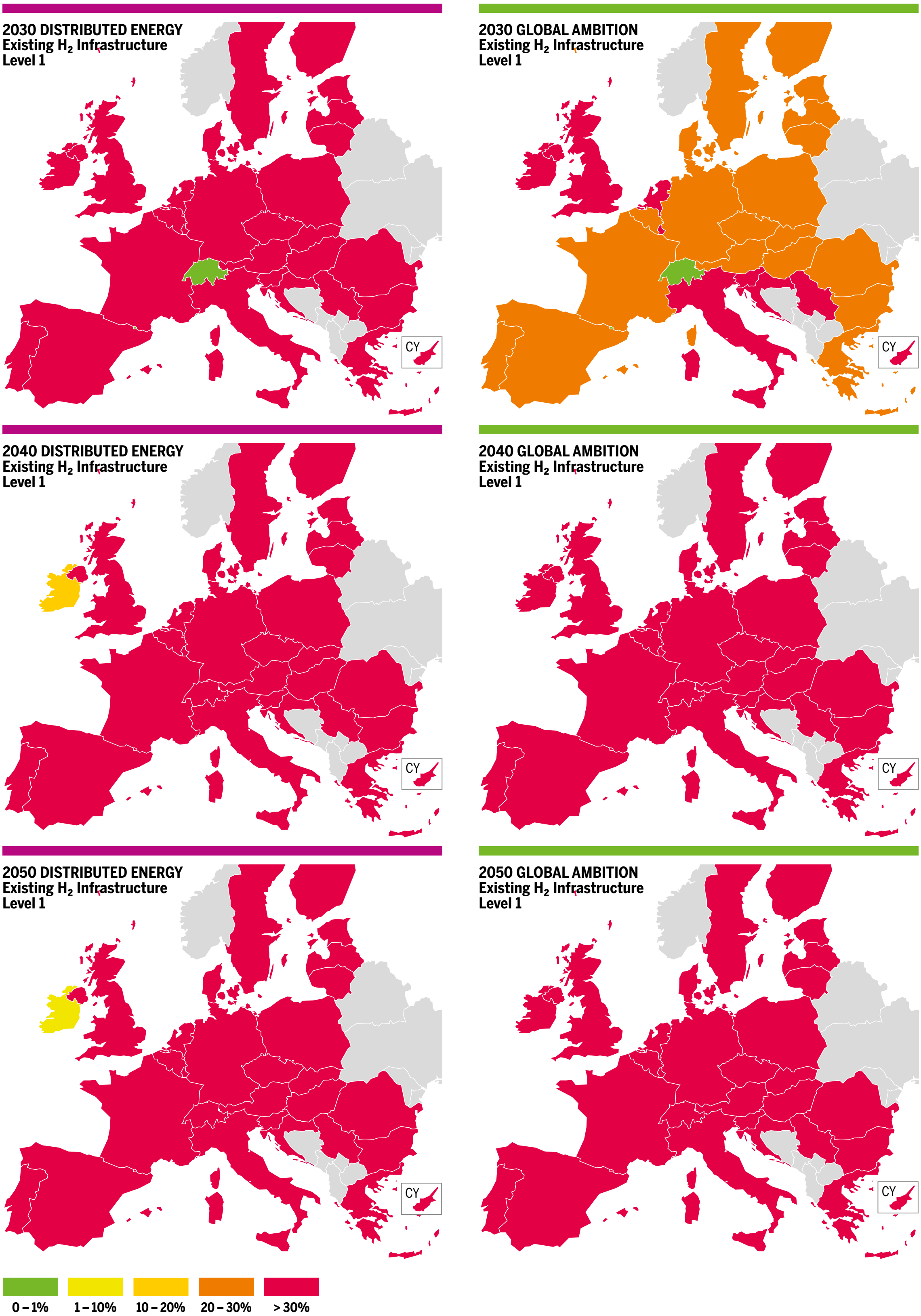


Figure 9.5a NA H_2 Supply Disruption – Hydrogen Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 1

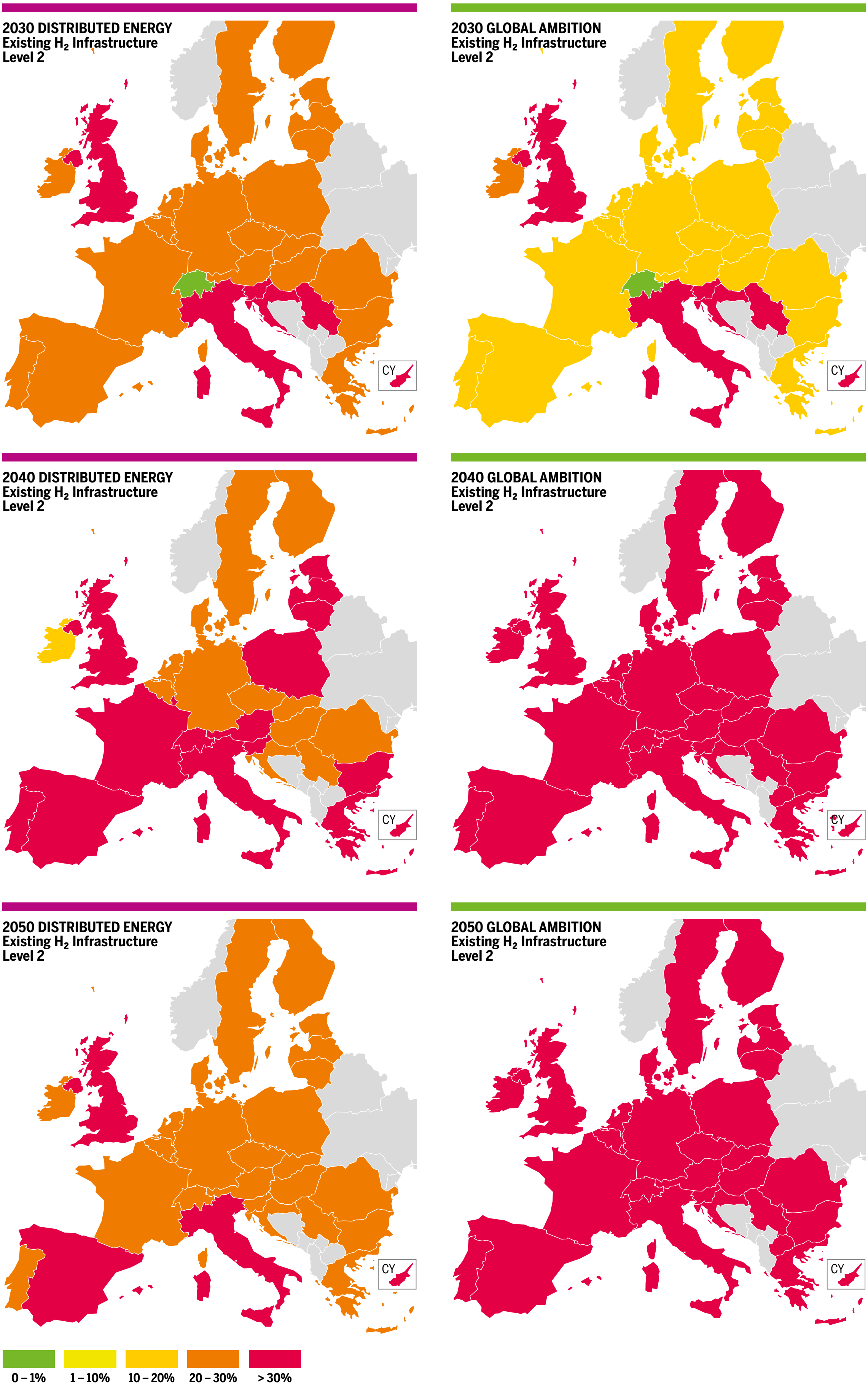


Figure 9.5b NA H_2 Supply Disruption – Hydrogen Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, Ireland (62 %), United Kingdom (78 %), Luxembourg (74 %), Croatia (49 %), Slovenia (91 %) and Serbia (100 %) are not interconnected and show demand curtailment. Their own production cannot satisfy their demand. Italy (58 %) without North Africa supply cannot satisfy its demand and a bottleneck does not allow Austria to cooperate more with Italy. The Netherlands shows 46 % demand curtailment. Belgium and Germany cannot cooperate more due to bottlenecks. The other countries show 33 % demand curtailment and infrastructure show no bottlenecks and allow a good cooperation.

In **Global Ambition** scenario, Ireland (62 %), United Kingdom (76 %), Luxembourg (71 %), Croatia (45 %), Slovenia (94 %) and Serbia (100 %) are not interconnected and show demand curtailment. Their own production cannot satisfy their demand. Italy (47 %) without North Africa supply cannot satisfy its demand and a bottleneck does not allow Austria to cooperate more with Italy. The Netherlands shows 41 % demand curtailment. Belgium and Germany cannot cooperate more due to bottlenecks. The other countries show 25 % demand curtailment and infrastructure show no bottlenecks and allow a good cooperation.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, Italy shows 58 % demand curtailment and Austria cannot cooperate more to mitigate demand curtailment in Italy due to an infrastructure limitation. Ireland (25 %), Serbia (49 %), Slovenia (42 %), United Kingdom (36 %) and Luxembourg (27 %) mitigate their demand curtailment as the rest of the countries (21 %). With terminal in United Kingdom, the use of storages, new interconnections and additional hydrogen production with the use of methane, those countries mitigate their demand curtailment. Eastern countries (Bulgaria, Greece, Hungary, Romania) show 25 % demand curtailment and other countries interconnected cannot cooperate with them due to infrastructure limitations.

In **Global Ambition** scenario, Italy shows 47 % demand curtailment and Austria cannot cooperate more to mitigate demand curtailment in Italy due to an infrastructure limitation. Ireland (20 %), Serbia (49 %), Slovenia (44 %), United Kingdom (40 %) and Luxembourg (29 %) mitigate their demand curtailment as the rest of the countries (14 %). With terminal in United Kingdom, the use of storages, new interconnections and additional hydrogen production with the use of methane, those countries mitigate their demand curtailment. Eastern countries (Bulgaria, Greece, Hungary, Romania) show 27 % demand curtailment and other countries interconnected cannot cooperate with them due to infrastructure limitations.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, Serbia and Luxembourg show respectively 100 % and 88 % demand curtailment. Most of the rest of the countries show 48 % demand curtailment without enough supply. Eastern countries (Bulgaria, Croatia, Greece, Hungary, Romania) show 43 % demand curtailment and cannot cooperate more with other countries due to infrastructure limitations. Ireland shows only 14 % demand curtailment due to national production and additional hydrogen production using methane.

In **Global Ambition** scenario, Ireland, United Kingdom, Serbia and Luxembourg show respectively 81 %, 90 %, 100 % and 93 % demand curtailment. Italy, Switzerland, Spain and Portugal show 68 % and due to infrastructure limitations Austria cannot cooperate more with Italy and neither France with Spain. Most of the countries show 62 % demand curtailment without enough supply and Ireland shows only 14 % demand curtailment due to national production and additional hydrogen production using methane.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, can be observed that a large improvement for all countries due to additional supply (LH_2 in United Kingdom) and more interconnections and increased capacities. United Kingdom shows 52 % demand curtailment and interconnected countries (Belgium and Ireland) cannot cooperate more due to infrastructure limitations. The rest of the countries show 46 % demand curtailment without any infrastructure limitations. Ireland shows only 16 % demand curtailment due to its national production and additional hydrogen production using methane.

In **Global Ambition** scenario, we observe a large improvement for all countries (–20 % demand curtailment in average). United Kingdom and Ireland show 52 % demand curtailment and Belgium cannot more cooperate due to a bottleneck. The rest of the countries show 46 % demand curtailment and good cooperation.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, Serbia, Luxembourg and United Kingdom are isolated countries (not interconnected) show respectively 100 %, 91 %, 68 % demand curtailment. Switzerland and Italy show 58 % demand curtailment and Spain, Austria and Slovenia cannot cooperate more with Italy due to infrastructure limitations. All the other countries show 54 % demand curtailment except for Eastern countries (Greece, Croatia, Bulgaria, Hungary, Slovakia and Romania) with 42 % demand curtailment cannot cooperate more due to infrastructure limitations. Portugal and Ireland show only 40 % and 8 % demand curtailment and cannot cooperate more with Spain and United Kingdom due infrastructure limitations (bottlenecks).

In **Global Ambition** scenario, Serbia, Luxembourg and United Kingdom are isolated countries (not interconnected) show respectively 100 %, 95 %, 79 % demand curtailment. Switzerland and Italy show 76 % demand curtailment and Spain, Austria and Slovenia cannot cooperate more with Italy due to infrastructure limitations. Portugal cooperates at the maximum with Spain but reaches 69 % demand curtailment and Spain 70 %. And France reaches 65 % demand curtailment. Ireland reaches 69 % demand curtailment and cannot cooperate more with United Kingdom. The rest pf the countries show 66 % demand curtailment.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, demand curtailment is mitigated for all countries and most of the countries reach 27 % demand curtailment. United Kingdom shows 44 % demand curtailment and Spain and Italy 34 %. Portugal is reaching 27 % and cannot cooperate more with Spain due to infrastructure limitation. Ireland is reaching 22 % and cannot cooperate more with United Kingdom sue to infrastructure limitation.

In **Global Ambition** scenario, demand curtailment is mitigated in all countries. United Kingdom and Ireland show 46 % demand curtailment and Belgium cannot cooperate more due to a bottleneck. Spain, Portugal, Austria and Slovenia show 37 % demand curtailment and cannot cooperate more with Italy (37 % demand curtailment). The rest of the countries show 33 % demand curtailment and cannot cooperate more with neighbouring countries more curtailed due to infrastructure limitations.

9.4.2.2 Advanced and PCI Hydrogen

Advanced and PCI methane infrastructure levels does not show any difference with Existing infrastructure level. Hydrogen infrastructure is limited in the use of methane to produce hydrogen and the Advanced or PCI infrastructure levels does not add any additional hydrogen.

10 NORWAY HYDROGEN SUPPLY DISRUPTION

Norway Hydrogen supply disruption does not impact simulations results in 2025 Best Estimate and in National Trends demand scenarios (2030 and 2040); in those scenarios, there is no hydrogen import potential and methane demand curtailment is not impacted compared to the Reference Case. The infrastructure assessment is limited to Distributed Energy and Global Ambition demand scenarios in 2030, 2040 and 2050.

10.1 YEARLY DEMAND

10.1.1 METHANE RESULTS

10.1.1.1 Existing Methane Infrastructure

In infrastructure Level 1, Norway hydrogen supply disruption impact only one demand scenario and one year. In 2040 Global Ambition, Hungary, Romania, Serbia, Bulgaria and North Macedonia show 2 % demand curtailment. Neighbouring countries cannot cooperate due to bottlenecks and do not mitigate demand curtailment.

In infrastructure Level 2, this 2 % demand curtailment in the east is fully mitigated.

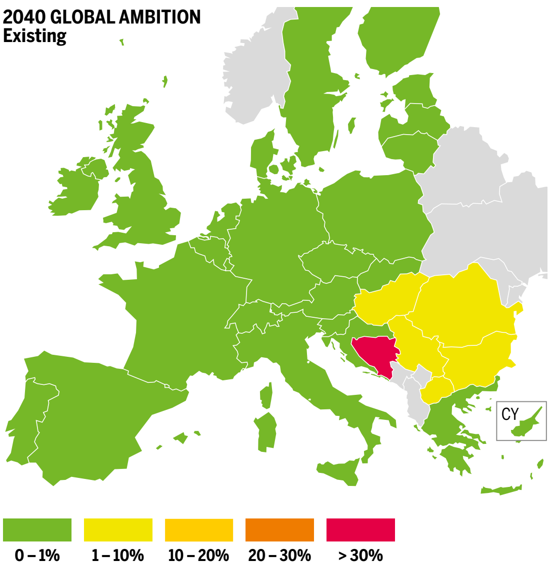


Figure 10.1 NO H_2 Supply Disruption – Methane Results for Yearly Demand in Existing CH_4 Infrastructure

10.1.1.2 Advanced and PCI Methane Infrastructure

There is no demand curtailment at all in Advanced and PCI Methane Infrastructure levels.

10.1.2 HYDROGEN RESULTS

10.1.2.1 Existing Methane Infrastructure

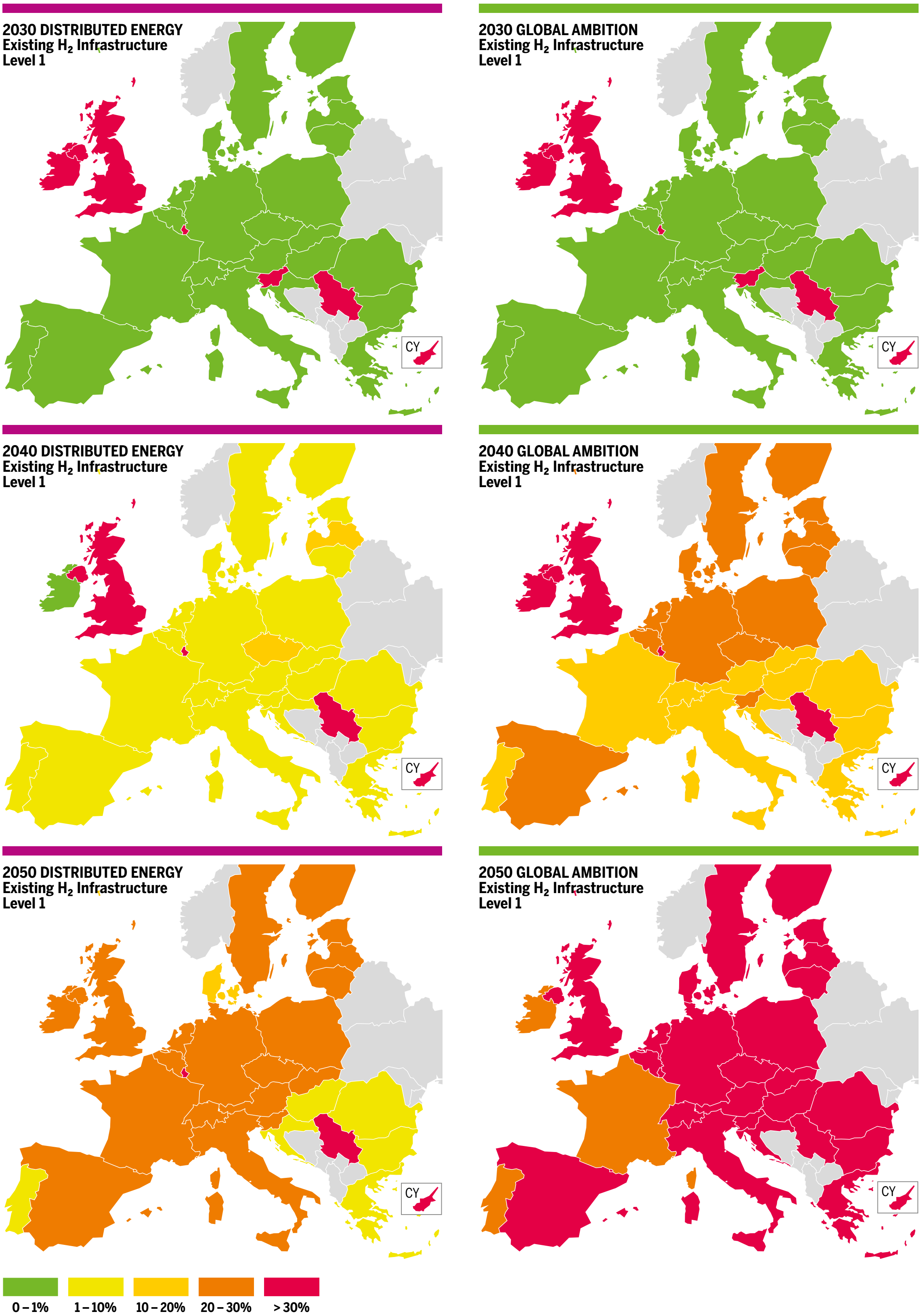


Figure 10.2a NO H_2 Supply Disruption – Hydrogen Results for Yearly Demand in Existing CH_4 Infrastructure and H_2 Level 1

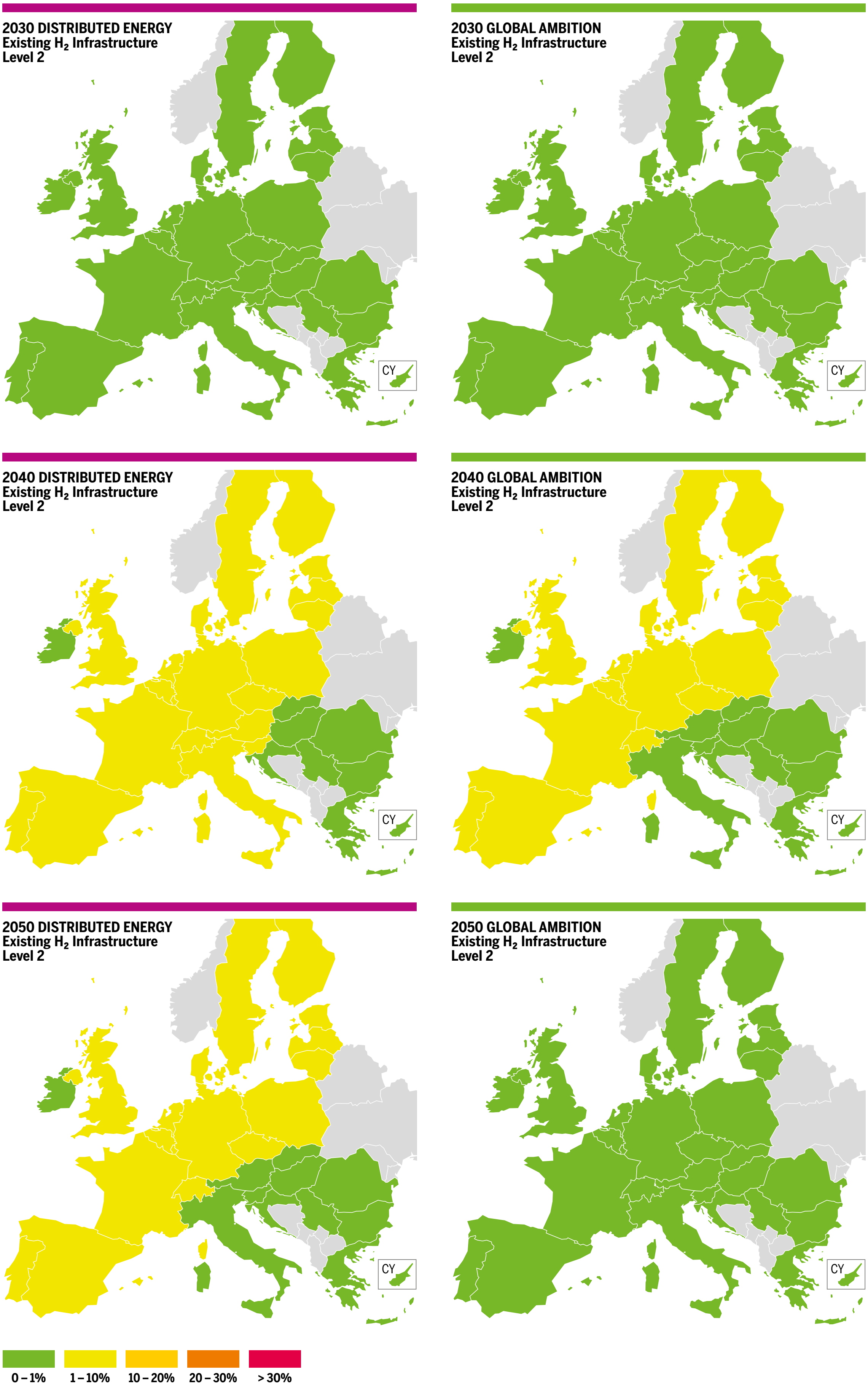


Figure 10.2b NO H_2 Supply Disruption – Hydrogen Results for Yearly Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, only countries not interconnected show demand curtailment Ireland 33 %, United Kingdom 46 %, Luxembourg 61 %, Slovenia 86 %, and Serbia 100 %. Other countries compensate the Norway supply disruption with additional Hydrogen produced with methane due to the flexibility of the methane infrastructure. In the **Global Ambition** scenario, we obtain the same results with different values of demand curtailment: Ireland 37 %, United Kingdom 46 %, Luxembourg 55 %, Slovenia 89 % and Serbia 100 %.

H_2 INFRASTRUCTURE LEVEL 2

Demand curtailment is fully mitigated in both scenarios due to the additional interconnection for the isolated countries in Infrastructure Level 1.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show demand curtailment (10 %). Italy, Switzerland and Austria show 8 % demand curtailment and cannot cooperate more with countries in the north due to infrastructure limitations between Austria and Germany. Eastern countries (Greece, Bulgaria, Romania, Hungary, Croatia and Slovakia) show 3 % to 5 % demand curtailment and cannot cooperate more due to infrastructure bottlenecks between Slovakia and Czech Republic, Slovakia and Austria, Hungary and Slovenia and Croatia to Slovenia. Romania cannot cooperate with Bulgaria due to a bottleneck and cannot mitigate demand curtailment in Bulgaria and Greece. Italy and Austria show 8 % demand curtailment and cannot cooperate with Germany due to a bottleneck between Austria and Germany. France also show 8 % demand curtailment and cannot cooperate more with Germany. Some countries which are not interconnected also show demand curtailment: United Kingdom 67 %, Luxembourg 83 % and Serbia 100 %.

In **Global Ambition** scenario, most of the countries show 22 % demand curtailment. Eastern countries Greece, (Romania, Hungary, Croatia and Slovakia) show 15 % demand curtailment and cannot cooperate more due to infrastructure bottlenecks between Slovakia and Czech Republic, Slovakia and Austria, Hungary and Slovenia and Croatia to Slovenia. Bulgaria and Greece show 17 % demand curtailment and Romania cannot cooperate with Bulgaria to mitigate demand curtailment due to a bottleneck) France, Italy, Switzerland and Austria show 20 % demand curtailment and cannot cooperate more with Germany. Spain shows 22 % demand curtailment and Portugal (20 %) and France (20 %) demand curtailment cannot cooperate to mitigate its demand curtailment. Some countries not interconnected show demand curtailment: Ireland 50 %, United Kingdom 71 %, Luxembourg 86 % and Serbia 100 %.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, most of the countries mitigate their demand curtailment to 2 % (including countries not interconnected in Infrastructure Level 1). Eastern countries (Greece, Bulgaria, Romania, Hungary, Croatia and Slovakia) are not curtailed and cannot cooperate more due to infrastructure bottlenecks between Slovakia and Czech Republic, Slovakia and Austria, Hungary and Slovenia and Croatia to Slovenia.

In **Global Ambition** scenario, most of the countries show only 6 % demand curtailment (including countries not interconnected in Infrastructure Level 1). Eastern countries (Greece, Bulgaria, Romania, Hungary, Croatia and Slovakia) show no demand curtailment and cannot cooperate more due to infrastructure bottlenecks between Slovakia and Czech Republic, Slovakia and Austria, Hungary and Slovenia and Croatia to Slovenia. Italy, Austria and Slovenia cannot cooperate more with Germany due to infrastructure limitations between Austria and Germany.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show demand curtailment (20 % to 22 %). Italy, Switzerland, Slovenia and Austria show 20 % demand curtailment and cannot cooperate more with countries in the north due to infrastructure limitations between Austria and Germany. Eastern countries (Greece, Bulgaria, Romania, Hungary, Croatia and Slovakia) are showing only 3 % demand curtailment but and cannot cooperate more due to infrastructure bottlenecks between Slovakia and Czech Republic, Slovakia and Austria, Hungary and Slovenia and Croatia to Slovenia. Portugal with 8 % demand curtailment cannot cooperate with Spain due to infrastructure limitations between Portugal and Spain. Some countries not interconnected show demand curtailment: United Kingdom 28 %, Luxembourg 87 % and Serbia 100 %.

In **Global Ambition** scenario, most of the countries show 33 % demand curtailment. Greece shows 39 % demand curtailment due to infrastructure bottleneck between Bulgaria and Greece. France shows 26 % demand curtailment and cannot cooperate with Belgium, Germany and Spain due to infrastructure limitations. Portugal shows 27 % demand curtailment and cannot cooperate with Spain due to infrastructure limitations (bottleneck between Portugal and Spain). Some countries not interconnected show demand curtailment: Ireland 27 %, United Kingdom 49 %, Luxembourg 91 % and Serbia 100 %.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, most of the countries mitigate their demand curtailment to 6 % (including countries not interconnected in Infrastructure Level 1). Italy, Switzerland, Slovenia and Austria fully mitigate their demand curtailment and cannot cooperate more with countries in the north due to infrastructure bottleneck between Austria and Germany. Eastern countries (Greece, Bulgaria, Romania, Hungary, Croatia and Slovakia) also fully mitigate demand curtailment and cannot cooperate more due to infrastructure bottlenecks between Slovakia and Czech Republic, Slovakia and Austria, Hungary and Slovenia and Croatia to Slovenia.

In **Global Ambition** scenario, all countries fully mitigate their demand curtailment.

10.1.2.2 Advanced and PCI Methane Infrastructure

Advanced and PCI infrastructure levels show no difference with Existing infrastructure level concerning hydrogen simulation results.

10.2 2-WEEK COLD SPELL DEMAND

The 2-Week Dunkelflaute country demands are generally very similar to the 2-Week Cold Spell demand values. Hydrogen demand is the same for Best Estimate and National Trends scenarios and it is also the same in the year 2030 of Distributed Energy and Global Ambition scenarios. Regarding Distributed Energy and Global Ambition scenarios in 2040 and 2050, only Italy, The Netherlands, Romania and United Kingdom show higher values in 2-Week Dunkelflaute.

Regarding the methane demand values, only Bulgaria, Czech Republic, Germany, Croatia and Italy present slight differences when comparing demand of 2-Week Dunkelflaute with 2-Week Cold in Best Estimate and National trends scenarios. In Distributed Energy and Global Ambition scenarios just Spain, France, Greece, Italy, The Netherlands, Portugal, Romania and United Kingdom present higher methane demand in 2-Week Dunkelflaute.

Consequently, the curtailment rate results in 2-Week Dunkelflaute and in 2-Week Cold Spell are exactly the same for most of the countries. The countries with higher demand in 2-Week Dunkelflaute are only increasing their demand curtailment rate in 1 or 2 % maximum.

10.2.1 METHANE RESULTS

10.2.1.1 Existing Methane Infrastructure

Demand curtailment results are similar to the curtailment rates in the Reference case.
The Norway Hydrogen disruption does not impact the methane simulation results.

10.2.1.2 Advanced and PCI Methane

Demand curtailment is fully mitigated as in Reference case. The Norway Hydrogen disruption does not impact the methane simulation results.

10.2.2 HYDROGEN RESULTS

10.2.2.1 Existing Infrastructure

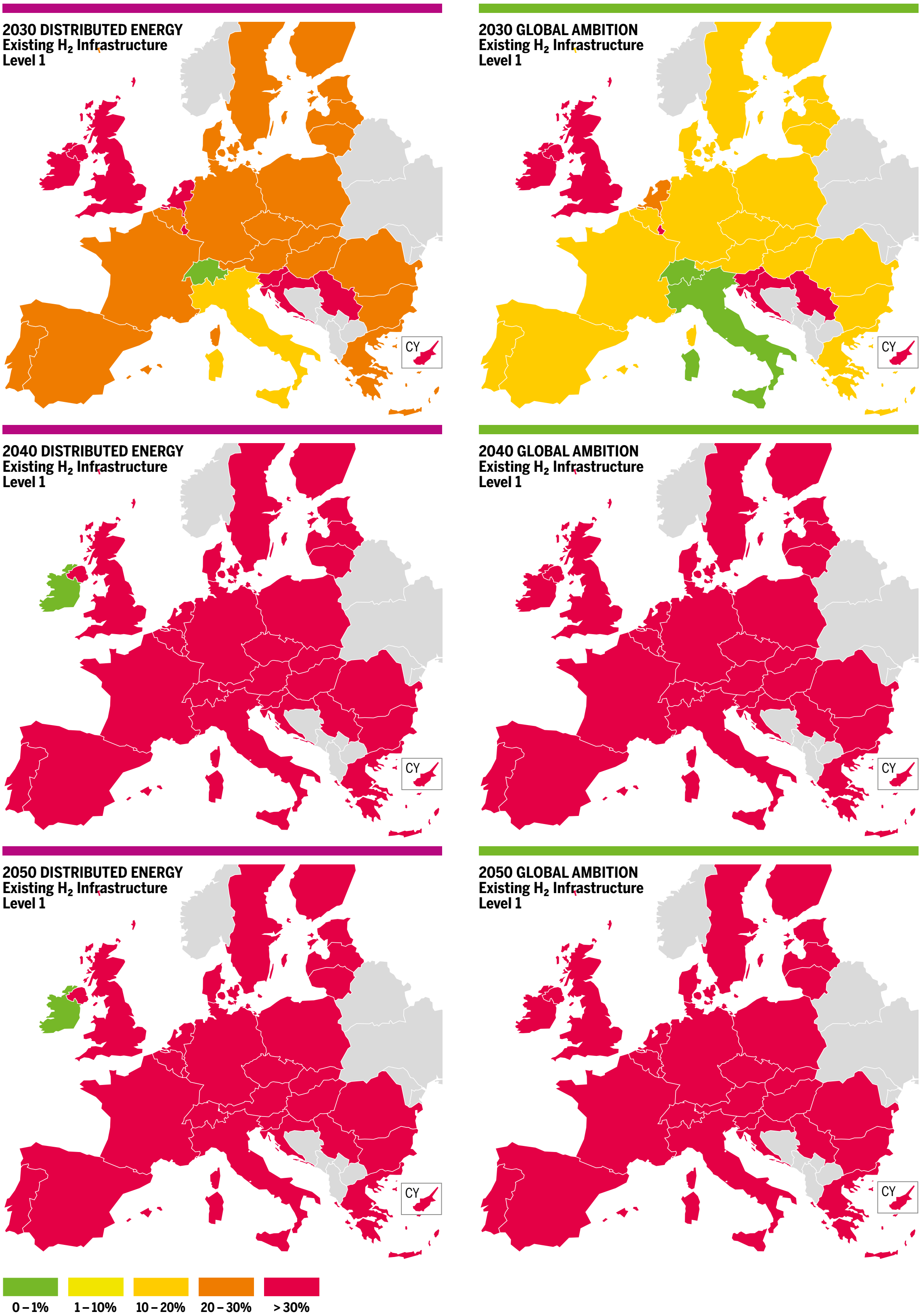


Figure 10.3a NO H_2 Supply Disruption – Hydrogen Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 1

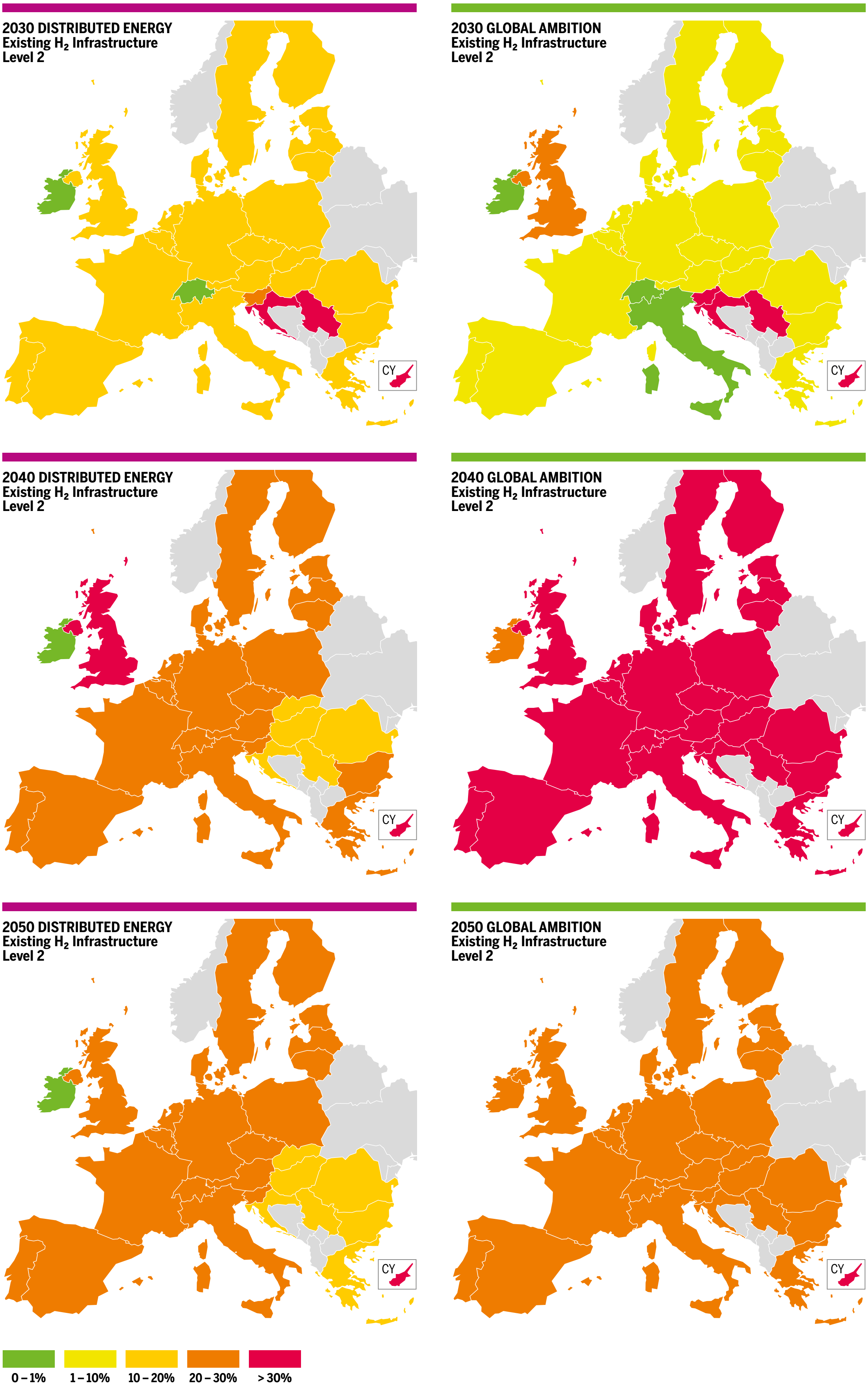


Figure 10.3b NO H_2 Supply Disruption – Hydrogen Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, all countries show demand curtailment. Serbia, Slovenia, United Kingdom, Luxembourg, Croatia and Ireland show respectively 100 %, 89 %, 71 %, 70 %, 38 % and 43 % demand curtailment. These countries are not connected to hydrogen infrastructure and do not satisfy their demand with their own production. The Netherlands shows 31 % demand curtailment and Belgium and Germany cannot cooperate more with The Netherlands due to bottlenecks. Italy shows only 15 % demand curtailment and cannot cooperate with Austria due to an infrastructure limitation between them. The rest of the countries show 26 % demand curtailment.

In **Global Ambition** scenario, all countries show demand curtailment except for Italy. Serbia, Slovenia, United Kingdom, Luxembourg, Croatia and Ireland show respectively 100 %, 92 %, 69 %, 66 %, 32 % and 46 % demand curtailment. These countries are not connected to hydrogen infrastructure and do not satisfy their demand with their own production. The Netherlands shows 23 % demand curtailment and Belgium and Germany cannot cooperate more with The Netherlands due to infrastructure limitations. The rest of the countries show 15 % to 17 % demand curtailment.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, all countries mitigate their demand curtailment due to additional hydrogen production using methane, except for Ireland who fully mitigates its demand curtailment. Serbia, Croatia, Slovenia, and United Kingdom mitigate respectively their demand curtailment to 41 %, 41 %, 29 % and 19 % and the other countries mitigate their demand curtailment to 15 %. Italy mitigates its demand curtailment to 14 %.

In **Global Ambition** scenario, all countries mitigate their demand curtailment due to additional hydrogen production using methane, except for Ireland and Italy who fully mitigate its demand curtailment. Serbia, Croatia, Slovenia, and United Kingdom mitigate respectively their demand curtailment to 41 %, 40 %, 32 % and 27 % and the other countries mitigate their demand curtailment to 5 % to 7 %. Italy cannot cooperate more with Austria due to a bottleneck.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, Serbia, Luxembourg and United Kingdom show respectively 100 %, 87 % and 83 %. These countries are not connected to hydrogen infrastructure and do not satisfy their demand with their own production. Most of the countries show 39 % demand curtailment. Eastern countries (Bulgaria, Greece, Slovakia, Croatia, Hungary, Romania) show 35 % demand curtailment and cannot cooperate with neighbouring countries due to infrastructure limitations. Ireland can satisfy its demand with enough hydrogen production.

In **Global Ambition** scenario, Serbia, Luxembourg, Ireland and United Kingdom show respectively 100 %, 91 %, 69 % and 85 %. These countries are not connected to hydrogen infrastructure and do not satisfy their demand with their own production. The rest of the countries show 54 % demand curtailment.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, all countries mitigate their demand curtailment. United Kingdom mitigates its demand curtailment to 32 % and the rest of the countries mitigate their demand curtailment to 28 %. Serbia, Croatia, Slovakia, Hungary and Romania mitigate their demand curtailment to 16 % but cannot cooperate more with other countries due to infrastructure limitations.

In **Global Ambition** scenario, all countries mitigate their demand curtailment to 38 % except for Ireland who mitigate its demand curtailment to 22 %.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, Serbia, Luxembourg and United Kingdom show respectively 100 %, 90 % and 57 % demand curtailment. These countries are not connected to hydrogen infrastructure and do not satisfy their demand with their own production. The other countries show 47 % demand curtailment except for Eastern countries (Greece, Slovakia, Bulgaria, Croatia, Hungary, and Romania) who show 32 % demand curtailment and cannot cooperate with other countries due to infrastructure limitations. Portugal shows 32 % demand curtailment and cannot cooperate more with Spain due to infrastructure limitations.

In **Global Ambition** scenario, Serbia, Luxembourg and United Kingdom show respectively 100 %, 94 % and 68 % demand curtailment. These countries are not connected to hydrogen infrastructure and do not satisfy their demand with their own production. The other countries show 61 % demand curtailment except for in Greece who show 65 % demand curtailment. Bulgaria cannot cooperate more with Greece to mitigate its demand curtailment due to abottleneck between Bulgaria and Greece.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, all countries mitigate their demand curtailment. United Kingdom mitigates its demand curtailment to 27 % and the other countries to 24 %. Eastern countries (Greece, Bulgaria, Serbia, Croatia, Slovakia, Hungary, and Romania) mitigate their demand curtailment to 15 % and cannot cooperate more with their neighbouring countries due to infrastructure limitations. Portugal mitigates its demand curtailment to 20 % and cannot cooperate more with Spain due to infrastructure limitation.

In **Global Ambition** scenario, most of the countries mitigate their demand curtailment to 25 % and 26 %. Spain, Portugal, Italy and France mitigate their demand curtailment to 21 %. They cannot cooperate with interconnected countries due to infrastructure limitations. Ireland mitigates its demand curtailment to 21 %.

10.2.2.2 Advanced and PCI Infrastructure

Advanced and PCI infrastructure levels show no difference with Existing infrastructure level concerning hydrogen simulation results.

10.3 2-WEEK DUNKELFLAUTE DEMAND

The 2-Week Dunkelflaute demand is generally very similar to the 2-Week Cold Spell demand. Hydrogen demand is basically the same for Best Estimate and National Trends scenarios and also the same in both Distributed Energy and Global Ambition scenarios for 2030. Regarding Distributed Energy and Global Ambition scenarios in 2040 and 2050, almost all the countries show the same demand values except for Italy, The Netherlands, Romania and United Kingdom.

Regarding the methane demand values, only Bulgaria, Czech Republic, Germany, Croatia and Italy have small demand differences when comparing 2-Week Dunkelflaute with 2-Week Cold in Best Estimate and National trends scenarios. In Distributed Energy and Global Ambition scenarios just Spain, France, Greece, Italy, The Netherlands, Portugal, Romania and United Kingdom present higher methane demand in 2-Week Dunkelflaute.

As a consequence, the curtailment rate results in 2-Week Dunkelflaute and in 2-Week Cold Spell are exactly the same for most of the countries. The countries with higher demand in 2-Week Dunkelflaute are only increasing their demand curtailment rate in 1 or 2 % maximum.

10.4 PEAK DEMAND

10.4.1 METHANE RESULTS

10.4.1.1 Existing Methane

In Peak demand, simulations results show that Norwegian Hydrogen supply disruption are similar to Reference case except in Global Ambition scenario in 2030 in Sweden, where the curtailment rate increases from 17 % to 21 % due to a very high methane peak demand. With less Hydrogen, Sweden is using more methane to produce Hydrogen and create more curtailment on the methane side.

10.4.2 HYDROGEN RESULTS

10.4.2.1 Existing Infrastructure

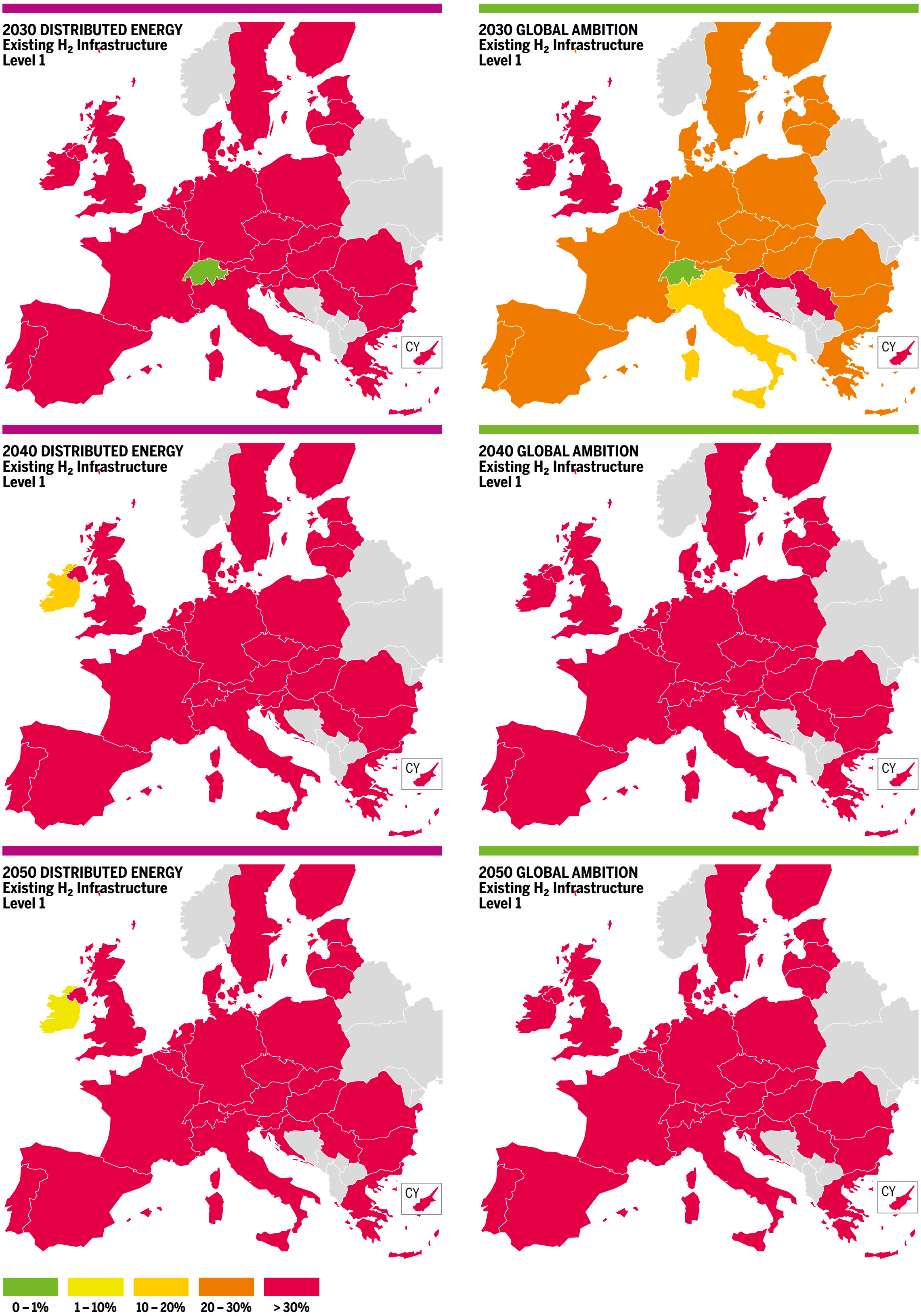


Figure 10.4a NO H_2 Supply Disruption – Hydrogen Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 1

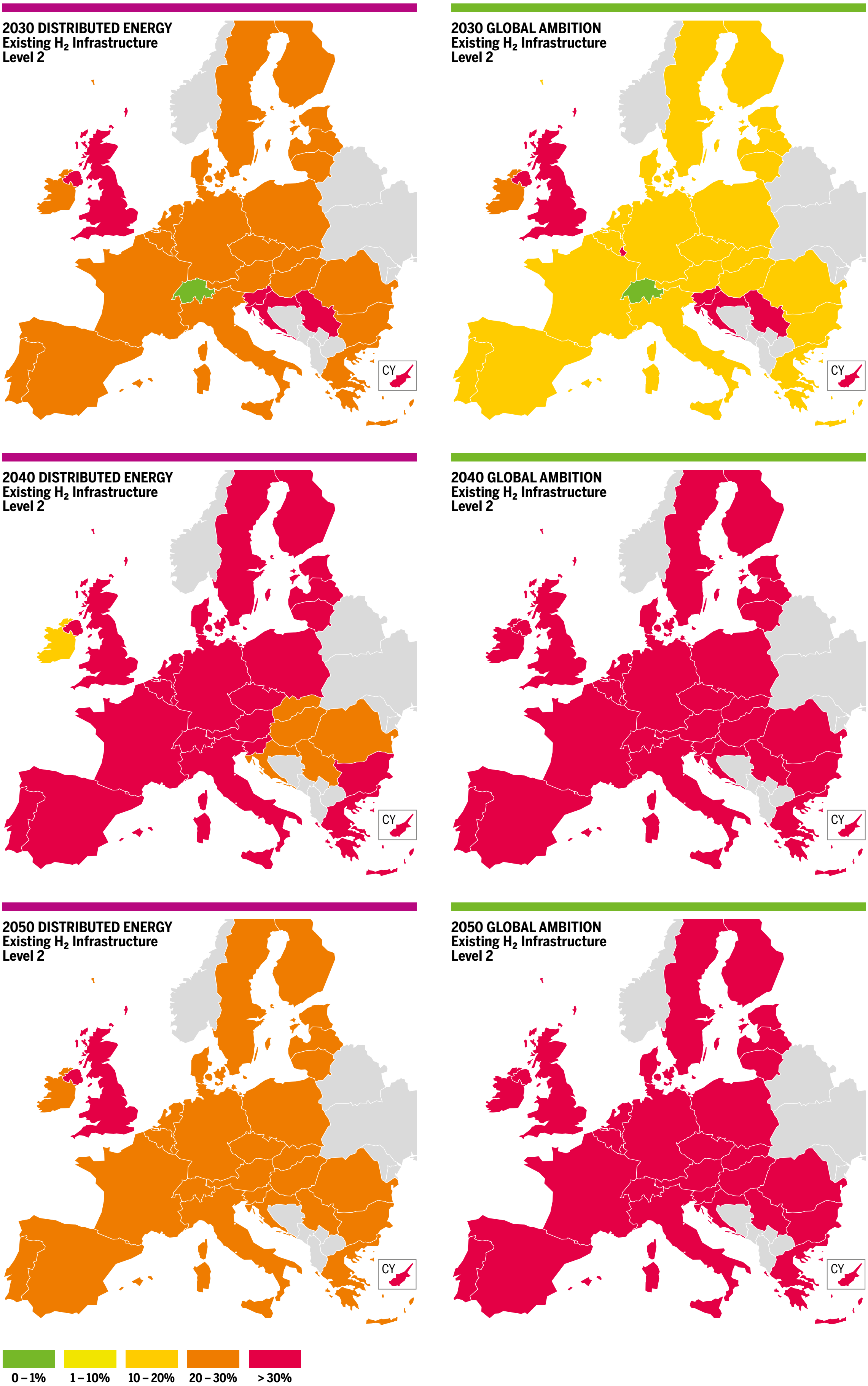


Figure 10.4b NO H_2 Supply Disruption – Hydrogen Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show 37 % demand curtailment. Countries not interconnected show more curtailment: Serbia (100 %), Slovenia (91 %), Ireland (62 %), United Kingdom (78 %), Luxembourg (74 %) and Croatia (49 %). The Netherlands shows 46 % demand curtailment and Belgium and Germany cannot cooperate more due to infrastructure limitations. Italy, with more supply from North Africa, shows 30 % demand curtailment and cannot cooperate more with Austria due to a bottleneck.

In **Global Ambition** scenario, situation is similar. Most of the countries show 29 % demand curtailment. Countries not interconnected show more curtailment: Serbia (100 %), Slovenia (94 %), Ireland (62 %), United Kingdom (76 %), Luxembourg (71 %) and Croatia (45 %). The Netherlands shows 41 % demand curtailment and Belgium and Germany interconnected cannot cooperate more due to infrastructure limitations. Italy with more supply from North Africa shows 16 % demand curtailment and cannot cooperate more with Austria due to a bottleneck.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, situation is improved for all countries due to more supply and more hydrogen production using methane. Most of the countries show 25 % demand curtailment. Countries not interconnected show more curtailment: Serbia (49 %), Slovenia (42 %), Ireland (25 %), United Kingdom (36 %), Luxembourg (27 %) and Croatia (49 %).

In **Global Ambition** scenario, situation is improved for all countries due to more supply and more hydrogen production using methane. Most of the countries show 18 % demand curtailment. Countries not interconnected show more curtailment: Serbia (49 %), Slovenia (44 %), Ireland (20 %), United Kingdom (40 %), Luxembourg (29 %) and Croatia (48 %).

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show 48 % demand curtailment. Eastern countries (Greece, Croatia, Romania, Hungary, Bulgaria and Slovakia) show 43 % demand curtailment and cannot cooperate with interconnected countries due to infrastructure limitations. Countries not interconnected show mode demand curtailment: Serbia (100 %), Luxembourg (88 %), United Kingdom (87 %). Ireland with more hydrogen production shows only 14 % demand curtailment.

In **Global Ambition** scenario, most of the countries show 63 % demand curtailment. Eastern countries (Greece, Croatia, Romania, Hungary, Bulgaria and Slovakia) show 61 % to 62 % demand curtailment and cannot cooperate with interconnected countries due to bottlenecks. Countries not interconnected show mode demand curtailment: Serbia (100 %), Luxembourg (93 %), Ireland (81 %), United Kingdom (90 %).

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, situation is improved for all countries due to more supply and more hydrogen production using methane. Most of the countries show 31 % demand curtailment. United Kingdom shows 48 % demand curtailment and Belgium and Ireland cannot cooperate more with United Kingdom due to infrastructure limitations. Greece and Bulgaria show 35 % demand curtailment and Romania cannot cooperate with them due to a bottleneck with Bulgaria. Eastern countries (Serbia, Croatia, Slovakia, Hungary, Romania) show 28 % demand curtailment and cannot cooperate more with interconnected countries due to bottlenecks. Ireland with more hydrogen production shows 16 % demand curtailment.

In **Global Ambition** scenario, situation is improved for all countries due to more supply and more hydrogen production using methane. Most of the countries show 45 % demand curtailment. Ireland and United Kingdom show 52 % demand curtailment. Belgium cannot cooperate with United Kingdom to mitigate demand curtailment due to abottleneck.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show 54 % demand curtailment. Eastern countries (Greece, Croatia, Romania, Hungary, Bulgaria and Slovakia) show 42 % demand curtailment and cannot cooperate with interconnected countries due to infrastructure limitations. Countries not interconnected show mode demand curtailment: Serbia (100 %), Luxembourg (91 %), United Kingdom (68 %). Ireland with more hydrogen production shows only 8 % demand curtailment. Eastern countries (Greece, Croatia, Hungary, Bulgaria, Slovakia and Romania) show 42 % demand curtailment cannot cooperate more with interconnected countries due to infrastructure limitations. Portugal with more hydrogen production shows 40 % demand curtailment and cannot cooperate more with Spain due to a bottleneck.

In **Global Ambition** scenario, most of the countries show 68 % demand curtailment. Countries not interconnected show mode demand curtailment: Serbia (100 %), Luxembourg (95 %), Ireland (69 %), United Kingdom (79 %).

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, situation is improved for all countries due to more supply and more hydrogen production using methane. Most of the countries show 27 % to 29 % demand curtailment. United Kingdom shows 44 % demand curtailment and Belgium and Ireland cannot cooperate more with United Kingdom due to bottlenecks. Ireland with more hydrogen production shows 22 % demand curtailment.

In **Global Ambition** scenario, situation is improved for all countries due to more supply and more hydrogen production using methane. Most of the countries show 35 % demand curtailment. Ireland and United Kingdom show 46 % demand curtailment. Belgium cannot cooperate with United Kingdom to mitigate demand curtailment due to a bottleneck. France, Spain and Portugal show 32 % demand curtailment and cannot cooperate with interconnected countries to mitigate their demand curtailment due to infrastructure limitations.

10.4.2.2 Advanced and PCI Hydrogen

Advanced and PCI infrastructure levels show no difference with Existing infrastructure level concerning hydrogen simulation results.

Picture courtesy of Gas Connect Austria

11 UKRAINIAN HYDROGEN SUPPLY DISRUPTION

The Ukrainian Hydrogen disruption does not impact simulations results in 2025 Best Estimate and in National Trends demand scenarios (2030 and 2040); in those scenarios, there is no hydrogen import potential and methane demand curtailment is not impacted compared to the Reference Case. The infrastructure assessment is therefore limited to Distributed Energy and Global Ambition demand scenarios in 2030, 2040 and 2050.

11.1 YEARLY DEMAND

11.1.1 METHANE RESULTS

11.1.1.1 Existing Infrastructure

Ukrainian hydrogen supply disruption impact methane infrastructure and create demand curtailment only in the **Global Ambition** scenario and in 2040.

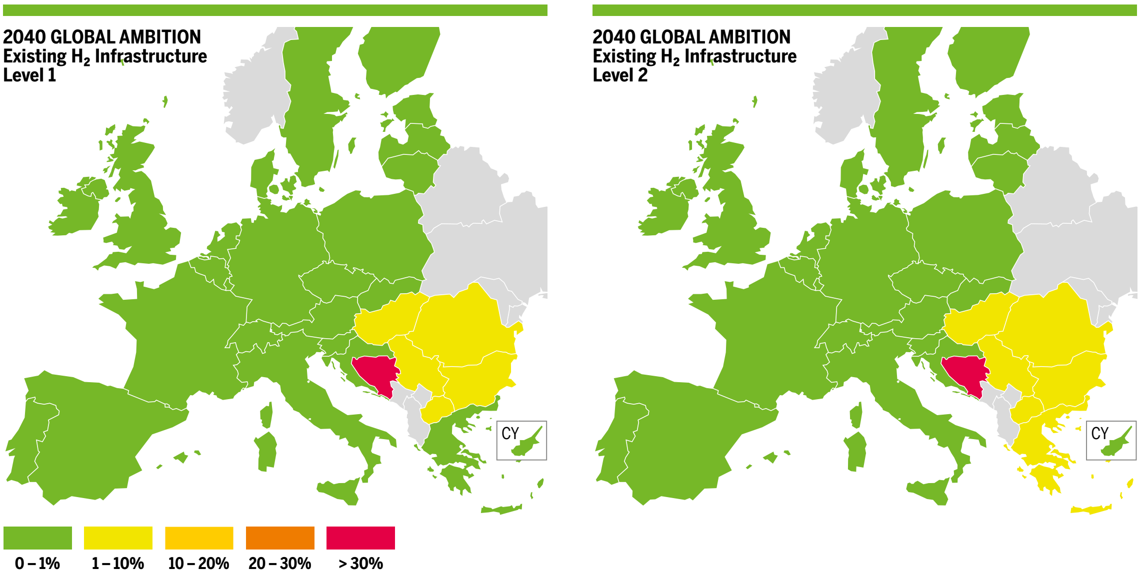


Figure 11.1 UA H_2 Supply Disruption – Methane Results for Yearly Demand in Existing CH_4 and H_2 Level 1 and 2

H_2 INFRASTRUCTURE LEVEL 1

Some Eastern countries show demand curtailment: Hungary (6 %), Romania, Serbia and North Macedonia (7 %) and Bulgaria 4 %. These countries are using at the maximum hydrogen production using methane and create demand curtailment. Other interconnected countries cannot cooperate with them due to infrastructure limitations.

H_2 INFRASTRUCTURE LEVEL 2

With more hydrogen production using methane and provided by interconnected countries, curtailed countries decreased their demand curtailment to 4 %–5 %. Bulgaria decreased its demand curtailment to 3 % and Greece shows now 2 % demand curtailment.

11.1.1.2 Advanced and PCI Infrastructure

The two methane infrastructure levels improve the situation and demand curtailment is fully mitigated.

11.1.2 HYDROGEN RESULTS

11.1.2.1 Existing Infrastructure

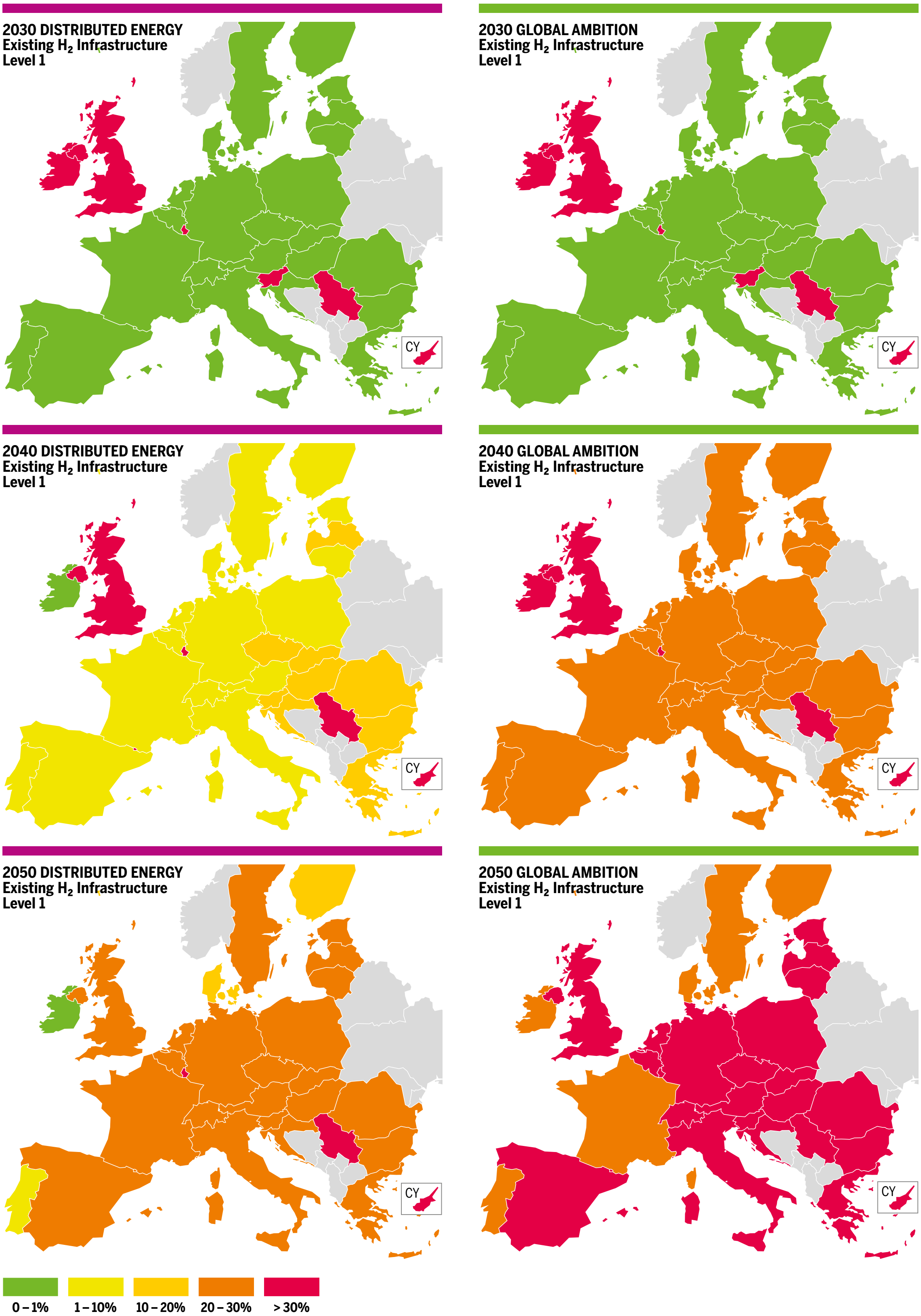


Figure 11.2a UA H_2 Supply Disruption – Hydrogen Results for Yearly Demand in Existing CH_4 Infrastructure and H_2 Level 1

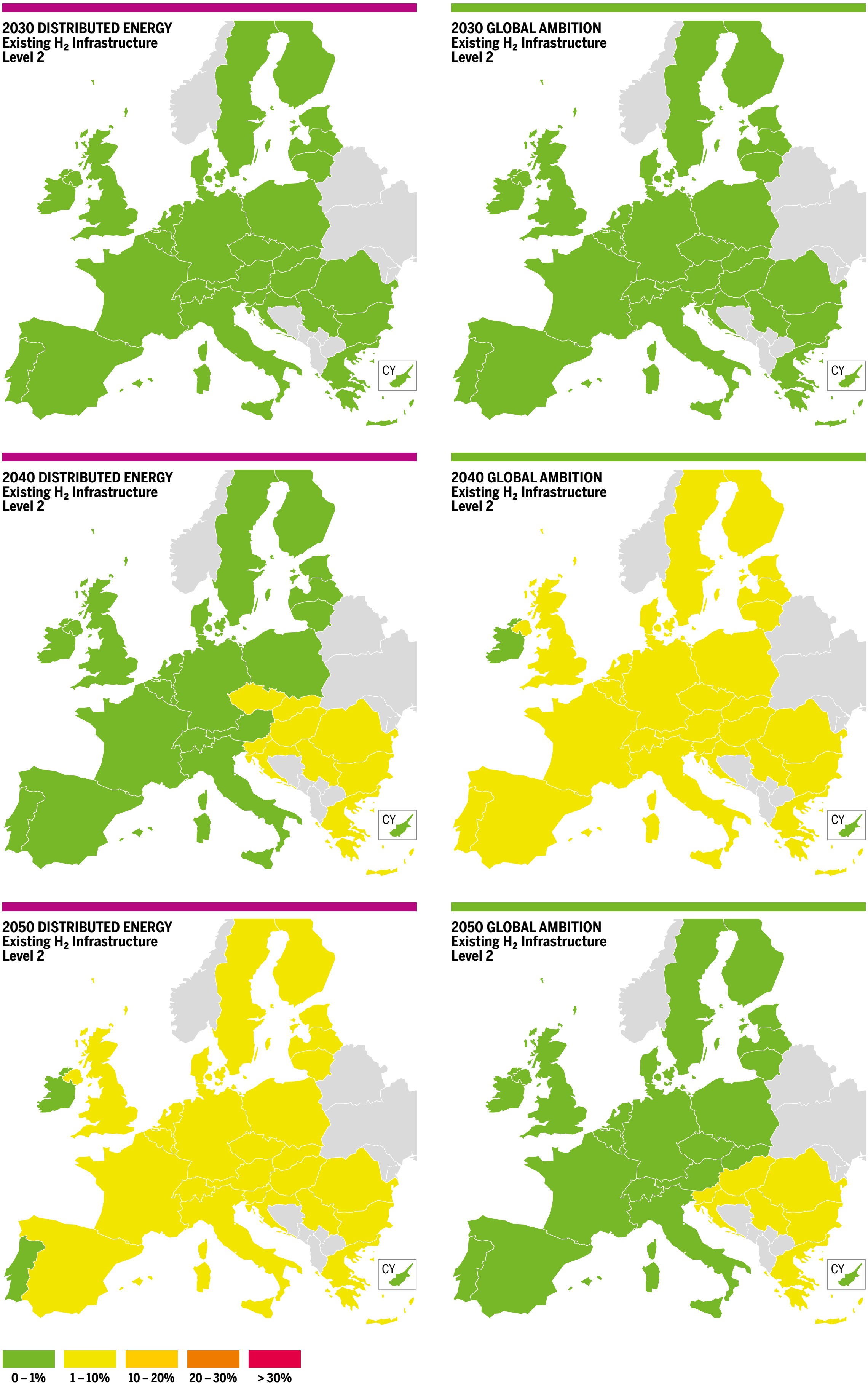


Figure 11.2b UA H_2 Supply Disruption – Hydrogen Results for Yearly Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

Only countries without any interconnections are curtailed.

In **Distributed Energy** scenario, those countries show demand curtailment: Ireland 33 %, United Kingdom 46 %, Luxembourg 61 %, Slovenia 86 % and Serbia 100 %. Other countries compensate the Ukrainian supply disruption with additional Hydrogen produced with methane due to the flexibility of the methane infrastructure.

In the **Global Ambition** scenario, those countries show demand curtailment: Ireland 37 %, United Kingdom 46 %, Luxembourg 55 %, Slovenia 89 % and Serbia 100 %.

H_2 INFRASTRUCTURE LEVEL 2

In both scenarios, all countries fully mitigate demand curtailment due to new interconnections and increased capacities.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, all countries show demand curtailment (9 % to 10 %). Eastern countries (Slovakia, Hungary, Croatia, Slovenia, Romania) show 13 % demand curtailment. Countries with interconnections cannot cooperate with them to mitigate their demand curtailment due to infrastructure limitations. Bulgaria and Greece show 15 % demand curtailment and Romania cannot cooperate more with Bulgaria due to a bottleneck. Portugal shows only 8 % demand curtailment with high hydrogen production and cannot cooperate more with Spain due to infrastructure limitations between Portugal and Spain. Other countries isolated and without enough production show higher demand curtailment: United Kingdom (67 %), Luxembourg (84 %) and Serbia (100 %).

In **Global Ambition** scenario, all countries show demand curtailment (22 %). Eastern countries (Slovakia, Hungary, Croatia, Slovenia, Romania, Bulgaria and Greece) show 28 % demand curtailment. Other countries cannot cooperate with them to mitigate their demand curtailment due to infrastructure limitations. Portugal and France and cannot cooperate more with Spain due to infrastructure limitations between Portugal, France and Spain. Other countries isolated and without enough production show higher demand curtailment: Ireland (55 %), United Kingdom (73 %), Luxembourg (84 %) and Serbia (100 %).

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, most of the countries fully mitigated their demand curtailment due to additional interconnections and increased interconnections capacities. Only Eastern countries (Slovakia, Hungary, Croatia, Slovenia, Romania, Serbia, Bulgaria and Greece) show 1 % to 2 % demand curtailment due to infrastructure limitations with interconnected countries.

In **Global Ambition** scenario, most of the countries mitigate their demand curtailment to 3 % to 4 %. Eastern countries, mitigate their demand curtailment to 6 % to 8 %. Infrastructure limitations do not allow countries on the North and on the West to cooperate more with those countries.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show demand curtailment (20 % to 21 %). Portugal with 8 % demand curtailment cannot cooperate with Spain due to infrastructure limitations between Portugal and Spain.

Some countries not interconnected show demand curtailment: United Kingdom 26 %, Luxembourg 87 % and Serbia 100 %.

In **Global Ambition** scenario, most of the countries show 29 % to 31 % demand curtailment. North and Western countries cannot cooperate with Eastern countries due to bottlenecks between Italy and Slovenia, Austria and Slovenia and finally between Austria to Slovakia. Eastern countries show 50 % demand curtailment. Bulgaria and Greece show 53 % demand curtailment due to a bottleneck between Romania and Bulgaria. Italy, Austria and Switzerland show 37 % demand curtailment due to the cooperation with Eastern countries. Spain cooperates with Italy and shows 34 % demand curtailment. France and Portugal cannot cooperate more with Spain due to infrastructure limitations and show respectively 25 % and 28 % demand curtailment. France also cannot cooperate with interconnected countries (Belgium, Germany) to mitigate their demand curtailment due to infrastructure limitations. Some countries not interconnected show demand curtailment: Ireland 22 %, United Kingdom 45 %, Luxembourg 87 % and Serbia 100 %.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, most of the countries mitigate their demand curtailment to 3 % (including countries not interconnected in Infrastructure Level 1). Ireland and Portugal fully mitigate their demand curtailment due to additional hydrogen production using methane. In Global Ambition scenario, all countries fully mitigate their demand curtailment except for Eastern countries dependant from Ukraine and show 4 % to 9 % demand curtailment. Countries on the North and on the West cannot cooperate due to infrastructure limitations. Bottlenecks do not allow Hungary to cooperate more with Romania and Romania with Bulgaria.

11.1.2.2 Advanced and PCI Hydrogen

Results remain unchanged in all years and scenarios.

11.2 2-WEEK COLD SPELL DEMAND

11.2.1 METHANE RESULTS

11.2.1.1 Existing Infrastructure

Bosnia shows demand curtailment due to a bottleneck with Serbia (no link with Ukrainian supply disruption) in all scenario and years.

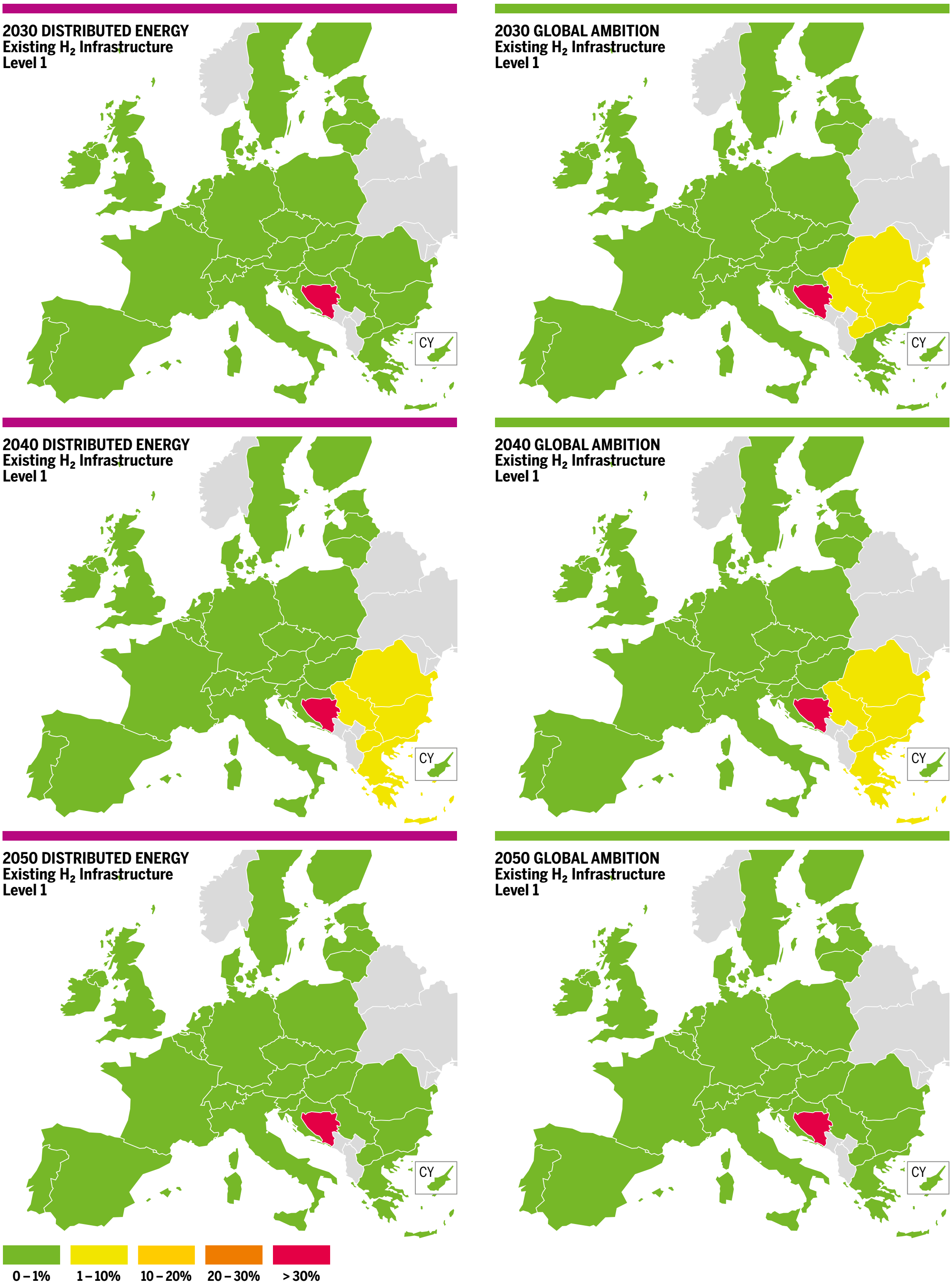


Figure 11.3a UA H_2 Supply Disruption – Methane Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 1

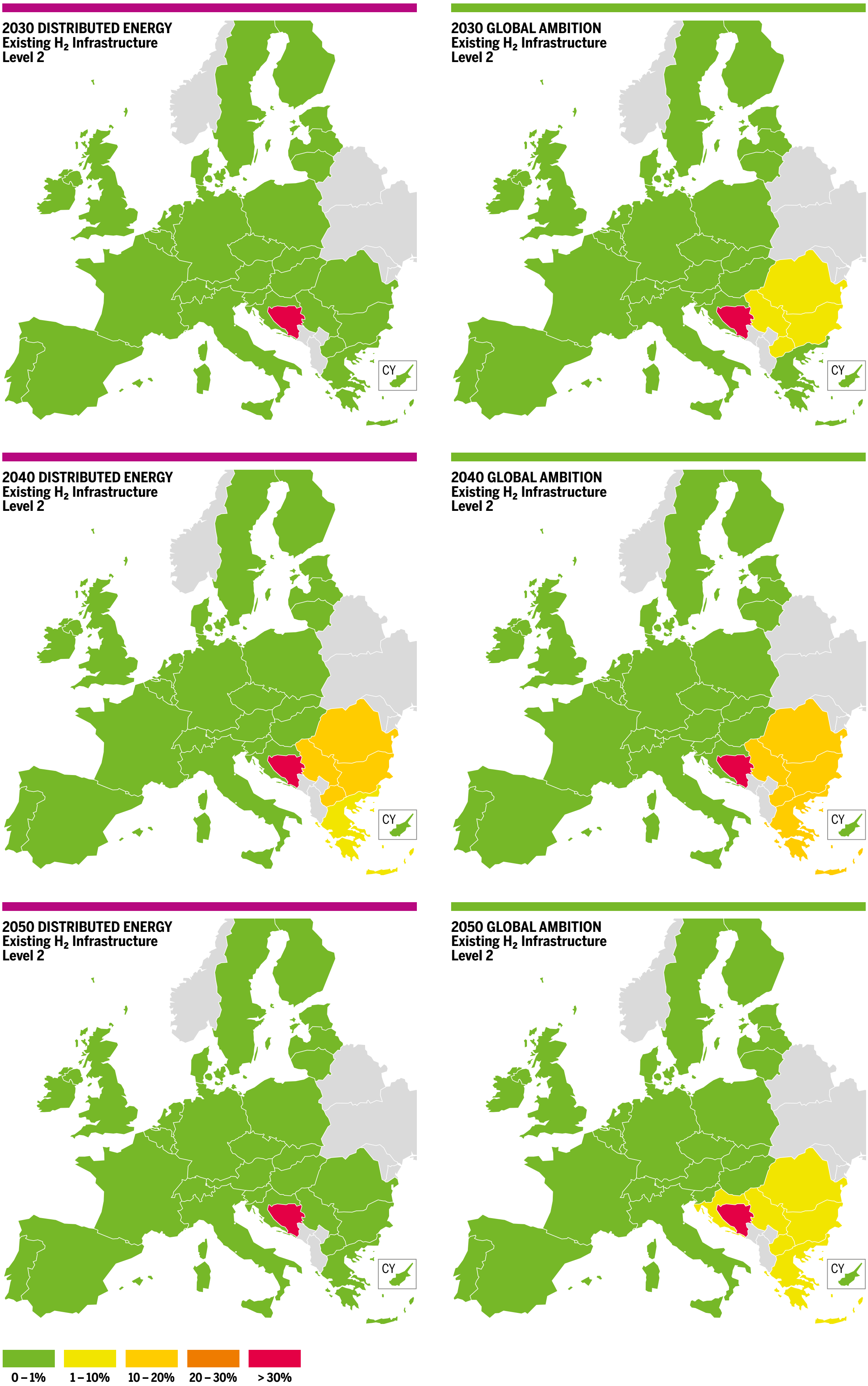


Figure 11.3b UA H_2 Supply Disruption – Methane Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

Only **Global Ambition** scenario shows some countries with demand curtailment. Romania, Serbia, North Macedonia and Bulgaria show 2 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

H_2 INFRASTRUCTURE LEVEL 2

Only **Global Ambition** scenario shows the same countries with demand curtailment. Romania, Serbia, North Macedonia and Bulgaria show 3 % demand curtailment. In infrastructure Level 2, the potential of hydrogen production increases and these countries go to the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, Romania, Serbia, North Macedonia, Greece and Bulgaria show 2 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

In **Global Ambition** scenario, Romania, Serbia, North Macedonia, Greece and Bulgaria show 2 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, Romania, Serbia, North Macedonia and Bulgaria show 12 % demand curtailment. Greece shows only 2 % demand curtailment and cannot cooperate more with Bulgaria due to a bottleneck. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

In **Global Ambition** scenario, countries need more hydrogen and Romania, Serbia, North Macedonia, Greece and Bulgaria show 16 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations (bottlenecks) with neighbouring countries do not allow them to cooperate with curtailed countries.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy and Global Ambition** scenario, Ukrainian hydrogen supply disruption does not create any methane curtailment.

H_2 INFRASTRUCTURE LEVEL 2

Only **Global Ambition** scenario shows some countries with demand curtailment. Romania, Serbia, North Macedonia, Greece and Bulgaria show 8 % to 9 % demand curtailment. Croatia shows only 1 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

11.2.1.2 Advanced and PCI Infrastructure

There is no demand curtailment in any year of any of the scenarios.

11.2.2 HYDROGEN RESULTS

11.2.2.1 Existing Infrastructure

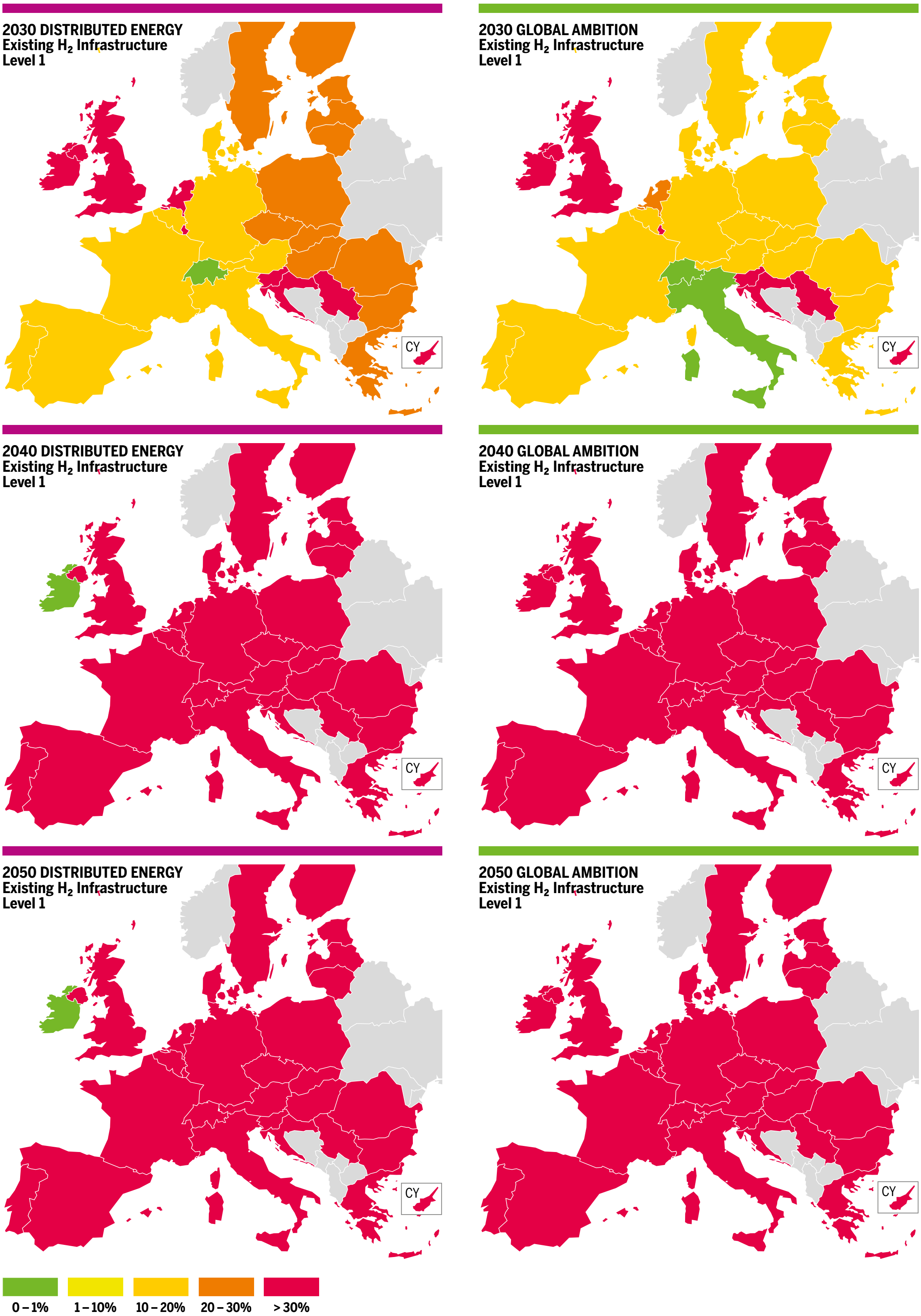


Figure 11.4a UA H_2 Supply Disruption – Hydrogen Results for 2W Demand in PCI & Advanced CH_4 Infrastructure and H_2 Level 1

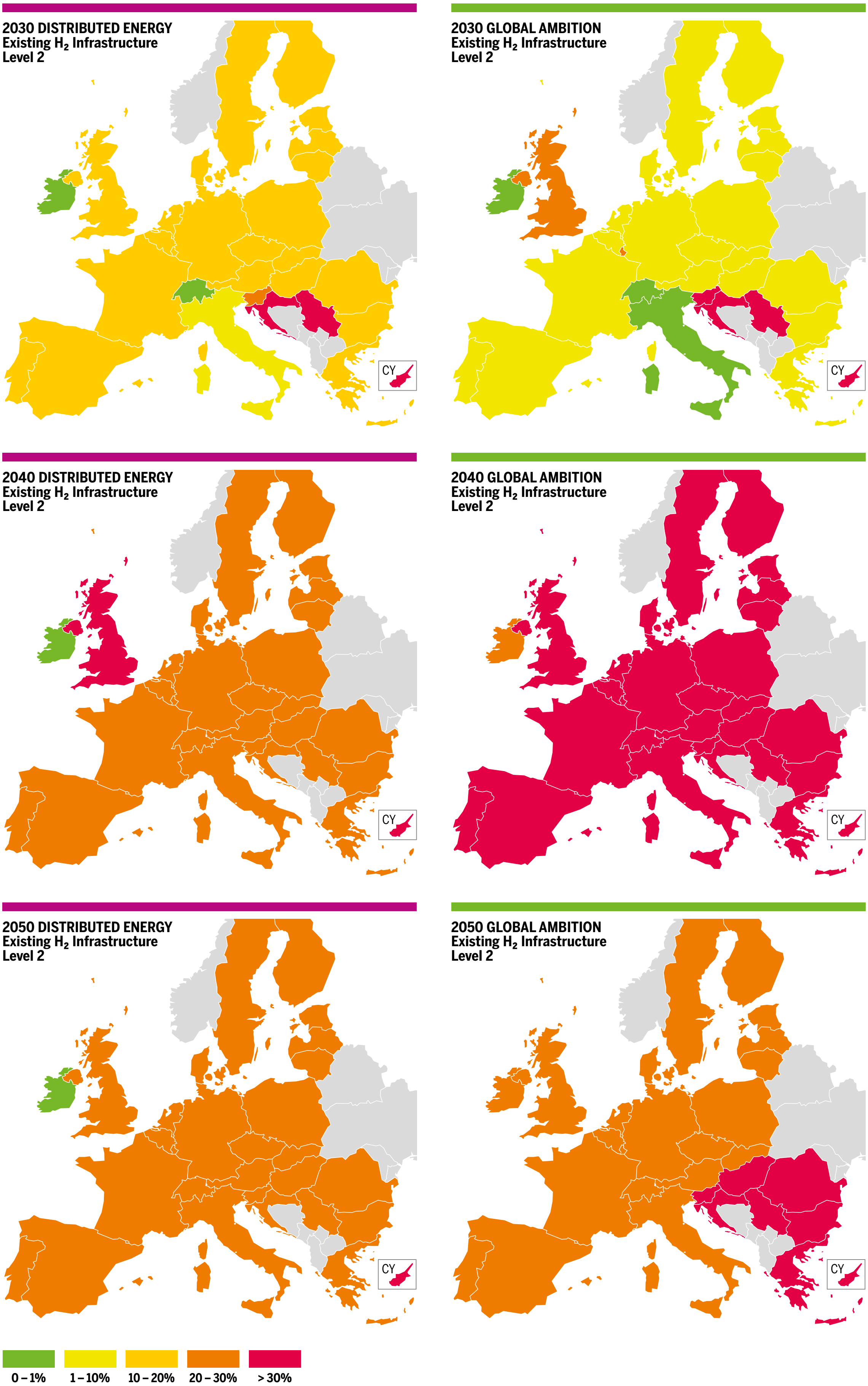


Figure 11.4b UA H_2 Supply Disruption – Hydrogen Results for 2W Demand in PCI & Advanced CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, all countries show demand curtailment. Most of the countries show 20 % demand curtailment. Italy shows 15 % demand curtailment and cannot cooperate with Austria due to a bottleneck and The Netherlands shows 32 % demand curtailment due to infrastructure limitations with Belgium and Germany. Some countries are not interconnected and show more demand curtailment: Serbia (100 %), Slovenia (89 %), United Kingdom (71 %), Luxembourg (70 %), Ireland (43 %) and Croatia (38 %). Their own production cannot satisfy their demand.

In **Global Ambition** scenario, situation is similar with different demand curtailment values due to different demand values. All countries show demand curtailment except for Italy. Most of the countries show 11 % demand curtailment. The Netherlands shows 23 % demand curtailment due to bottlenecks with Belgium and Germany. Some countries are not interconnected and show more demand curtailment: Serbia (100 %), Slovenia (92 %), United Kingdom (69 %), Luxembourg (66 %), Ireland (46 %) and Croatia (32 %). Their own production cannot satisfy their demand.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, all demand curtailment is mitigated due to the new interconnections and additional hydrogen production using methane. Most of the countries show 10 % demand curtailment and countries not interconnected show more demand curtailment: Serbia (41 %), Croatia (41 %), Slovenia (29 %), United Kingdom (19 %) and Luxembourg (15 %).

In **Global Ambition** scenario, all demand curtailment is mitigated due to the new interconnections and additional hydrogen production using methane. Most of the countries show 2 % demand curtailment only and countries not interconnected show more demand curtailment: Serbia (41 %), Croatia (40 %), Slovenia (32 %), United Kingdom (27 %) and Luxembourg (17 %). Italy fully mitigates its demand curtailment.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, all countries show demand curtailment. Most of the countries show 41 % demand curtailment. Some countries are not interconnected and show more demand curtailment: Serbia (100 %), United Kingdom (83 %) and Luxembourg (87 %). Their own production cannot satisfy their demand. Ireland can satisfy its demand with its own hydrogen production.

In **Global Ambition** scenario, most of the countries show 55 % demand curtailment. Eastern countries (Greece, Bulgaria, Romania, Slovenia, Croatia, Hungary and Slovakia) are directly impacted by the Ukrainian hydrogen supply disruption and show 60 % demand curtailment. Infrastructure limitations within interconnected countries do not allow them to cooperate more to mitigate Eastern countries demand curtailment. Countries which are not interconnected also show more demand curtailment: Serbia (100 %), Luxembourg (91 %), United Kingdom (85 %) and Ireland (69 %). Their own production cannot satisfy their demand.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, all countries mitigate their demand curtailment due to the new interconnections and additional hydrogen production using methane. Most of the countries show 28 % demand curtailment. United Kingdom shows 32 % demand curtailment due to infrastructure limitations with Ireland and Belgium.

In **Global Ambition** scenario, all countries mitigate their demand curtailment due to the new interconnections and additional hydrogen production using methane. Most of the countries show 38 % demand curtailment. Eastern countries (Greece, Bulgaria, Romania, Slovenia, Croatia and Hungary) are directly impacted by the Ukrainian hydrogen supply disruption and show 42 % demand curtailment. Infrastructure limitations with interconnected countries do not allow them to cooperate more to mitigate Eastern countries demand curtailment. Ireland mitigates its demand curtailment to 22 % due to the additional hydrogen production using methane.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, all countries show demand curtailment. Most of the countries show 47 % demand curtailment. Some countries are not interconnected and show more demand curtailment: Serbia (100 %), United Kingdom (57 %) and Luxembourg (90 %). Their own production cannot satisfy their demand. Ireland can satisfy its demand with its own hydrogen production. Portugal shows 32 % demand curtailment and cannot cooperate more with Spain due to a bottleneck.

In **Global Ambition** scenario, most of the countries show 59 % demand curtailment. Eastern countries (Greece, Bulgaria, Romania, Slovenia, Croatia, Hungary and Slovakia) are directly impacted by the Ukrainian hydrogen supply disruption and show 73 % demand curtailment. Infrastructure limitations with interconnected countries do not allow them to cooperate more to mitigate Eastern countries demand curtailment. Other countries (Austria, Switzerland, Italy, Spain and Portugal) cooperate at the maximum with Eastern countries and show 65 % demand curtailment. France cannot cooperate more with Spain due to infrastructure limitations. Countries not interconnected show more demand curtailment: Serbia (100 %), Luxembourg (94 %) and United Kingdom (68 %). Their own production cannot satisfy their demand. Ireland shows 51 % demand curtailment.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, all countries mitigate their demand curtailment due to the new interconnections and additional hydrogen production using methane. Most of the countries show 23 % demand curtailment. Portugal mitigates its demand curtailment to 20 % and Ireland fully mitigates its demand curtailment. United Kingdom mitigates its demand curtailment to 27 % and Belgium and Ireland cannot cooperate more due to infrastructure limitations.

In **Global Ambition** scenario, all countries mitigate their demand curtailment due to the new interconnections and additional hydrogen production using methane. Most of the countries show 24 % demand curtailment. Eastern countries (Greece, Bulgaria, Romania, Slovenia, Croatia, Hungary and Slovakia) are directly impacted by the Ukrainian hydrogen supply disruption and show 38 % to 43 % demand curtailment. Infrastructure limitations (bottlenecks) with interconnected countries do not allow them to cooperate more to mitigate Eastern countries demand curtailment. Romania, Bulgaria and Greece show 43 % demand curtailment and Hungary cannot cooperate more with Romania due to a bottleneck. Other countries (France, Switzerland, Italy, Spain and Portugal) cooperate at the maximum with Eastern countries and show 21 % demand curtailment.

11.2.2.2 Advanced and PCI Infrastructure

Advanced and PCI methane infrastructure levels do not change simulation results in Existing. Advanced and PCI infrastructure levels add more flexibility on the methane side, but hydrogen production is capped and this additional flexibility cannot be used.

11.3 2-WEEK DUNKELFLAUTE DEMAND

The 2-Week Dunkelflaute country demands are generally very similar to the 2-Week Cold Spell demand values. Hydrogen demand is the same for Best Estimate and National Trends scenarios and it is also the same in the year 2030 of Distributed Energy and Global Ambition scenarios. Regarding Distributed Energy and Global Ambition scenarios in 2040 and 2050, only Italy, The Netherlands, Romania and United Kingdom show higher values in 2-Week Dunkelflaute. Regarding the methane demand values, only Bulgaria, Czech Republic, Germany, Croatia and Italy present slight differences when comparing demand of 2-Week Dunkelflaute with 2-Week Cold in Best Estimate and National trends scenarios. In Distributed Energy and Global Ambition scenarios just Spain, France, Greece, Italy, The Netherlands, Portugal, Romania and United Kingdom present higher methane demand in 2-Week Dunkelflaute.

Consequently, the curtailment rate results in 2-Week Dunkelflaute and in 2-Week Cold Spell are exactly the same for most of the countries. The countries with higher demand in 2-Week Dunkelflaute are only increasing their demand curtailment rate in 1 or 2 % maximum.

11.4 PEAK DEMAND

11.4.1 METHANE RESULTS

11.4.1.1 Existing Infrastructure

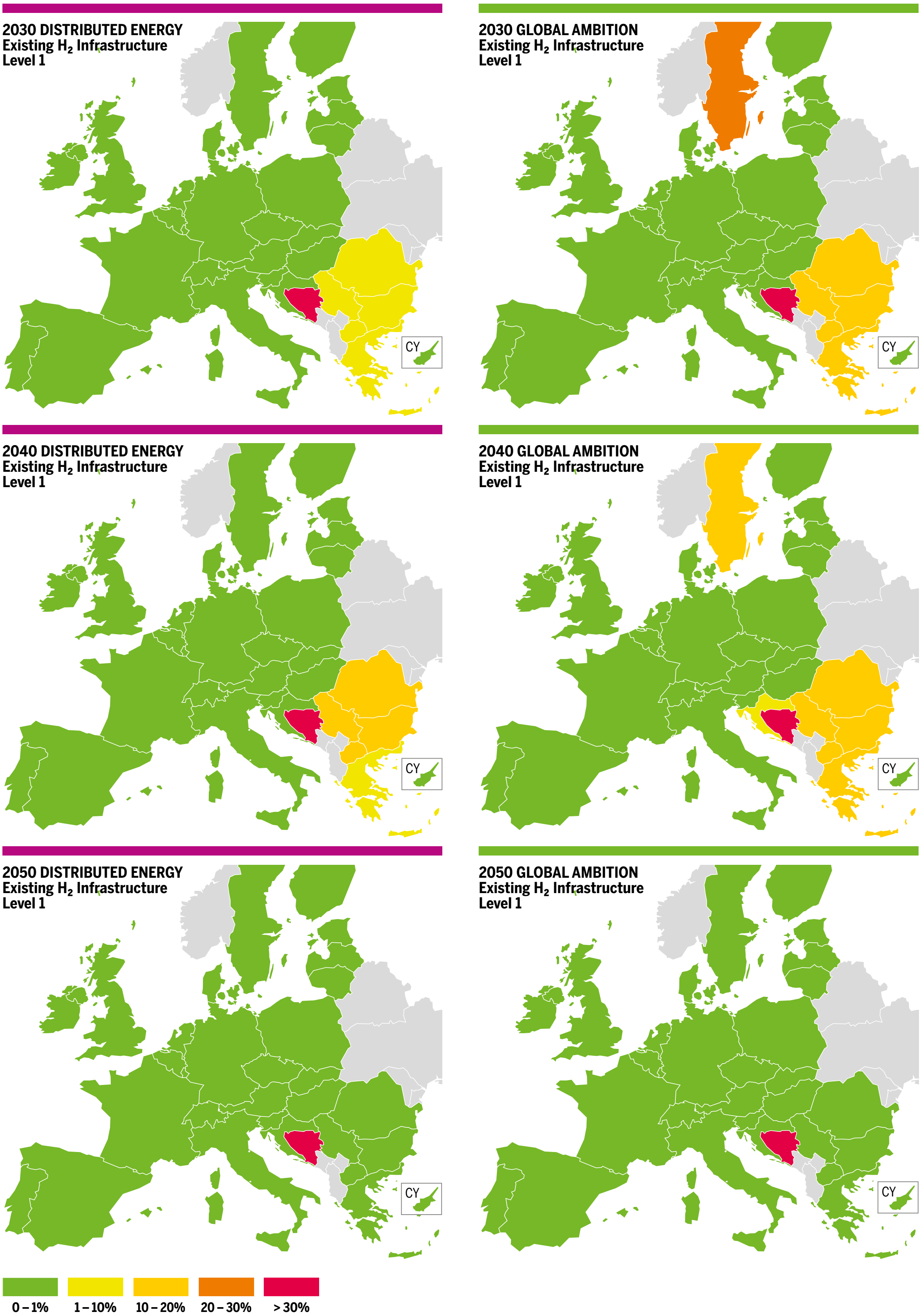


Figure 11.5a UA H_2 Supply Disruption – Methane Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 1

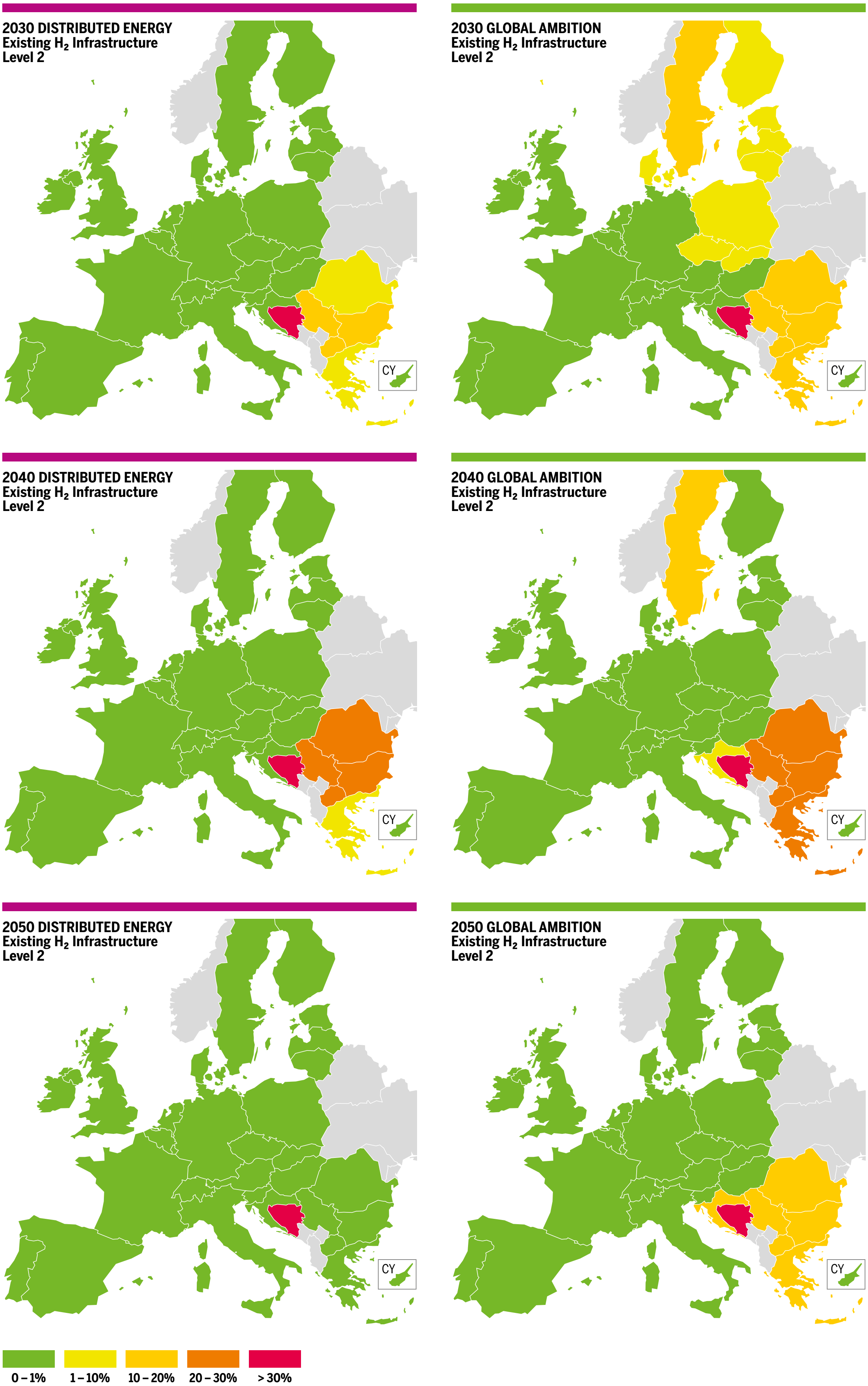


Figure 11.5b UA H_2 Supply Disruption – Methane Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

Distributed Energy scenario shows some countries with demand curtailment. Romania, Serbia, North Macedonia, Greece and Bulgaria show 7 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

Global Ambition scenario shows some countries with demand curtailment. Romania, Serbia, North Macedonia, Greece and Bulgaria show 18 % demand curtailment. Sweden shows 21 % demand curtailment due to a very high methane peak demand. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, the same countries show demand curtailment with highest values (10 %). In infrastructure Level 2, the potential of hydrogen production using methane increases and these countries go to the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

Global Ambition scenario shows the same countries with highest demand curtailment (18 %). Sweden mitigates its demand curtailment to 14 % and Poland, Czech Republic and Slovakia show 1 % demand curtailment. In infrastructure Level 2, the potential of hydrogen production increases and these countries go to the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, Romania, Serbia, North Macedonia, Greece and Bulgaria show 11 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with countries curtailed.

In **Global Ambition** scenario, Romania, Serbia, North Macedonia, Greece and Bulgaria show 12 % demand curtailment and Sweden 11 % due to a very high methane peak demand. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, Romania, Serbia, North Macedonia and Bulgaria show 24 % demand curtailment. Greece shows only 9 % demand curtailment and cannot cooperate more with Bulgaria due to abottleneck. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

In **Global Ambition** scenario, countries need more hydrogen and Romania, Serbia, North Macedonia, Greece and Bulgaria show 27 % demand curtailment and Croatia 8 %. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

2050

H_2 INFRASTRUCTURE LEVEL 1

In the **Distributed Energy and the Global Ambition** scenario, Ukrainian hydrogen supply disruption does not create any methane curtailment.

H_2 INFRASTRUCTURE LEVEL 2

Only **Global Ambition** scenario shows some countries with demand curtailment. Romania, Serbia, North Macedonia, Greece and Bulgaria show 18 % demand curtailment. Croatia shows 13 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

11.4.1.2 Advanced and PCI Infrastructure

There is no demand curtailment in both scenarios and years except for Sweden, in Global Ambition scenario in 2030 and 2040 in both hydrogen infrastructure levels due to a very high methane peak demand. Demand curtailment values for Sweden remain unchanged compared to Existing Methane infrastructure level.

11.4.2 HYDROGEN RESULTS

11.4.2.1 Existing Infrastructure

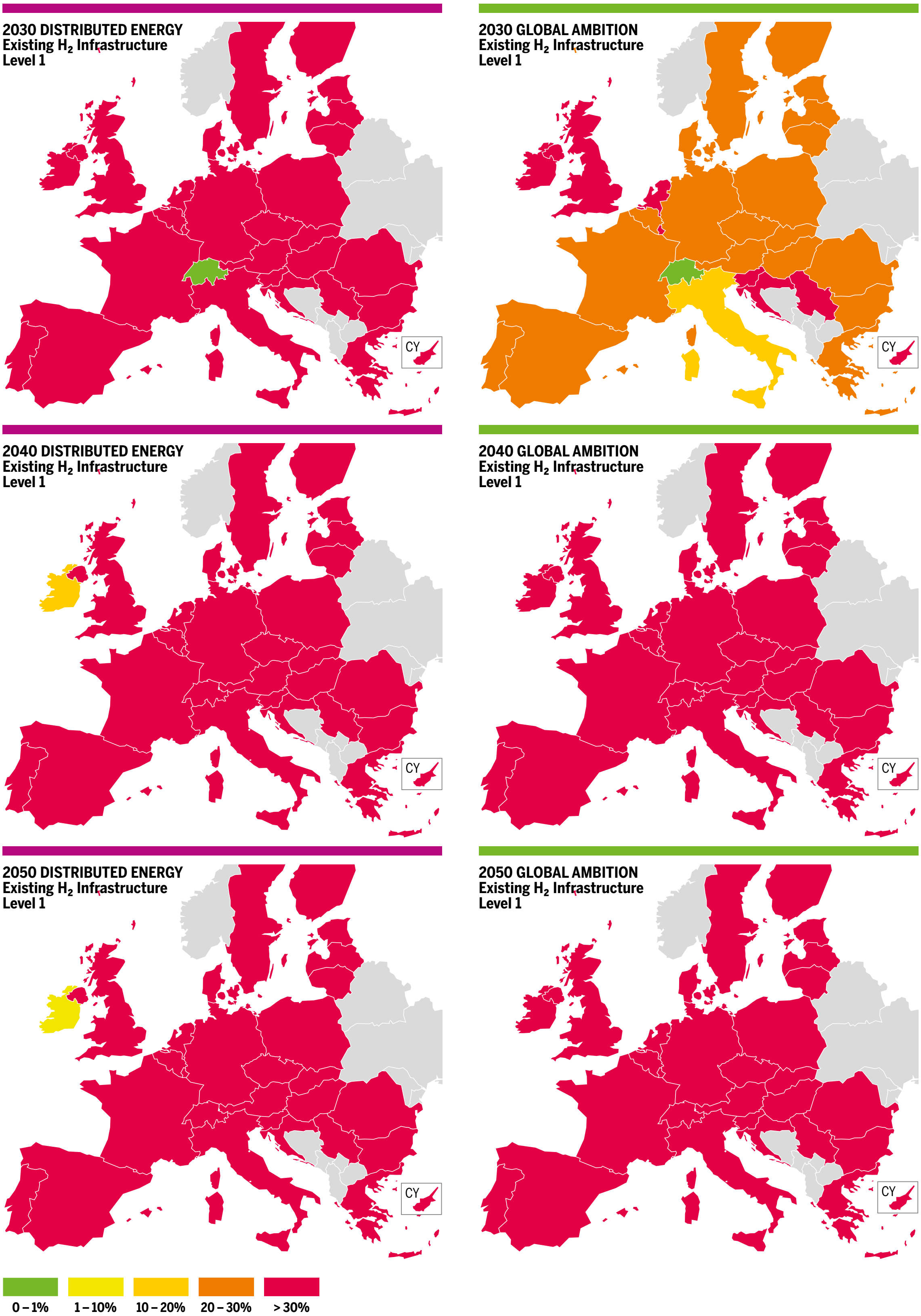


Figure 11.6a UA H_2 Supply Disruption – Hydrogen Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 1

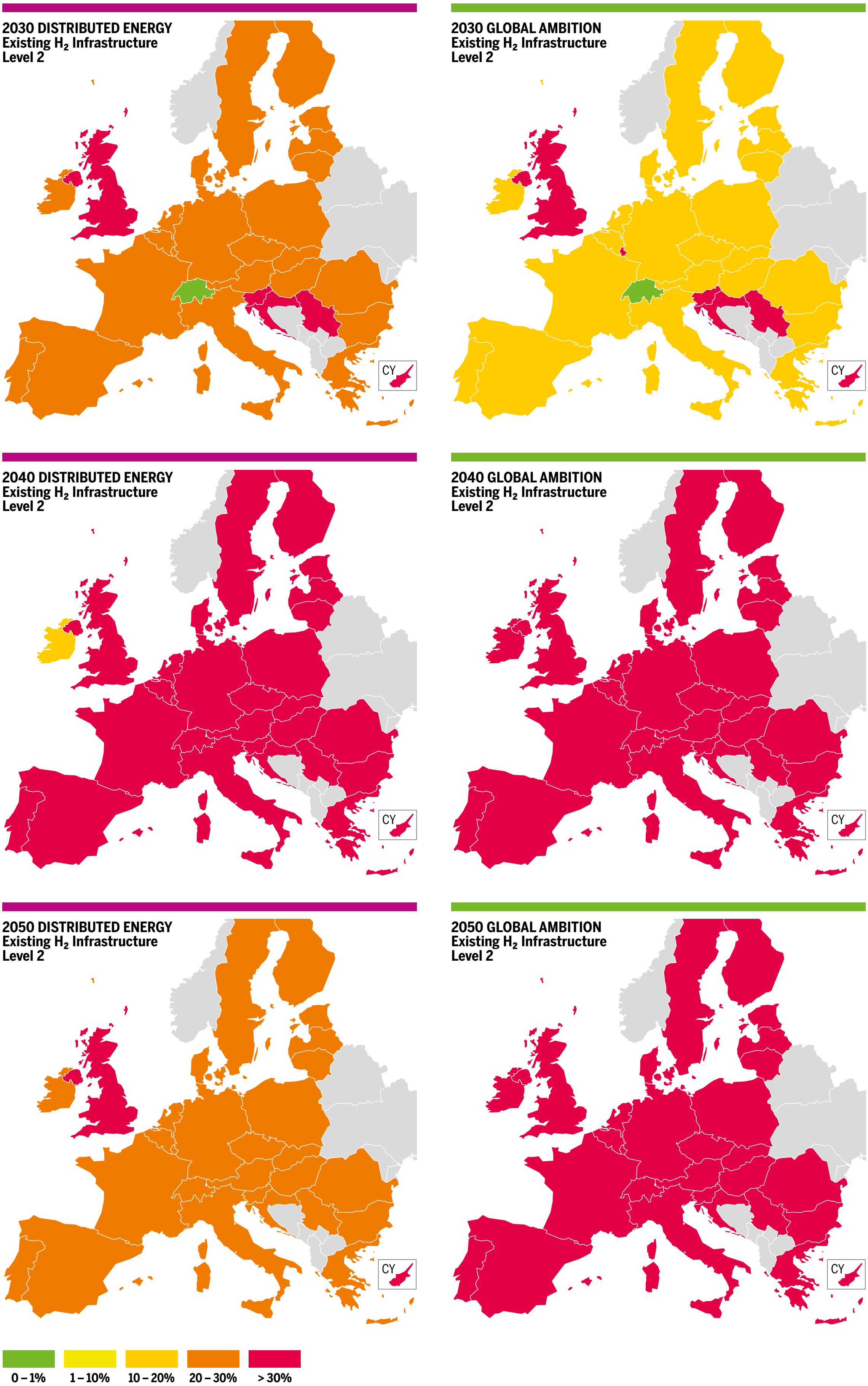


Figure 11.6b UA H_2 Supply Disruption – Hydrogen Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, all countries show demand curtailment. Most of the countries show 32 % demand curtailment. The Netherlands shows 46 % demand curtailment and Belgium and Germany cannot cooperate more due to infrastructure limitations (bottlenecks). Countries not interconnected to the hydrogen network show highest demand curtailment values: Serbia (100 %), Slovenia (91 %), United Kingdom (78 %), Luxembourg (74 %), Ireland (62 %) and Croatia (49 %). Their own production cannot satisfy their demand.

In **Global Ambition** scenario, all countries show demand curtailment. Most of the countries show 24 % demand curtailment. The Netherlands shows 41 % demand curtailment and Belgium and Germany cannot cooperate more due to bottlenecks. Italy shows 16 % demand curtailment and cannot cooperate with Austria due to infrastructure limitations. Countries not interconnected to the hydrogen network show highest demand curtailment values: Serbia (100 %), Slovenia (94 %), United Kingdom (76 %), Luxembourg (71 %), Ireland (62 %) and Croatia (45 %). Their own production cannot satisfy their demand.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, all countries mitigate their demand curtailment due to additional interconnections and more hydrogen production using methane. Most of the countries mitigate their demand curtailment to 21 %. Eastern countries (Bulgaria, Greece, Romania and Hungary) directly impacted by the Ukrainian supply disruption show 24 % demand curtailment. Other interconnected countries cannot more cooperate due to infrastructure limitations. Countries not interconnected mitigate their demand curtailment: Serbia (49 %), Croatia (49 %), Slovenia (42 %), United Kingdom (36 %), Ireland (25 %) and Luxembourg (27 %).

In **Global Ambition** scenario, all countries mitigate their demand curtailment due to additional interconnections and more hydrogen production using methane. Most of the countries mitigate their demand curtailment to 13 %. Eastern countries (Bulgaria, Greece, Romania and Hungary) directly impacted by the Ukrainian supply disruption show 17 % demand curtailment. Other interconnected countries cannot more cooperate due to bottlenecks. Countries which are not interconnected mitigate their demand curtailment: Serbia (49 %), Croatia (48 %), Slovenia (49 %), United Kingdom (36 %), Ireland (25 %) and Luxembourg (27 %).

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, all countries show demand curtailment. Most of the countries show 49 % demand curtailment. Countries not interconnected to the hydrogen network show highest demand curtailment values: Serbia (100 %), United Kingdom (87 %), Luxembourg (88 %) and Ireland (14 %). Their own production cannot satisfy their demand.

In **Global Ambition** scenario, all countries show demand curtailment. Most of the countries show 64 % demand curtailment. Countries not interconnected to the hydrogen network show highest demand curtailment values: Serbia (100 %), United Kingdom (90 %), Luxembourg (93 %) and Ireland (81 %). Their own production cannot satisfy their demand.

H_2 INFRASTRUCTURE LEVEL 2

In the **Distributed Energy** scenario, all countries mitigate their demand curtailment due to additional interconnections and more hydrogen production using methane. Most of the countries mitigate their demand curtailment to 31 %. Eastern countries (Greece, Bulgaria, Serbia, Romania, Croatia, Slovenia and Hungary) show 33 % demand curtailment and other interconnected countries cannot cooperate more due to infrastructure limitations. United Kingdom shows higher demand curtailment (48 %) due to bottlenecks with Belgium and Ireland. Ireland increases its demand curtailment to 16 % due to a higher cooperation with United Kingdom.

In **Global Ambition** scenario, all countries mitigate their demand curtailment due to additional interconnections and more hydrogen production using methane. Most of the countries mitigate their demand curtailment to 44 %. Eastern countries (Greece, Bulgaria, Serbia, Romania, Croatia, Slovenia, Slovakia and Hungary) show 49 % demand curtailment and other countries interconnected cannot cooperate more due to infrastructure limitations. United Kingdom and Ireland show higher demand curtailment (52 %) due to a bottleneck with Belgium. Poland, Latvia, Lithuania, Czech Republic and Estonia show 48 % demand curtailment. Other interconnected countries cannot cooperate more with them due to infrastructure limitations (bottlenecks).


Picture courtesy of Plinacro

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show 55 % demand curtailment. Portugal shows 40 % demand curtailment and cannot cooperate more with Spain to mitigate its demand curtailment due to a bottleneck. Ireland is isolated but shows only 8 % demand curtailment due to high hydrogen production. Other countries which are not interconnected show a higher demand curtailment. Serbia (100 %), Luxembourg (91 %) and United Kingdom (68 %) cannot satisfy their demand with their own hydrogen production.

In **Global Ambition** scenario, most of the countries show 67 % demand curtailment. Eastern countries (Greece, Bulgaria, Romania, Slovenia, Croatia, Slovakia and Hungary) show 76 % demand curtailment and other countries cannot cooperate more due to infrastructure limitations. Austria, Switzerland, Italy, Spain and Portugal cooperate at the maximum with Eastern countries, but bottlenecks do not allow them to mitigate demand curtailment. Other countries which are not interconnected show a higher demand curtailment. Serbia (100 %), Luxembourg (95 %), Ireland (69 %) and United Kingdom (79 %) cannot satisfy their demand with their own hydrogen production.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, all countries mitigated their demand curtailment due to additional interconnections and more hydrogen production using methane. Most of them show 29 % demand curtailment. United Kingdom shows 44 % demand curtailment due to infrastructure limitations with Belgium (28 %) and Ireland (22 %).

In **Global Ambition** scenario, all countries mitigated their demand curtailment due to additional interconnections and more hydrogen production using methane. Most of the countries show 34 % demand curtailment. Eastern countries (Greece, Bulgaria, Romania, Slovenia, Croatia, Slovakia and Hungary) show 47 % demand curtailment and other countries cannot cooperate more due to infrastructure limitations. Other countries mitigate their demand curtailment: Serbia (47 %), Ireland (46 %) and United Kingdom (46 %). Belgium shows 32 % demand curtailment and cannot cooperate more with United Kingdom due to infrastructure limitation (bottleneck).

11.4.2.2 Advanced and PCI hydrogen

Advanced and PCI methane infrastructure levels do not change simulation results in Existing. Advanced and PCI infrastructure levels add more flexibility on the methane side, but hydrogen production is capped, and this additional flexibility cannot be used.

12 LIQUEFIED HYDROGEN SUPPLY DISRUPTION

Liquefied Hydrogen supply disruption does not impact simulations results in 2025 Best Estimate and in National Trends demand scenarios (2030 and 2040); in those scenarios, there is no hydrogen import potential and methane demand curtailment is not impacted compared to the Reference Case. The infrastructure assessment is therefore limited to Distributed Energy and Global Ambition demand scenarios in 2030, 2040 and 2050.

12.1 YEARLY DEMAND

12.1.1 METHANE RESULTS

12.1.1.1 Existing Infrastructure

Liquefied Hydrogen supply disruption shows 4 % demand curtailment in **2040 in Infrastructure Level 1,** in **Global Ambition** scenario, in Hungary, Romania, Serbia, Bulgaria and North Macedonia. Additional hydrogen production using methane create demand curtailment in these countries.

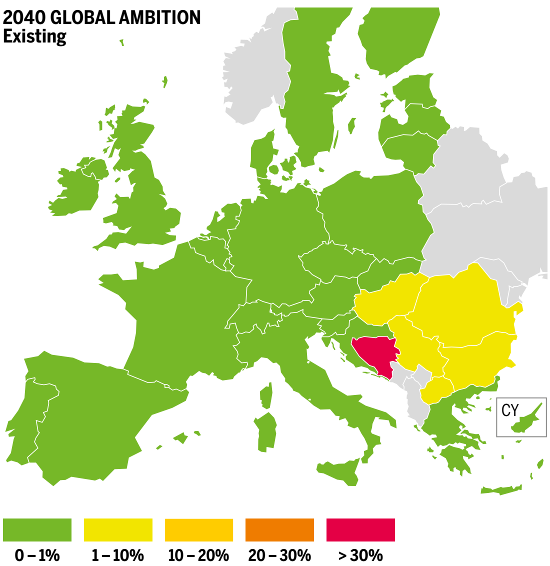


Figure 12.1 LH_2 H_2 Supply Disruption – Methane Results for Yearly Demand in Existing CH_4 with H_2 Level 1

12.1.1.2 Advanced and PCI Infrastructure

Demand curtailment is fully mitigated in Advanced and PCI infrastructure levels.

12.1.2 HYDROGEN RESULTS

12.1.2.1 Existing Infrastructure

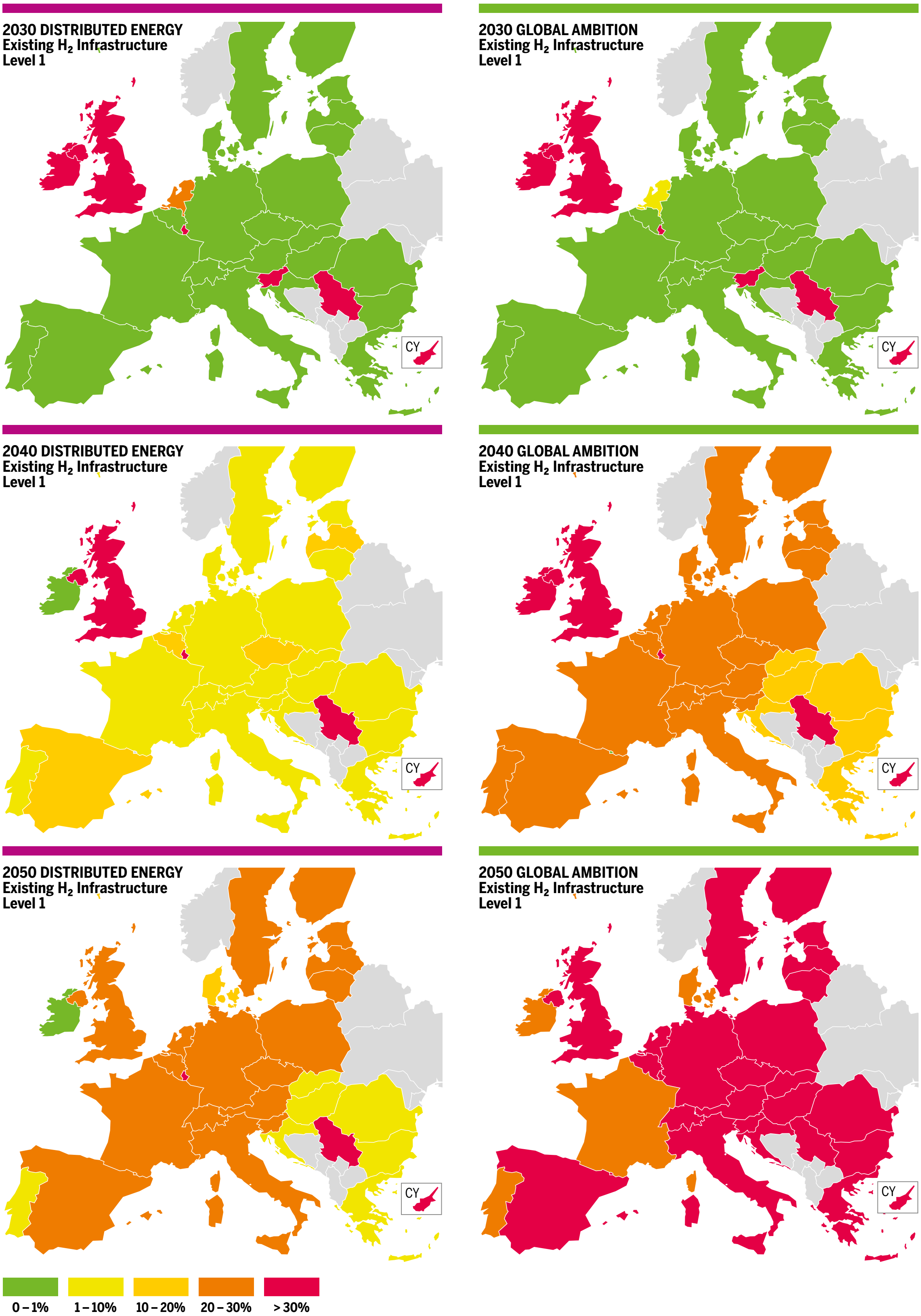


Figure 12.2a LH_2 H_2 Supply Disruption – Hydrogen Results for Yearly Demand in Existing CH_4 Infrastructure and H_2 Level 1

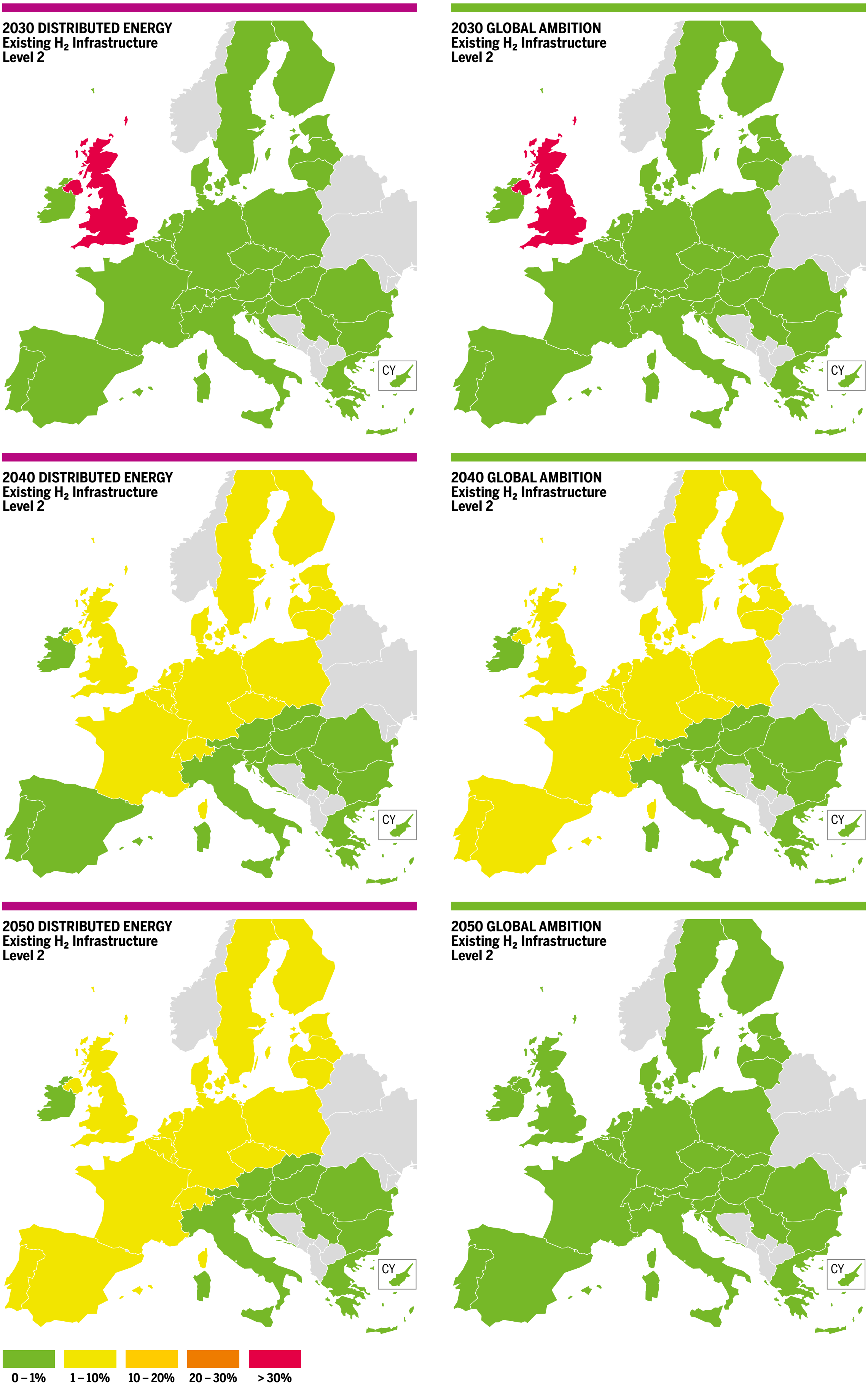


Figure 12.2b LH_2 H_2 Supply Disruption – Hydrogen Results for Yearly Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, the Netherlands shows 23 % demand curtailment. Belgium and Germany cannot cooperate more with The Netherlands due to infrastructure limitations. Countries without any interconnections are curtailed: Ireland 33 %, United Kingdom 46 %, Luxembourg 61 %, Slovenia 86 % and Serbia 100 %. Other countries compensate the Liquefied Hydrogen supply disruption with additional Hydrogen produced with methane due to the flexibility of the methane infrastructure.

In **Global Ambition** scenario, the Netherlands shows 1 % demand curtailment. Belgium and Germany cannot cooperate more with The Netherlands due to infrastructure limitations. Countries without any interconnections are curtailed: Ireland 37 %, United Kingdom 46 %, Luxembourg 55 %, Slovenia 89 % and Serbia 100 %. Other countries compensate the Liquefied Hydrogen supply disruption with additional Hydrogen produced with methane due to the flexibility of the methane infrastructure.

H_2 INFRASTRUCTURE LEVEL 2

In both scenarios, all countries fully mitigate demand curtailment due to new interconnections and increased capacities and additional hydrogen production using methane. Only United Kingdom shows 44 % and 46 % demand curtailment in Distributed Energy scenario and in Global Ambition scenario still show a dependence with Liquefied Hydrogen.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show 10 % demand curtailment. Italy, Switzerland, Slovenia and Austria show 8 % demand curtailment and Eastern countries (Slovakia, Hungary, Croatia, Romania, Bulgaria and Greece) show 3 % demand curtailment. Those countries cannot cooperate more due to infrastructure limitations (bottlenecks). Portugal shows 8 % demand curtailment and cannot cooperate more with Spain to mitigate Spain demand curtailment due to infrastructure limitation. United Kingdom (67 %), Luxembourg (83 %) and Serbia (100 %) are curtailed due to no interconnections with neighbouring countries.

In **Global Ambition** scenario, the situation is similar. Most of the countries show 22 % demand curtailment. Italy, Switzerland, Slovenia and Austria show 20 % demand curtailment and Eastern countries (Slovakia, Hungary, Croatia, Romania, Bulgaria and Greece) show 15 % demand curtailment. Those countries cannot cooperate more due to infrastructure limitations (bottlenecks). Ireland (50 %), United Kingdom (71 %), Luxembourg (86 %) and Serbia (100 %) are curtailment due to no interconnections with neighbouring countries.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, due to the additional interconnections and the additional hydrogen production using methane, most of the countries in the south (Portugal, Spain and Italy) and countries in the East (Austria, Slovakia, Hungary, Croatia, Serbia, Romania, Bulgaria and Greece) fully mitigate their demand curtailment. Ireland fully mitigates its demand curtailment The other countries show a low demand curtailment (1 %) except for United Kingdom with 3 % demand curtailment.

In **Global Ambition** scenario, due to the additional interconnections and the additional hydrogen production using methane, Italy and countries in the East (Austria, Slovakia, Hungary, Croatia, Serbia, Romania, Bulgaria and Greece) fully mitigate their demand curtailment. Ireland fully mitigates its demand curtailment The other countries show 4 % to 6 % demand curtailment. Countries which are not curtailed cannot cooperate with other countries due to infrastructure limitations (bottlenecks).

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show demand curtailment to 21 %. Eastern countries (Slovakia, Hungary, Croatia, Romania, Bulgaria and Greece) show 3 % demand curtailment. Those countries cannot cooperate more due to infrastructure limitations (bottlenecks). Portugal shows 8 % demand curtailment and cannot cooperate with Spain due to a bottleneck. United Kingdom (26 %), Luxembourg (87 %) and Serbia (100 %) are curtailed due to no interconnections with neighbouring countries. Ireland shows no demand curtailment.

In **Global Ambition** scenario, most of the countries show 33 % demand curtailment. Eastern countries (Slovakia, Hungary, Croatia, Romania and Bulgaria) show 31 % demand curtailment and cannot cooperate more due to infrastructure limitations (bottlenecks). Greece shows 39 % demand curtailment and Bulgaria cannot cooperate more due to a bottleneck). Portugal shows 28 % demand curtailment and cannot cooperate with Spain due to infrastructure limitations. France shows 28 % demand curtailment and cannot cooperate more with interconnected countries due to infrastructure limitations (bottlenecks). United Kingdom (45 %), Luxembourg (91 %) and Serbia(100 %) are curtailed due to no interconnections with neighbouring countries. Ireland shows 22 % demand curtailment.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, Spain and Portugal show 2 % demand curtailment and cannot cooperate with France due to infrastructure limitation. Most of the countries show 6 % demand curtailment except for Italy, Eastern countries (Austria, Slovenia, Croatia, Slovakia, Hungary, Romania, Serbia, Bulgaria and Greece) and Ireland fully mitigate their demand curtailment.

In **Global Ambition** scenario, demand curtailment is fully mitigated for all countries.

12.1.2.2 Advanced and PCI Infrastructure

Results remain unchanged in the Advanced and PCI infrastructure level compared to Existing Infrastructure level.

Picture courtesy of GAZ-SYSTEM

12.2 2-WEEK COLD SPELL DEMAND

12.2.1 METHANE RESULTS

12.2.1.1 Existing Infrastructure

In all scenarios and years Bosnia shows demand curtailment due to a bottleneck with Serbia.

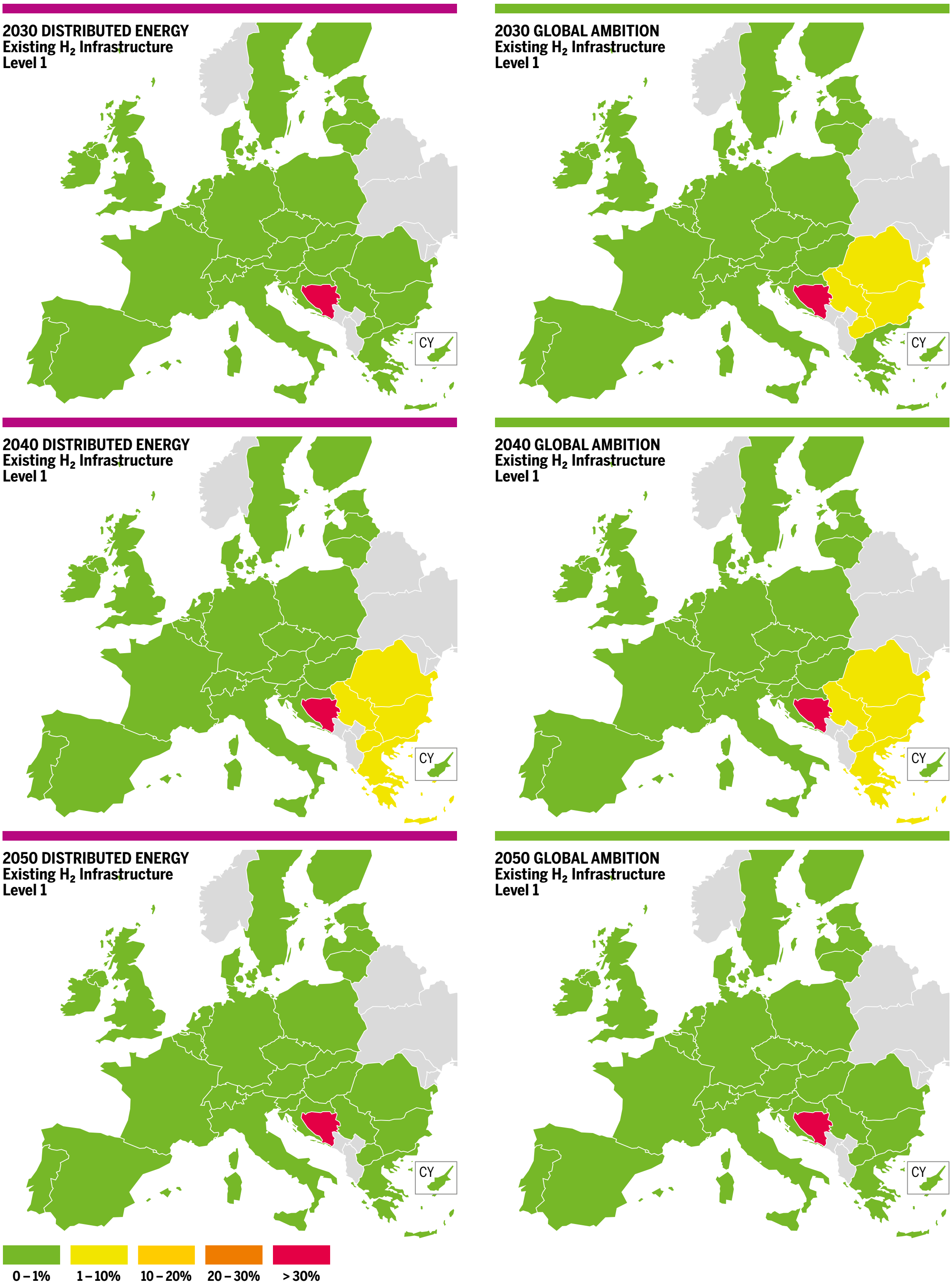


Figure 12.3a LH_2 H_2 Supply Disruption – Methane Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 1

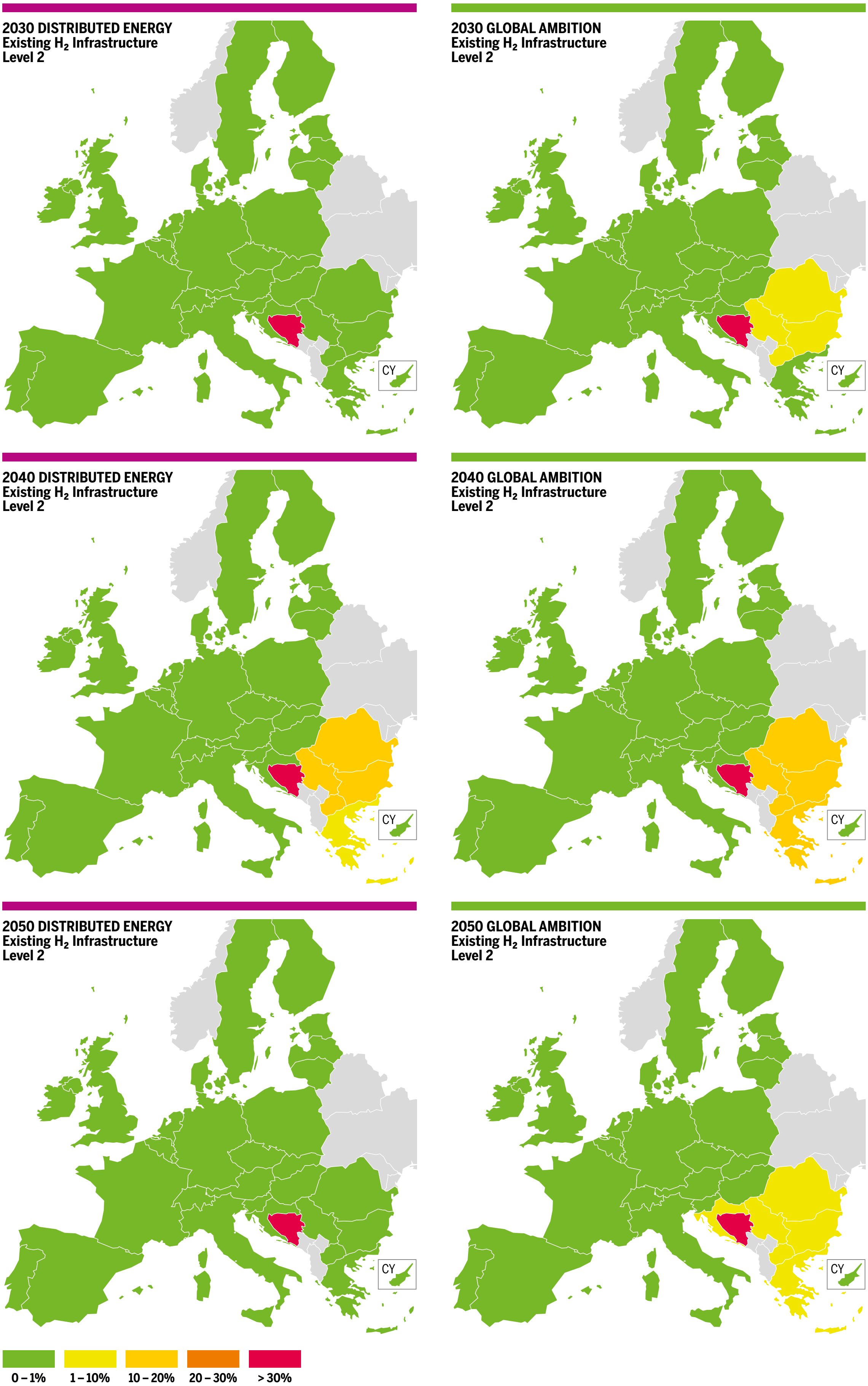


Figure 12.3b LH_2 H_2 Supply Disruption – Methane Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

Only **Global Ambition** scenario shows some countries with demand curtailment. Romania, Serbia, North Macedonia and Bulgaria show 2 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries

H_2 INFRASTRUCTURE LEVEL 2

Only **Global Ambition** scenario shows the same countries with demand curtailment. Romania, Serbia, North Macedonia and Bulgaria show 3 % demand curtailment. In infrastructure Level 2, the potential of hydrogen production increases and these countries go to the maximum and infrastructure limitations (bottlenecks) with neighbouring countries do not allow them to cooperate with curtailed countries.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, Romania, Serbia, North Macedonia, Greece and Bulgaria show 2 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

In **Global Ambition** scenario, Romania, Serbia, North Macedonia, Greece and Bulgaria show 2 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, Romania, Serbia, North Macedonia and Bulgaria show 12 % demand curtailment. Greece shows only 2 % demand curtailment and cannot cooperate more with Bulgaria due to a bottleneck. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

In **Global Ambition** scenario, countries need more hydrogen and Romania, Serbia, North Macedonia, Greece and Bulgaria show 16 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy and Global Ambition** scenario, Ukrainian hydrogen supply disruption does not create any methane curtailment.

H_2 INFRASTRUCTURE LEVEL 2

Only the **Global Ambition** scenario shows some countries with demand curtailment. Romania, Serbia, North Macedonia, Greece and Bulgaria show 8 % to 9 % demand curtailment. Croatia shows only 1 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations (bottlenecks) with neighbouring countries do not allow them to cooperate with curtailed countries.

12.2.1.2 Advanced and PCI Infrastructure

There is no demand curtailment at all in any year of any scenario.

12.2.2 HYDROGEN RESULTS

12.2.2.1 Existing Infrastructure

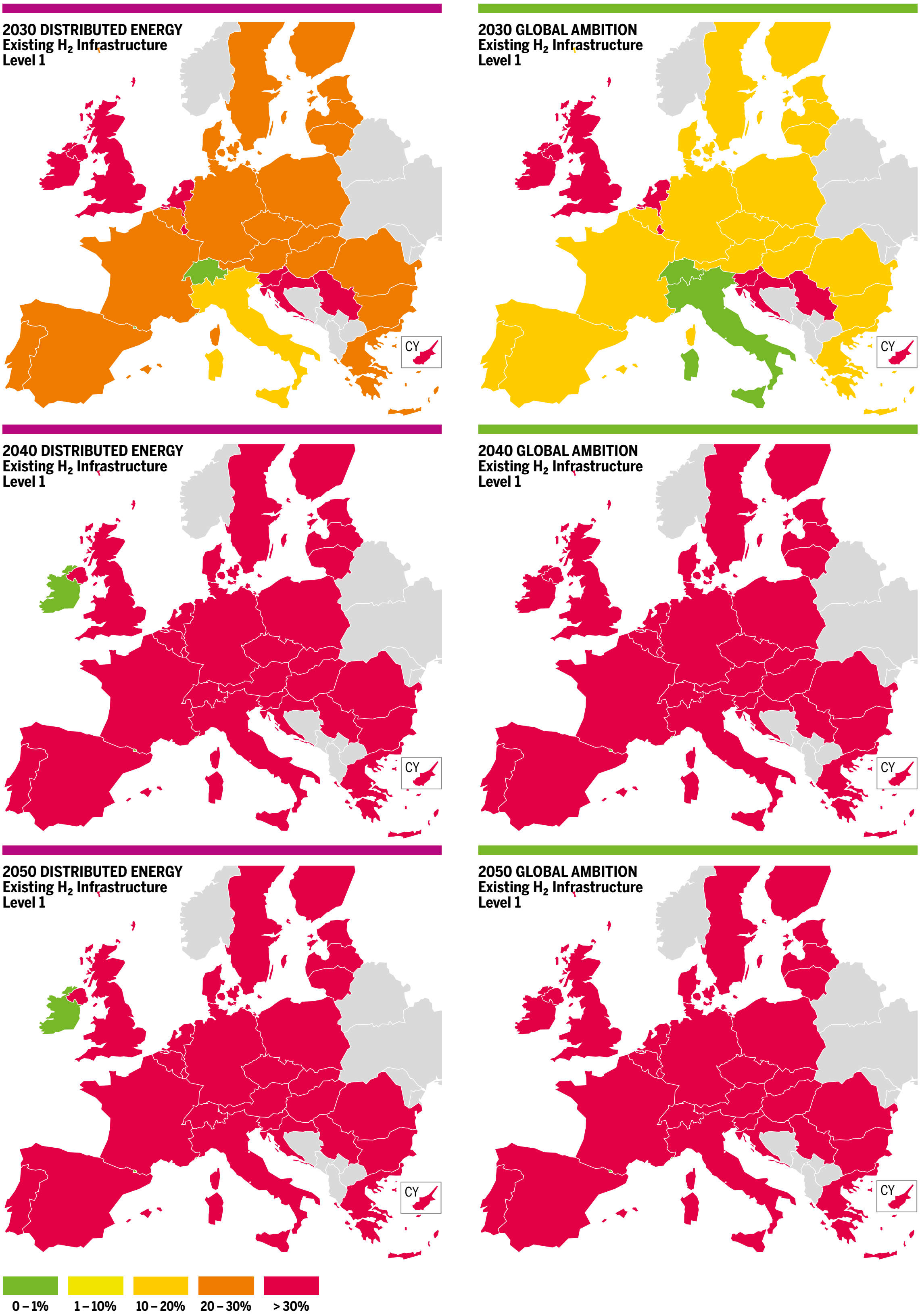


Figure 12.4a LH_2 H_2 Supply Disruption – Hydrogen Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 1

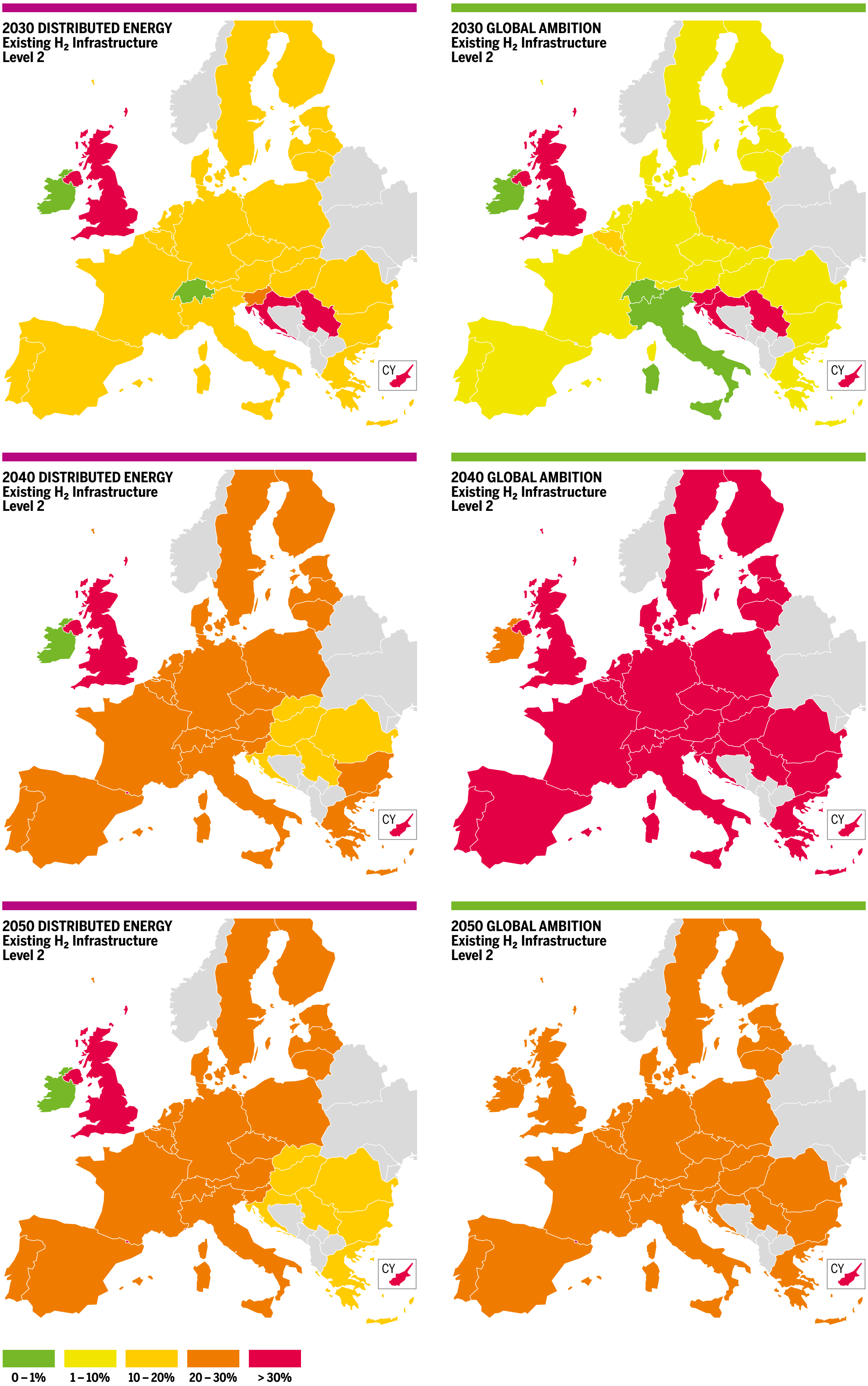


Figure 12.4b LH_2 H_2 Supply Disruption – Hydrogen Results for 2W Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, all countries are curtailed. Most of the countries show 24 % demand curtailment. Italy with more supply from North Africa, shows 15 % demand curtailment and cannot cooperate more with Austria to mitigate demand curtailment in the north. Other countries not interconnected show highest demand curtailment: Serbia (100 %), Slovenia (89 %), United Kingdom (71 %), Luxembourg (70 %), Croatia (38 %) and Ireland (43 %). The Netherlands, shows 57 % demand curtailment and Belgium and Germany cannot cooperate more with The Netherlands due to infrastructure limitations (bottlenecks).

In **Global Ambition** scenario, all countries show demand curtailment except for Italy. Most the countries show 15 % demand curtailment. Other countries not interconnected show highest demand curtailment: Serbia (100 %), Slovenia (89 %), United Kingdom (69 %), Luxembourg (66 %), Croatia (32 %) and Ireland (46 %). The Netherlands, shows 46 % demand curtailment and Belgium and Germany cannot cooperate more with The Netherlands due to bottlenecks.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, due to additional interconnections and more hydrogen production using methane, all countries mitigate their demand curtailment. Ireland fully mitigates its demand curtailment. Most of the countries show 18 % demand curtailment. Italy and Luxembourg show 15 % demand curtailment. Italy cannot cooperate with Austria due to a bottleneck. Other countries not interconnected show higher values of demand curtailment: Serbia (41 %), Croatia (401), Slovenia (29 %) and United Kingdom (64 %).

In **Global Ambition** scenario, due to additional interconnections and more hydrogen production using methane, all countries mitigate their demand curtailment. Ireland fully mitigates its demand curtailment. Most of the countries show 10 % demand curtailment. Eastern countries (Romania, Hungary, Bulgaria, Greece and Slovakia) and Austria show 6 % demand curtailment and cannot cooperate with other countries due to infrastructure limitations. Other countries not interconnected mitigate their demand curtailment: United Kingdom (64 %), Serbia (41 %), Croatia (40 %), Slovenia (32 %), Luxembourg (17 %).

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show 40 % demand curtailment. Ireland shows no demand curtailment and can satisfy its demand with its own production. Eastern countries (Bulgaria, Greece, Slovakia, Croatia, Hungary, Romania) show 34 % demand curtailment and cannot cooperate more with interconnected countries due to infrastructure limitations (bottlenecks). Serbia (100 %), Luxembourg (87 %) and United Kingdom (83 %) are isolated and cannot satisfy their demand with their own production.

In **Global Ambition** scenario, most of the countries show 54 % demand curtailment. Serbia (100 %), Luxembourg (91 %), United Kingdom (85 %) and Ireland (69 %) are isolated and cannot satisfy their demand with their own production.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, due to additional interconnections and more hydrogen production using methane, all countries mitigate demand curtailment. Most of the countries show 26 % demand curtailment. Eastern countries (Slovakia, Croatia, Hungary, Romania and Serbia) show 16 % demand curtailment and cannot cooperate more with interconnected countries due to bottlenecks. United Kingdom shows 40 % demand curtailment and Ireland and Belgium cannot cooperate more due to infrastructure limitations. Greece and Bulgaria show 28 % demand curtailment and Romania cannot cooperate more with Bulgaria due to a bottleneck.

In **Global Ambition** scenario, due to additional interconnections and more hydrogen production using methane, all countries mitigate demand curtailment. Most of the countries show 37 % demand curtailment. Ireland shows 22 % demand curtailment and Ireland and Belgium cannot cooperate with United Kingdom (41 %) to mitigate its demand curtailment due to infrastructure limitations.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show 47 % demand curtailment. Eastern countries (Greece, Slovakia, Bulgaria, Croatia, Hungary and Romania) show 32 % demand curtailment and cannot cooperate with other countries due to infrastructure limitations. Portugal shows 32 % demand curtailment and cannot more cooperate with Spain due to a bottleneck. Some countries are still not interconnected and show demand curtailment: United Kingdom (57 %), Serbia (100 %) and Luxembourg (90 %). Ireland can satisfy its demand with its own production.

In **Global Ambition** scenario, most of the countries show 61 % demand curtailment. Ireland shows 51 % demand curtailment and cannot cooperate more with United Kingdom (68 % demand curtailment) due to infrastructure limitations. Some countries are still not interconnected and show demand curtailment: United Kingdom (68 %), Serbia (100 %) and Luxembourg (94 %). Greece shows 65 % demand curtailment rate and Bulgaria cannot cooperate to mitigate Greece demand curtailment due to a bottleneck).

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, due to additional interconnections and more hydrogen production using methane, all countries mitigate demand curtailment. Most of the countries show 22 % demand curtailment. Eastern countries (Slovakia, Croatia, Hungary, Romania and Serbia) show 15 % demand curtailment and cannot cooperate more with interconnected countries due to infrastructure limitations. United Kingdom shows 34 % demand curtailment and Ireland and Belgium cannot cooperate more due to bottlenecks.

In **Global Ambition** scenario, due to additional interconnections and more hydrogen production using methane, all countries mitigate demand curtailment. Most of the countries show 25 % demand curtailment. Southern countries (Portugal, France, Italy and Spain) show 22 % demand curtailment and cannot cooperate with interconnected countries due to infrastructure limitations.

12.2.2.2 Advanced and PCI Infrastructure

Advanced and PCI methane infrastructure levels do not change simulation results in existing. Advanced and PCI infrastructure levels add more flexibility on the methane side, but hydrogen production is capped and this additional flexibility cannot be used.

12.3 2-WEEK DUNKELFLAUTE DEMAND

The 2-Week Dunkelflaute country demands are generally very similar to the 2-Week Cold Spell demand values. Hydrogen demand is the same for Best Estimate and National Trends scenarios and it is also the same in the year 2030 of Distributed Energy and Global Ambition scenarios. Regarding Distributed Energy and Global Ambition scenarios in 2040 and 2050, only Italy, The Netherlands, Romania and United Kingdom show higher values in 2-Week Dunkelflaute.

Regarding the methane demand values, only Bulgaria, Czech Republic, Germany, Croatia and Italy present slight differences when comparing demand of 2-Week Dunkelflaute with 2-Week Cold in Best Estimate and National trends scenarios. In Distributed Energy and Global Ambition scenarios just Spain, France, Greece, Italy, The Netherlands, Portugal, Romania and United Kingdom present higher methane demand in 2-Week Dunkelflaute.

Consequently, the curtailment rate results in 2-Week Dunkelflaute and in 2-Week Cold Spell are exactly the same for most of the countries. The countries with higher demand in 2-Week Dunkelflaute are only increasing their demand curtailment rate in 1 or 2 % maximum.

12.4 PEAK DEMAND

12.4.1 METHANE RESULTS

12.4.1.1 Existing Infrastructure

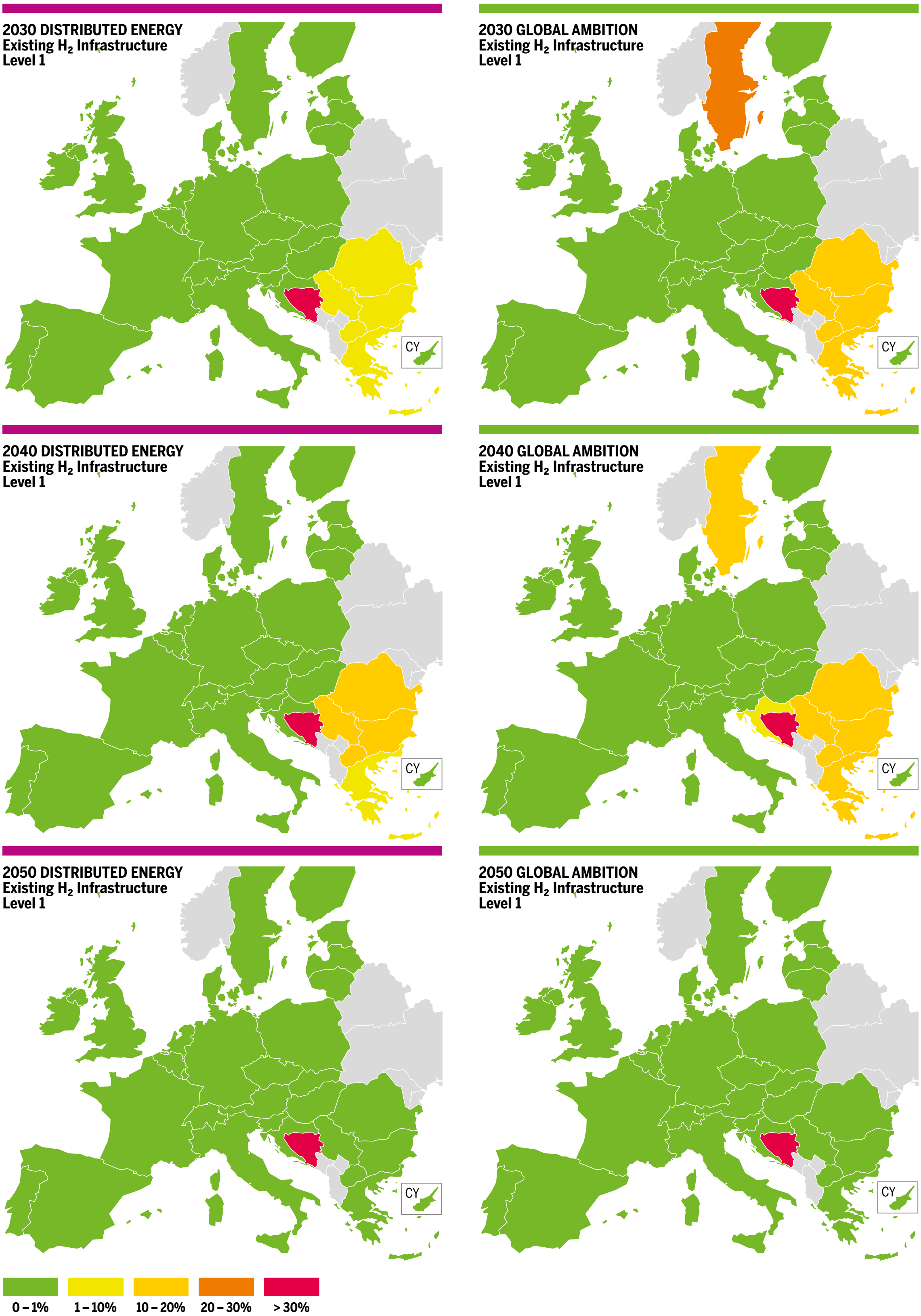


Figure 12.5a LH_2 H_2 Supply Disruption – Methane Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 1

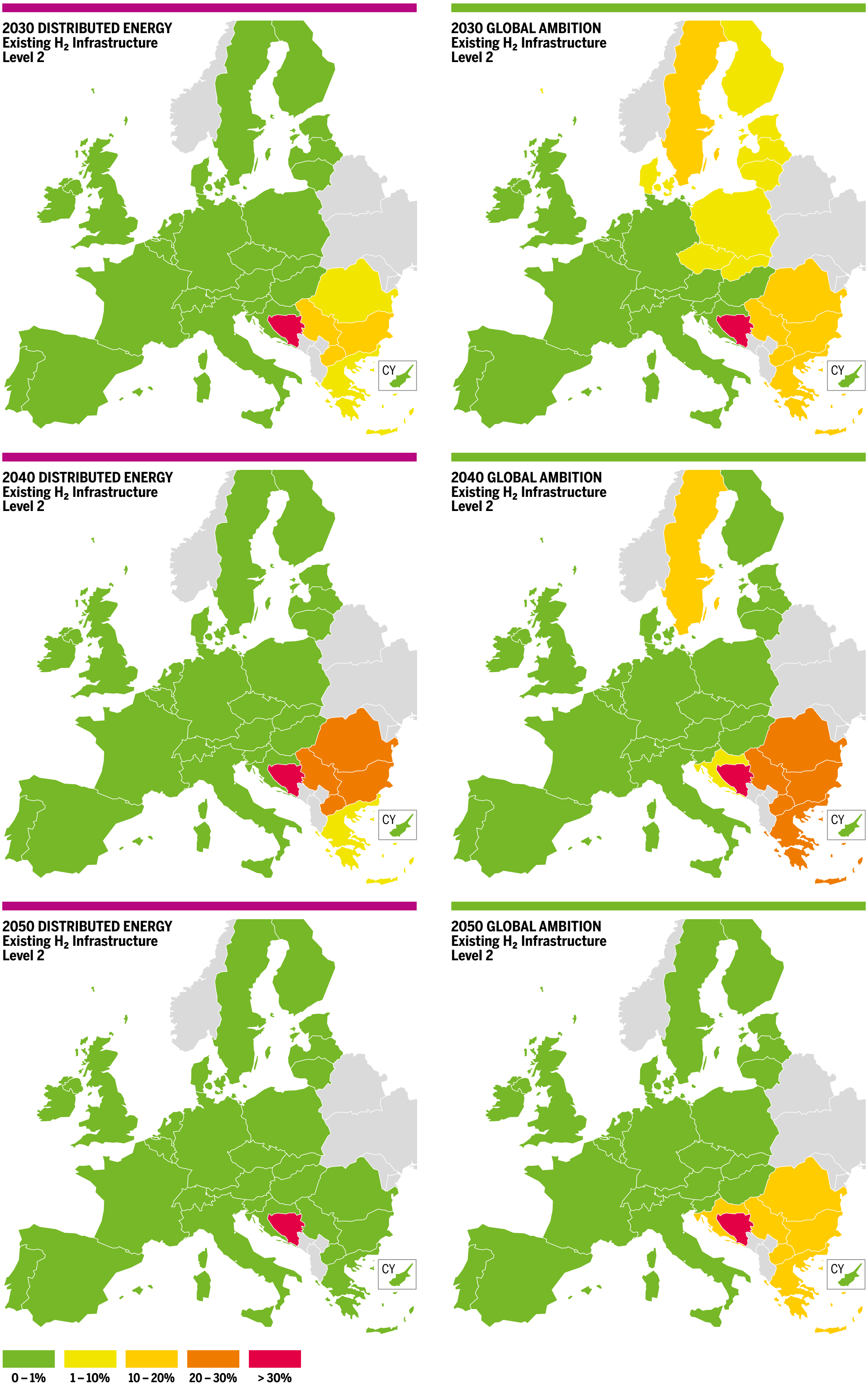


Figure 12.5b LH_2 H_2 Supply Disruption – Methane Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

The **Distributed Energy** scenario shows some countries with demand curtailment. Romania, Serbia, North Macedonia, Greece and Bulgaria show 7 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

The **Global Ambition** scenario shows some countries with demand curtailment. Romania, Serbia, North Macedonia, Greece and Bulgaria show 18 % demand curtailment. Sweden shows 21 % demand curtailment due to a very high methane peak demand. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, the same countries show demand curtailment with highest values (10 %). In infrastructure level 2, the potential of hydrogen production using methane increases and these countries go to the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

The **Global Ambition** scenario shows the same countries with highest demand curtailment (18 %). Sweden mitigates its demand curtailment to 14 % and Poland, Czech Republic and Slovakia show 1 % demand curtailment. In infrastructure level 2, the potential of hydrogen production increases and these countries go to the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

2040

H_2 INFRASTRUCTURE LEVEL 1

In the **Distributed Energy** scenario, Romania, Serbia, North Macedonia, Greece and Bulgaria show 11 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

In **Global Ambition** scenario, Romania, Serbia, North Macedonia, Greece and Bulgaria show 12 % demand curtailment and Sweden 11 %. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations (bottlenecks) with neighbouring countries do not allow them to cooperate with countries curtailed.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, Romania, Serbia, North Macedonia and Bulgaria show 24 % demand curtailment. Greece shows only 9 % demand curtailment and cannot cooperate more with Bulgaria due to a bottleneck. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

In the **Global Ambition** scenario, countries need more hydrogen and Romania, Serbia, North Macedonia, Greece and Bulgaria show 27 % demand curtailment and Croatia 8 %. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

2050

H_2 INFRASTRUCTURELEVEL 1

In **Distributed Energy** and **Global Ambition** scenario, Ukrainian hydrogen supply disruption does not create any methane curtailment.

H_2 INFRASTRUCTURE LEVEL 2

Only the **Global Ambition** scenario shows some countries with demand curtailment. Romania, Serbia, North Macedonia, Greece and Bulgaria show 18 % demand curtailment. Croatia shows 13 % demand curtailment. Without any hydrogen supply from Ukraine, hydrogen production from methane is used at the maximum and infrastructure limitations with neighbouring countries do not allow them to cooperate with curtailed countries.

12.4.1.2 Advanced and PCI Methane

There is no demand curtailment in both scenarios and years except for in Sweden, in Global Ambition scenario in 2030 and 2040 in both hydrogen infrastructure levels due to a very high methane peak demand. Demand curtailment values for Sweden remain unchanged compared to Existing Methane infrastructure level.

12.4.2 HYDROGEN RESULTS

12.4.2.1 Existing Infrastructure

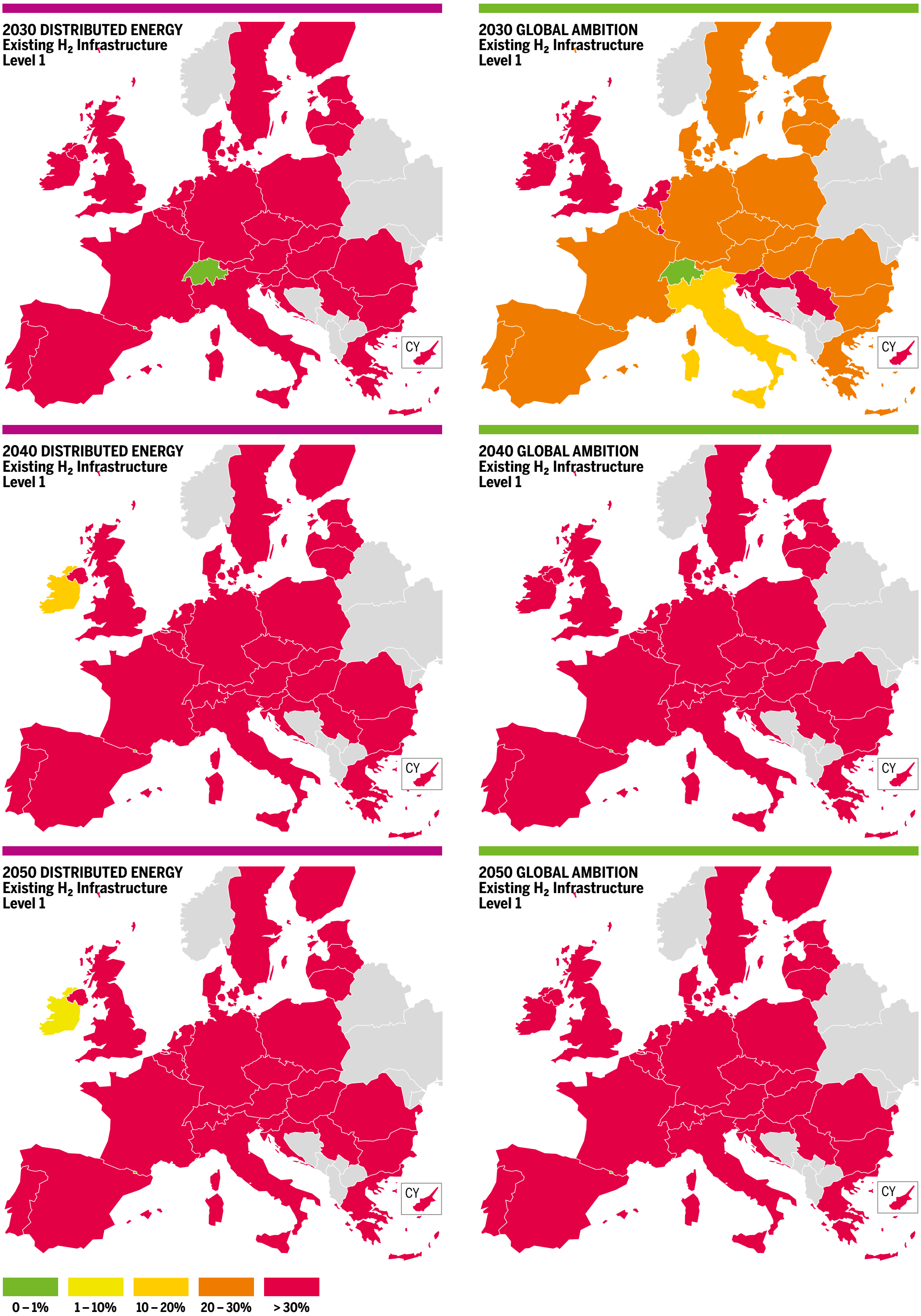


Figure 12.6a LH_2 H_2 Supply Disruption – Hydrogen Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 1

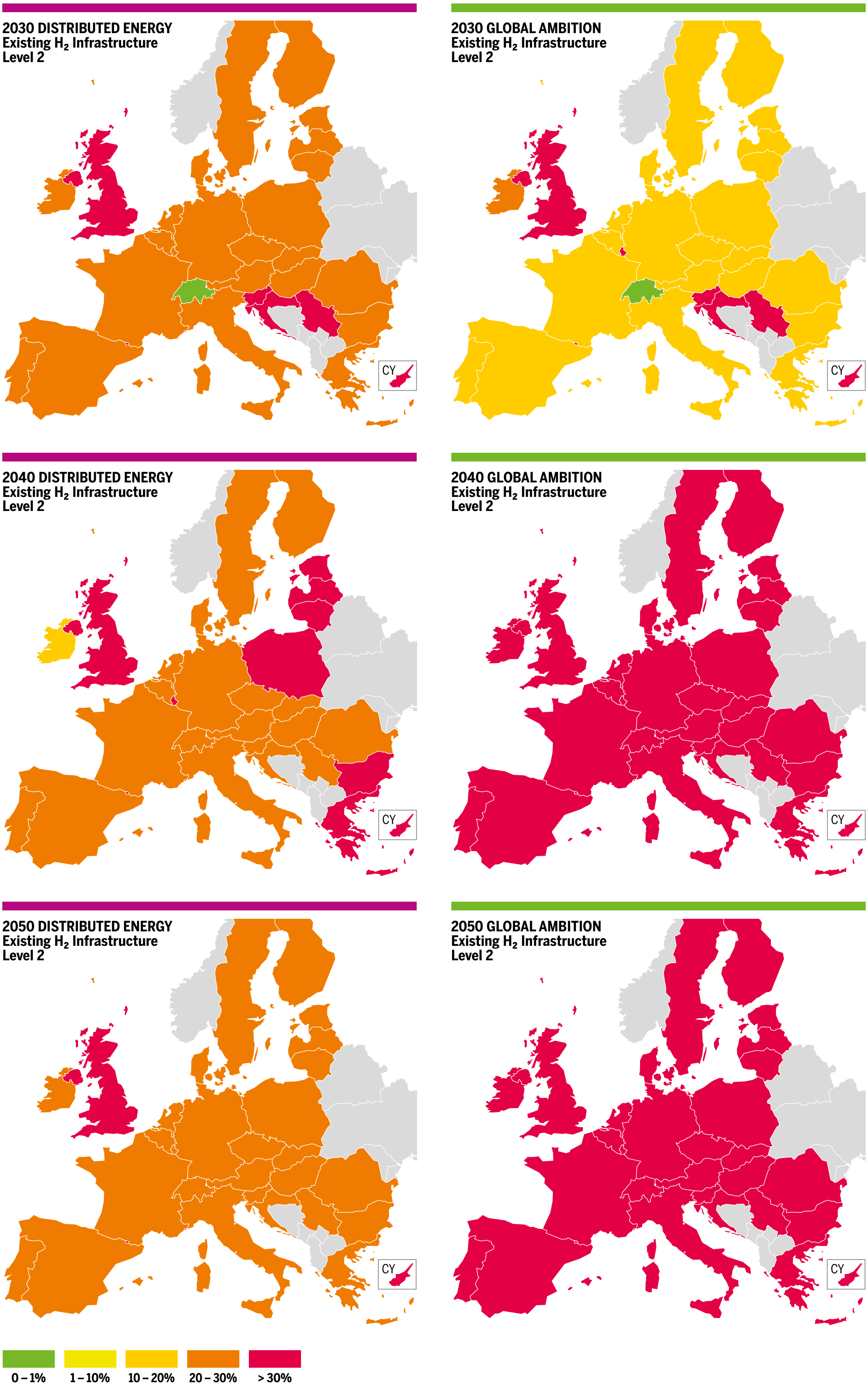


Figure 12.6b LH_2 H_2 Supply Disruption – Hydrogen Results for Peak Demand in Existing CH_4 Infrastructure and H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, all countries show demand curtailment. Most of the countries show 35 % demand curtailment. Italy with more supply from North Africa shows 30 % demand curtailment and cannot cooperate more with Austria due to a bottleneck. Some countries are not interconnected and show higher demand curtailment: United Kingdom (78 %), Luxembourg (74 %), Slovenia (91 %), Ireland (62 %), Croatia (49 %) and Serbia(100 %). The Netherlands shows 67 % demand curtailment and Belgium and Germany cannot cooperate more due to infrastructure limitations.

In **Global Ambition** scenario, all countries show demand curtailment. Most of the countries show 27 % demand curtailment. Italy, with more supply from North Africa, shows 16 % demand curtailment and cannot cooperate more with Austria due to infrastructure limitations. The Netherlands shows 58 % demand curtailment and Belgium and Germany cannot cooperate more due to bottlenecks.Some countries are not interconnected and show higher demand curtailment: United Kingdom (76 %), Luxembourg (71 %), Slovenia (94 %), Ireland (62 %), Croatia (45 %) and Serbia (100 %).

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, due to additional interconnections and more hydrogen production using methane, all countries mitigate demand curtailment. Most of the countries show 27 % demand curtailment. Some countries are not interconnected and show higher demand curtailment: United Kingdom (70 %), Ireland (25 %), Croatia (49 %) and Serbia(49 %).

In **Global Ambition** scenario, thanks to additional interconnections and more hydrogen production using methane, all countries mitigate demand curtailment. Most of the countries show 19 % demand curtailment. Italy shows 16 % demand curtailment and cannot cooperate with Austria due to infrastructure limitations. Some countries are not interconnected and show higher demand curtailment: United Kingdom (69 %), Ireland (20 %), Croatia (48 %) and Serbia(49 %).

2040

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, all countries show demand curtailment. Most of the countries show 48 % demand curtailment. Eastern countries (Greece, Croatia, Romania, Hungary, Bulgaria and Slovakia) show 43 % demand curtailment and cannot cooperate more with interconnected countries to mitigate demand curtailment due to infrastructure limitations (bottlenecks). Ireland shows 14 % demand curtailment. Some countries that are not interconnected and show a higher demand curtailment: United Kingdom (87 %), Luxembourg (88 %) and Serbia (100 %).

In **Global Ambition** scenario, most of the countries show 61 % to 66 % demand curtailment. The countries that are not interconnected and show higher demand curtailment: United Kingdom (90 %), Luxembourg (93 %), Ireland (81 %) and Serbia (100 %).

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, all countries mitigate their demand curtailment. Most of the countries show 27 % to 30 % demand curtailment. Greece and Bulgaria show 35 % demand curtailment and Romania cannot cooperate more with Bulgaria due to a bottleneck. United Kingdom show 54 % demand curtailment and Ireland (16 %) and Belgium (29 %) cannot cooperate more due to infrastructure limitations (bottlenecks).

In **Global Ambition** scenario, all countries mitigate their demand curtailment. Most of the countries show 43 to 45 % demand curtailment. United Kingdom show 57 % demand curtailment and Ireland (52 %) and Belgium (44 %) cannot cooperate more due to infrastructure limitations (bottlenecks).

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, all countries show demand curtailment. Most of the countries show 55 % demand curtailment. Eastern countries (Greece, Croatia, Romania, Hungary, Bulgaria and Slovakia) show 42 % demand curtailment and cannot cooperate with interconnected countries to mitigate demand curtailment due to infrastructure limitations. Some countries are not interconnected and show higher demand curtailment: United Kingdom (68 %), Luxembourg (91 %), Ireland (8 %) and Serbia(100 %).

In **Global Ambition** scenario, all countries show curtailment and most of the countries show 68 % demand curtailment. Some countries are not interconnected and show higher demand curtailment: United Kingdom (79 %), Luxembourg (95 %), Ireland (69 %) and Serbia (100 %).

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, all countries mitigate demand curtailment. Ireland mitigates its demand curtailment to 22 % and most of the countries mitigate their demand curtailment to 27 %. United Kingdom mitigates its demand curtailment to 49 %.

In **Global Ambition** scenario, all countries mitigate demand curtailment. Most of the countries mitigate their demand curtailment to 33 %. United Kingdom and Ireland mitigate their demand curtailment to 49 %. Greece, Bulgaria and Romania show 35 % demand curtailment and interconnected countries cannot cooperate more with them due to bottlenecks.

12.4.2.2 Advanced and PCI

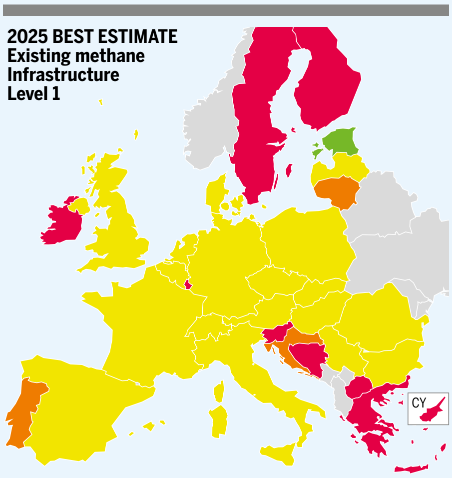
Advanced and PCI methane infrastructure levels do not change simulation results compared to Existing. Advanced and PCI infrastructure levels add more flexibility on the methane side, but hydrogen production is capped, and this additional flexibility cannot be used.

13 SINGLE LARGEST INFRASTRUCTURE DISRUPTION (SLID) – METHANE

This section investigates the impact of the Single Largest Infrastructure Disruption (SLID) of a country during a Peak day. The SLID measures the curtailed demand following the disruption of this infrastructure in a given country (excluding storage and national production). For each country, the Single Largest Infrastructure depends on the year and the infrastructure level.

The table with the Single Largest Infrastructure considered for each country can be found in Annex D. The results presented correspond to the possible additional curtailment for a country in case of disruption of its Single Largest Infrastructure, and its impact on other countries, compared to the climatic stress in peak day. The demand curtailment in Peak Day without any disruption is not represented in this chapter (see Climatic Stress chapter).

13.1 EXISTING INFRASTRUCTURE (METHANE RESULTS)



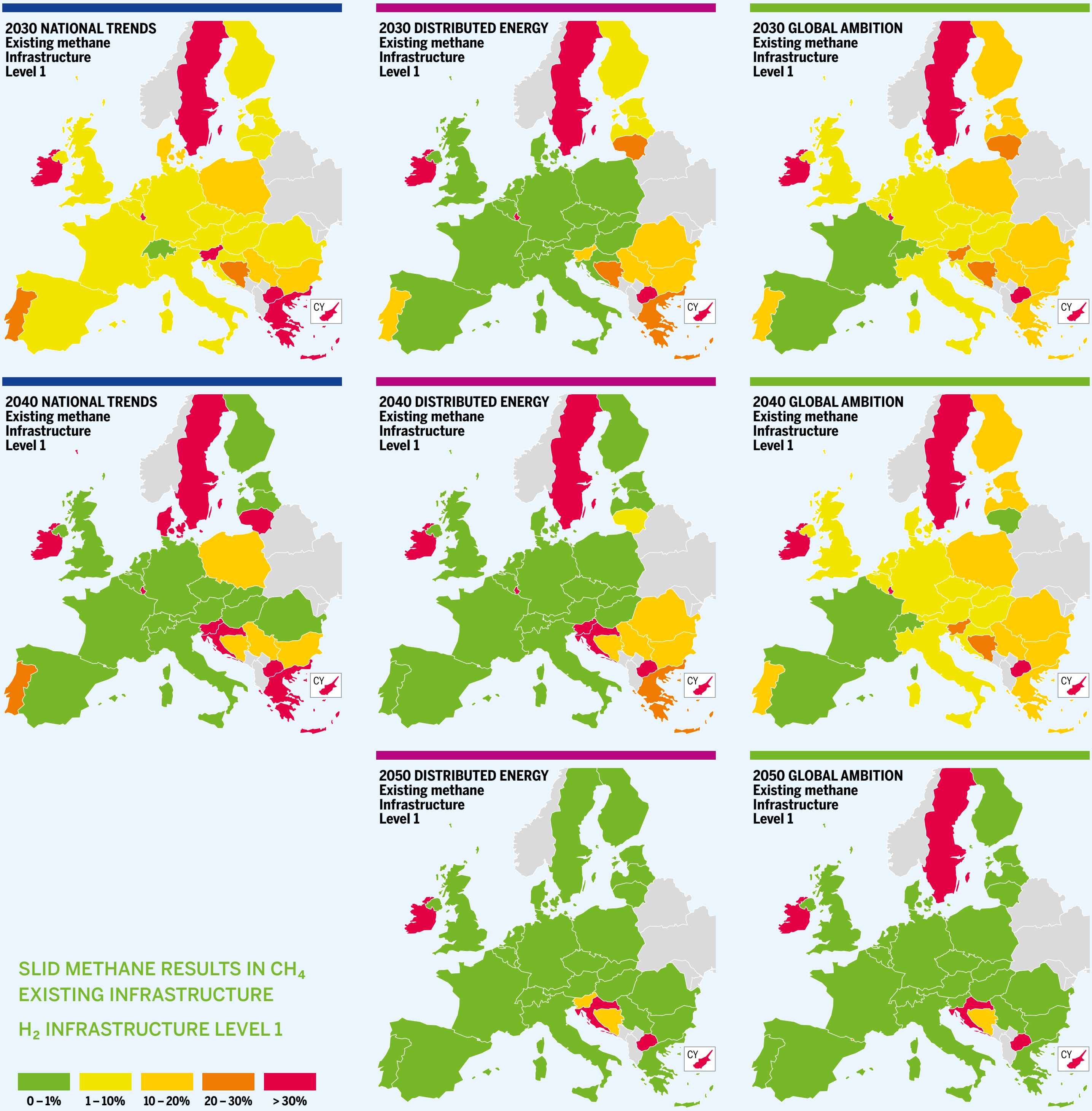


Figure 13.1 Methane SLID Results for Peak Demand in Existing CH_4 Infrastructure with H_2 Level 1

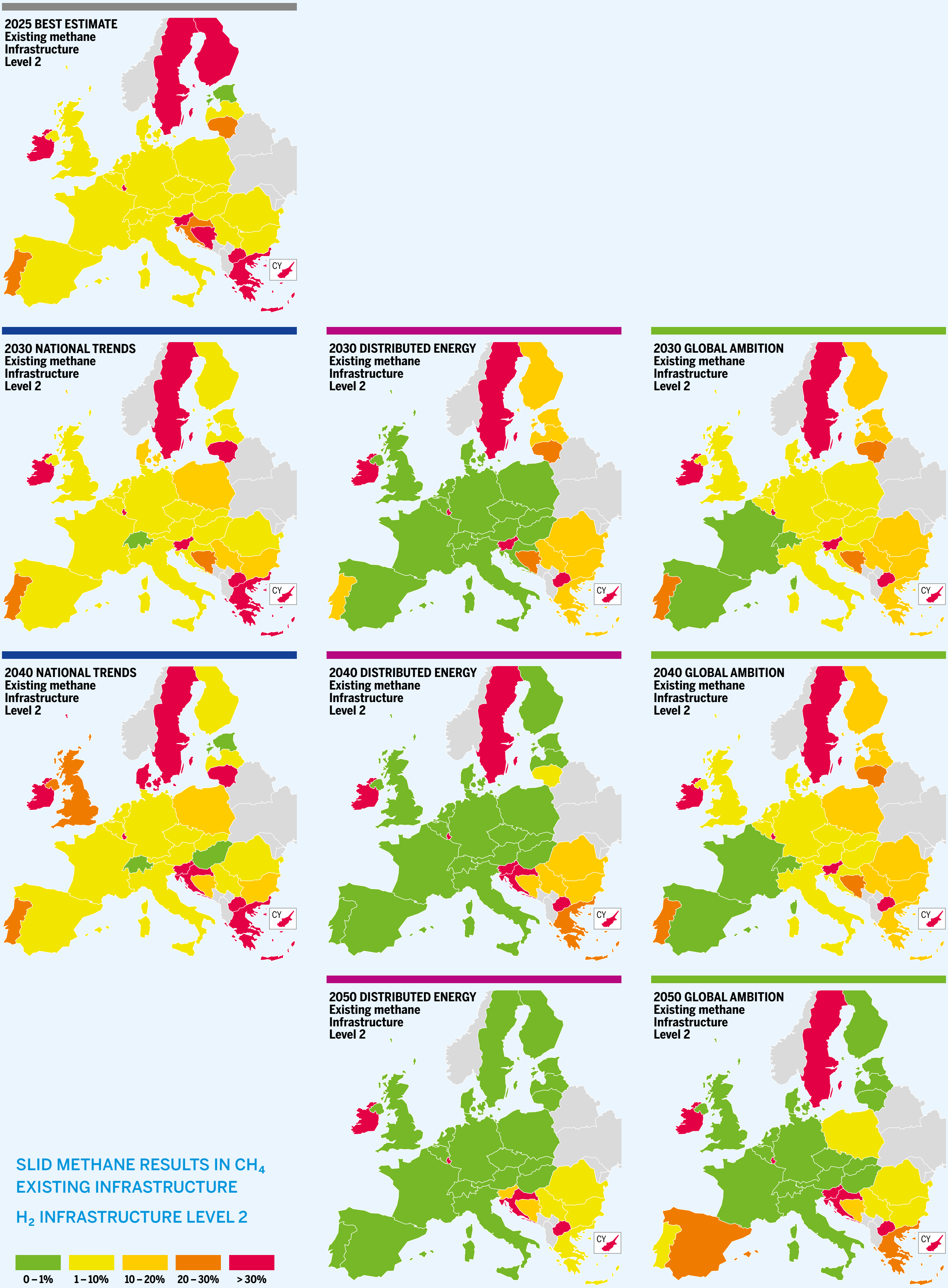


Figure 13.2 Methane SLID Results for Peak Demand in Existing CH_4 Infrastructure with H_2 Level 2

Picture courtesy of Moldovatransgaz

2025 – Best estimate

H_2 INFRASTRUCTURE LEVEL 1

In **Best Estimate** scenario, the SLID impacts all the countries except for Estonia. SLID is Balticconnector but Estonia has enough interconnection capacity with Latvia. Most of the countries show 2 % to 3 % demand curtailment and good cooperation between them. Countries with low interconnection diversification are the most impacted by SLIDs.

- United Kingdom is exposed to 10 % demand curtailment and Belgium and The Netherlands cannot cooperate more due to infrastructure limitations (bottlenecks).
- Northern Ireland is exposed to 48 % demand curtailment due to SLID Ireland (Moffat), without any other interconnections.
- Ireland is exposed to 79 % demand curtailment due to SLID (Moffat).
- Croatia is exposed to 24 % demand curtailment, SLID corresponds to the Croatia LNG terminal and there are infrastructure limitations with Hungary and Slovenia.
- Bosnia and Herzegovina is exposed to 39 % demand curtailment. Bosnia and Herzegovina has only one interconnection with Serbia which already shows a bottleneck in the Reference Climatic Stress (Peak demand).
- Greece is exposed to 50 % demand curtailment, SLID corresponds to Agia Triada terminal and interconnections with Trans Adriatic Pipeline and with Bulgaria are not enough to mitigate Greece demand curtailment.
- Slovenia is exposed to 41 % demand curtailment, SLID corresponds to the interconnection with Austria and the only interconnection left with Italy cannot satisfy the demand.
- North Macedonia is exposed to 91 % demand curtailment, SLID is the interconnection with Greece and there are no other options to meet its demand.
- Portugal shows 24 % demand curtailment, SLID corresponds to the interconnection with Sines terminal and there are infrastructure limitations with Spain.
- Lithuania shows 28 % demand curtailment, SLID corresponds to the interconnection with Klaipėda LNG terminal and there are bottlenecks with Poland and Latvia.
- Finland shows 34 % demand curtailment, SLID corresponds to the import capacity and without enough interconnections, Finland cannot satisfy its demand.
- Luxembourg is exposed to 49 % demand curtailment, SLID corresponds to Belgium interconnection and the one with Germany shows infrastructure limitations.
- Sweden is exposed to 79 % demand curtailment with the SLID of their only interconnection with Denmark.

H_2 INFRASTRUCTURE LEVEL 2

In **Best estimate** scenario, demand curtailment is the same to the one in Level 1 in all countries.

2030

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, all countries show demand curtailment except for Switzerland. Due to a large diversification, Switzerland can satisfy its demand. Most of the countries show 3 % to 8 % demand curtailment. See below detail comments for countries with more than 10 % demand curtailment.

- Serbia is exposed to 13 % demand curtailment with their SLID Kireeva-Zaychar interconnection and there are infrastructure limitations with Hungary.
- Bulgaria is exposed to 13 % demand curtailment, SLID is Turkstream interconnection and interconnections with Serbia, Romania and Greece cannot mitigate Bulgarian demand curtailment.
- Poland is exposed to 15 % demand curtailment, SLID is Baltic pipe and other interconnections cannot mitigate Poland demand curtailment.
- Denmark is exposed to 16 % demand curtailment, SLID is North Sea Entry interconnection (imports from Norway) and other interconnections with Poland or Germany cannot mitigate Denmark demand curtailment.
- Bosnia and Herzegovina is exposed to 21 % demand curtailment, SLID is the interconnection with Serbia and, without any other interconnection, Bosnia and Herzegovina cannot mitigate its demand curtailment.
- Portugal shows 24 % demand curtailment, SLID corresponds to the interconnection with Sines terminal and there is infrastructure limitations (bottleneck) with Spain.
- Lithuania shows 30 % demand curtailment, SLID corresponds to the Klaipėda LNG terminal and there are infrastructure bottlenecks with Poland and Latvia.
- Slovenia is exposed to 47 % demand curtailment, SLID corresponds to the interconnection with Austria and the only interconnection left with Italy cannot satisfy the demand.
- Greece is exposed to 52 % demand curtailment, SLID corresponds to Agia Triada terminal and interconnections with Trans Adriatic Pipeline and with Bulgaria are not enough to mitigate Greece demand curtailment.
- Luxembourg is exposed to 52 % demand curtailment, SLID corresponds to Belgium interconnection and the one with Germany shows infrastructure limitations.
- Northern Ireland is exposed to 68 % demand curtailment due to SLID Ireland (Moffat), without any other interconnections.
- Ireland is exposed to 82 % demand curtailment due to SLID (Moffat).
- North Macedonia is exposed to 96 % demand curtailment, SLID is the interconnection with Greece and there are no other option to meet its demand.

In **H_2 Infrastructure level 1, Distributed Energy** scenario, most of the countries can satisfy their demand in case of SLIDs.

- Baltic states and Finland show 6 % demand curtailment (26 % for Lithuania) due to infrastructure limitations with Poland and LNG Terminal in Finland and Lithuania.
- Slovenia is exposed to 12 % demand curtailment due infrastructure limitations with Italy and Croatia.
- Serbia, Romania and Bulgaria show 14 % demand curtailment and infrastructure limitations with interconnected countries do not allow them to mitigate demand curtailment.
- Portugal is exposed to 18 % demand curtailment and a bottleneck with Spain does not allow to mitigate the demand curtailment in Portugal.
- Bosnia and Herzegovina is exposed to 21 % demand curtailment, SLID is the interconnection with Serbia and, without any other interconnection, Bosnia and Herzegovina cannot mitigate its demand curtailment.
- Greece is exposed to 24 % demand curtailment, SLID corresponds to Agia Triada terminal and interconnections with Trans Adriatic Pipeline and with Bulgaria are not enough to mitigate Greece demand curtailment.
- Lithuania shows 26 % demand curtailment, SLID corresponds to the Klaipėda LNG terminal and there are infrastructure limitations with Poland and Latvia.
- Luxembourg is exposed to 35 % demand curtailment, SLID corresponds to Belgium interconnection and i the one with Germany shows infrastructure limitations (bottleneck).

- Sweden is exposed to 45 % demand curtailment with the SLID of their only interconnection with Denmark.
- Northern Ireland is exposed to 73 % demand curtailment due to SLID Ireland (Moffat), without any other interconnections.
- Ireland is exposed to 88 % demand curtailment due to SLID (Moffat).
- North Macedonia is exposed to 93 % demand curtailment, SLID is the interconnection with Greece and there are no other options to meet its demand.

In **H_2 Infrastructure level 1 Global Ambition** scenario, most of the countries cannot satisfy their demand in case of SLIDs. Only Spain, France and Switzerland are not impacted by SLIDs. Most of the countries show 4 % to 5 % demand curtailment (2 % in Italy).

- Poland is exposed to 10 % demand curtailment, SLID corresponds to Baltic pipe and interconnections with other countries show infrastructure limitations (bottlenecks).
- Romania, Bulgaria and Serbia show 11 % demand curtailment. Due to a good cooperation between these countries, demand curtailment is mitigated and interconnections with Hungary and Greece show bottlenecks.
- Greece shows 18 % demand curtailment and infrastructure limitation with Bulgaria do not allow Bulgaria to mitigate demand curtailment.
- Finland, Estonia and Latvia show 15 % demand curtailment. Due to a good cooperation between these countries, demand curtailment is mitigated and interconnections with neighbouring countries show infrastructure limitations.
- Lithuania shows 25 % demand curtailment, SLID corresponds to the Klaipėda LNG terminal and there are infrastructure limitations with Poland and Latvia.
- Portugal is exposed to 19 % demand curtailment, SLID corresponds to Sines LNG terminal and the infrastructure limitations with Spain do not allow to mitigate the demand curtailment in Portugal.
- Slovenia is exposed to 20 % demand curtailment due infrastructure limitations with Italy and Croatia.
- Bosnia and Herzegovina is exposed to 21 % demand curtailment, SLID is the interconnection with Serbia and, without any other interconnection, Bosnia and Herzegovina cannot mitigate its demand curtailment.
- Luxembourg is exposed to 46 % demand curtailment, SLID corresponds to Belgium interconnection and the one with Germany shows a bottleneck.
- Sweden is exposed to 56 % demand curtailment, SLID is the interconnection with Denmark.
- Northern Ireland is exposed to 65 % demand curtailment due to SLID Ireland (Moffat), without any other interconnections.
- Ireland is exposed to 90 % demand curtailment due to SLID (Moffat).
- North Macedonia is exposed to 82 % demand curtailment, SLID is the interconnection with Greece and there are no other options to meet its demand.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, most of the countries increase their demand curtailment (1 % to 2 %) due to more hydrogen production using methane.

In **Distributed energy** scenario, most of the countries already curtailed in infrastructure level 1 increase their demand curtailment by 1 % to 2 % due to higher hydrogen production using methane.

In **Global Ambition** scenario, some countries already curtailed in infrastructure level 1 increase their demand curtailment due to higher hydrogen production using methane. If some countries increase their demand curtailment of 1 %, Slovenia and Sweden increase their demand curtailment by 19 % and 7 %.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, most of countries can satisfy their demand.

- Serbia is exposed to 14 % demand curtailment, SLID is Kireeva-Zaychar interconnection and the interconnection with Hungary shows a bottleneck.
- Bulgaria is exposed to 13 % demand curtailment, SLID is Turkstream and interconnections with Serbia, Romania and Greece cannot mitigate Bulgarian demand curtailment.
- Poland is exposed to 12 % demand curtailment, SLID is Baltic pipe interconnection and other interconnections cannot mitigate Poland demand curtailment.
- Denmark is exposed to 37 % demand curtailment, SLID is North Sea Entry interconnection (imports from Norway) and other interconnections cannot help to mitigate this demand curtailment mostly because of the decreased capacity between Denmark and Germany due to the repurposing of pipelines to hydrogen.
- Bosnia and Herzegovina is exposed to 16 % demand curtailment, SLID is the interconnection with Serbia and, without any other interconnection, Bosnia and Herzegovina cannot mitigate its demand curtailment.
- Portugal shows 22 % demand curtailment, SLID corresponds to the interconnection with Sines terminal and there is a bottleneck with Spain.
- Lithuania shows 31 % demand curtailment, SLID corresponds to the Klaipėda LNG terminal and there are infrastructure limitations with Poland and Latvia.
- Slovenia is exposed to 64 % demand curtailment, SLID corresponds to the interconnection with Austria and the only interconnection left with Italy cannot satisfy the demand.
- Greece is exposed to 40 % demand curtailment, SLID corresponds to Agia Triada terminal and interconnections with Trans Adriatic Pipeline and with Bulgaria are not enough to mitigate Greece demand curtailment.
- Luxembourg is exposed to 58 % demand curtailment, SLID corresponds to Belgium interconnection and interconnection with Germany shows a bottleneck.
- Northern Ireland is exposed to 88 % demand curtailment due to SLID Ireland (Moffat), without any other interconnections.
- Ireland is exposed to 87 % demand curtailment due to SLID (Moffat).
- North Macedonia is exposed to 79 % demand curtailment, SLID is the interconnection with Greece and there are no other options to meet its demand.
- Croatia shows 42 % demand curtailment, SLID is the Croatia LNG terminal and the interconnections with Slovenia and Hungary show infrastructure limitations.
- Sweden shows 83 % demand curtailment, SLID is their only interconnection with Denmark.

In **H_2 Infrastructure Level 1 Distributed Energy** scenario, most of the countries are not exposed to demand curtailment, due to the indigenous production and enough interconnection diversification. Despite a high indigenous production in Distributed Energy scenario, some countries do not satisfy their demand.

- Serbia is exposed to 19 % demand curtailment, SLID is Kireeva–Zaychar interconnection and the interconnection with Hungary shows infrastructure limitations.
- Bulgaria is exposed to 19 % demand curtailment, SLID is Turkstream and interconnections with Serbia, Romania and Greece cannot mitigate Bulgarian demand curtailment.
- Bosnia and Herzegovina is exposed to 16 % demand curtailment, SLID is the interconnection with Serbia and, without any other interconnection, Bosnia and Herzegovina cannot mitigate its demand curtailment.
- Lithuania shows 7 % demand curtailment, SLID corresponds to the Klaipėda LNG terminal and there are bottlenecks with Poland and Latvia.
- Slovenia is exposed to 35 % demand curtailment, SLID corresponds to the interconnection with Austria and the only interconnection left with Italy cannot satisfy the demand.
- Greece is exposed to 21 % demand curtailment, SLID corresponds to Agia Triada terminal and interconnections with Trans Adriatic Pipeline and with Bulgaria are not enough to mitigate Greece demand curtailment.

- Luxembourg is exposed to 21 % demand curtailment, SLID corresponds to Belgium interconnection and the one with Germany shows infrastructure limitations.
- Northern Ireland is exposed to 100 % demand curtailment due to SLID Ireland (Moffat), without any other interconnections.
- Ireland is exposed to 87 % demand curtailment due to SLID (Moffat).
- North Macedonia is exposed to 89 % demand curtailment, SLID is the interconnection with Greece and there are no other options to meet its demand.
- Croatia shows 54 % demand curtailment, SLID is the Croatia LNG terminal and the interconnections with Slovenia and Hungary show infrastructure limitations.
- Sweden shows 36 % demand curtailment, SLID is their only interconnection with Denmark.

In **H_2 Infrastructure Level 1 Global Ambition** scenario, most of the countries are not exposed to demand curtailment, due to the indigenous production and enough interconnection diversification. Despite a high indigenous production in Global Ambition scenario, some countries do not satisfy their demand.

- Serbia is exposed to 21 % demand curtailment, SLID is Kireeva-Zaychar interconnection and the interconnection with Hungary shows infrastructure limitations.
- Bulgaria is exposed to 21 % demand curtailment, SLID is Turkstream and interconnections with Serbia, Romania and Greece cannot mitigate Bulgarian demand curtailment.
- Bosnia and Herzegovina is exposed to 16 % demand curtailment, SLID is the interconnection with Serbia and, without any other interconnection, Bosnia and Herzegovina cannot mitigate its demand curtailment.
- Lithuania shows 30 % demand curtailment, SLID corresponds to the Klaipėda LNG terminal and there are infrastructure limitations with Poland and Latvia.
- Slovenia is exposed to 25 % demand curtailment, SLID corresponds to the interconnection with Austria and the only interconnection left with Italy cannot satisfy the demand.
- Greece is exposed to 22 % demand curtailment, SLID corresponds to Agia Triada terminal and interconnections with Trans Adriatic Pipeline and with Bulgaria are not enough to mitigate Greece demand curtailment.
- Luxembourg is exposed to 19 % demand curtailment, SLID corresponds to Belgium interconnection and the one with Germany shows a bottleneck.
- Northern Ireland is exposed to 97 % demand curtailment due to SLID Ireland (Moffat), without any other interconnections.
- Ireland is exposed to 90 % demand curtailment due to SLID (Moffat).
- North Macedonia is exposed to 88 % demand curtailment, SLID is the interconnection with Greece and there are no other options to meet its demand.
- Croatia shows 50 % demand curtailment, SLID is the Croatia LNG terminal and the interconnections with Slovenia and Hungary show infrastructure limitations.
- Sweden shows 36 % demand curtailment, SLID is their only interconnection with Denmark.
- Poland is exposed to 2 % demand curtailment, SLID is Baltic pipe interconnection and the other interconnections cannot mitigate Poland demand curtailment.
- Denmark is exposed to 3 % demand curtailment, SLID is North Sea Entry interconnection (imports from Norway) and the other interconnections with Poland and Germany (with repurposed infrastructure) cannot mitigate Denmark demand curtailment.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, due to higher hydrogen production using methane, all countries already curtailed in H_2 Infrastructure level 1 increase their demand curtailment and countries not curtailed show 2 % to 4 % demand curtailment.

In **Distributed Energy** scenario, demand curtailment values remain unchanged for most of the countries. Demand curtailment is mitigated in Bulgaria, Romania, Serbia and Sweden due to additional flexibility on the hydrogen infrastructure and less hydrogen production using methane. Demand curtailment increases in Greece and Luxembourg due to infrastructure limitations and the need of more hydrogen production.

In **Global Ambition** scenario, demand curtailment values remain unchanged for most of the countries. Demand curtailment is mitigated in Bulgaria, Romania, Greece, Croatia, North Macedonia, Serbia and Sweden due to additional flexibility on the hydrogen infrastructure and less hydrogen production using methane. Demand curtailment increases in Denmark, Poland, United Kingdom and Luxembourg due to infrastructure limitations and the need of more hydrogen production.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, most of the countries show no demand curtailment. Some countries show demand curtailment due to infrastructure limitations and to hydrogen production using methane.

- Slovenia is exposed to 15 % demand curtailment, SLID corresponds to the interconnection with Austria and the only interconnection left with Italy cannot satisfy the demand.
- Bosnia and Herzegovina is exposed to 16 % demand curtailment, SLID is the interconnection with Serbia and, without any other interconnection, Bosnia and Herzegovina cannot mitigate its demand curtailment.
- Croatia shows 40 % demand curtailment, SLID is the Croatia LNG terminal and the interconnections with Slovenia and Hungary show infrastructure limitations (bottlenecks).
- Northern Ireland is exposed to 100 % demand curtailment due to SLID Ireland (Moffat), without any other interconnections.
- Ireland is exposed to 78 % demand curtailment due to SLID (Moffat).
- North Macedonia is exposed to 100 % demand curtailment, SLID is the interconnection with Greece and there are no other options to meet its demand.

In **H_2 Infrastructure level 1 Global Ambition** scenario, most of the countries show no demand curtailment. Some countries show demand curtailment due to infrastructure limitations and to hydrogen production using methane.

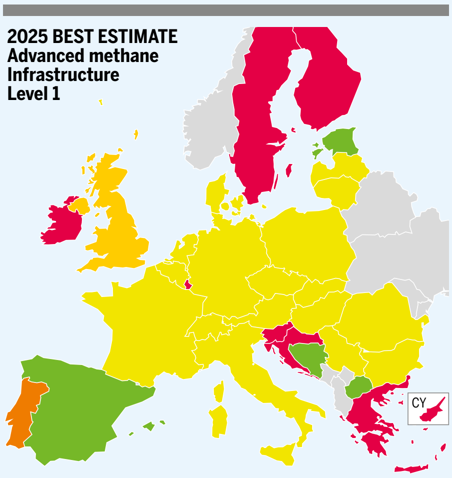
- Bosnia and Herzegovina is exposed to 16 % demand curtailment, SLID is the interconnection with Serbia and, without any other interconnection, Bosnia and Herzegovina cannot mitigate its demand curtailment.
- Croatia shows 64 % demand curtailment, SLID is the Croatia LNG terminal and the interconnections with Slovenia and Hungary show infrastructure limitations.
- Northern Ireland is exposed to 100 % demand curtailment due to SLID Ireland (Moffat), without any other interconnections.
- Ireland is exposed to 79 % demand curtailment due to SLID (Moffat).
- North Macedonia is exposed to 100 % demand curtailment, SLID is the interconnection with Greece and there are no other options to meet its demand.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, some countries not curtailed in H_2 Infrastructure level 1 show now curtailment due to higher hydrogen production using methane: Bulgaria, Greece, Luxembourg, Romania and Serbia.

In **Global Ambition** scenario, some countries not curtailed in H_2 Infrastructure level 1 show now curtailment due to higher hydrogen production using methane: Bulgaria, Greece, Spain, Luxembourg, Romania and Serbia.

Due to additional interconnection in H_2 Infrastructure level 2 and less hydrogen production using methane, Croatia, North Macedonia and Sweden mitigate their demand curtailment.



13.2 ADVANCED INFRASTRUCTURE (METHANE RESULTS)

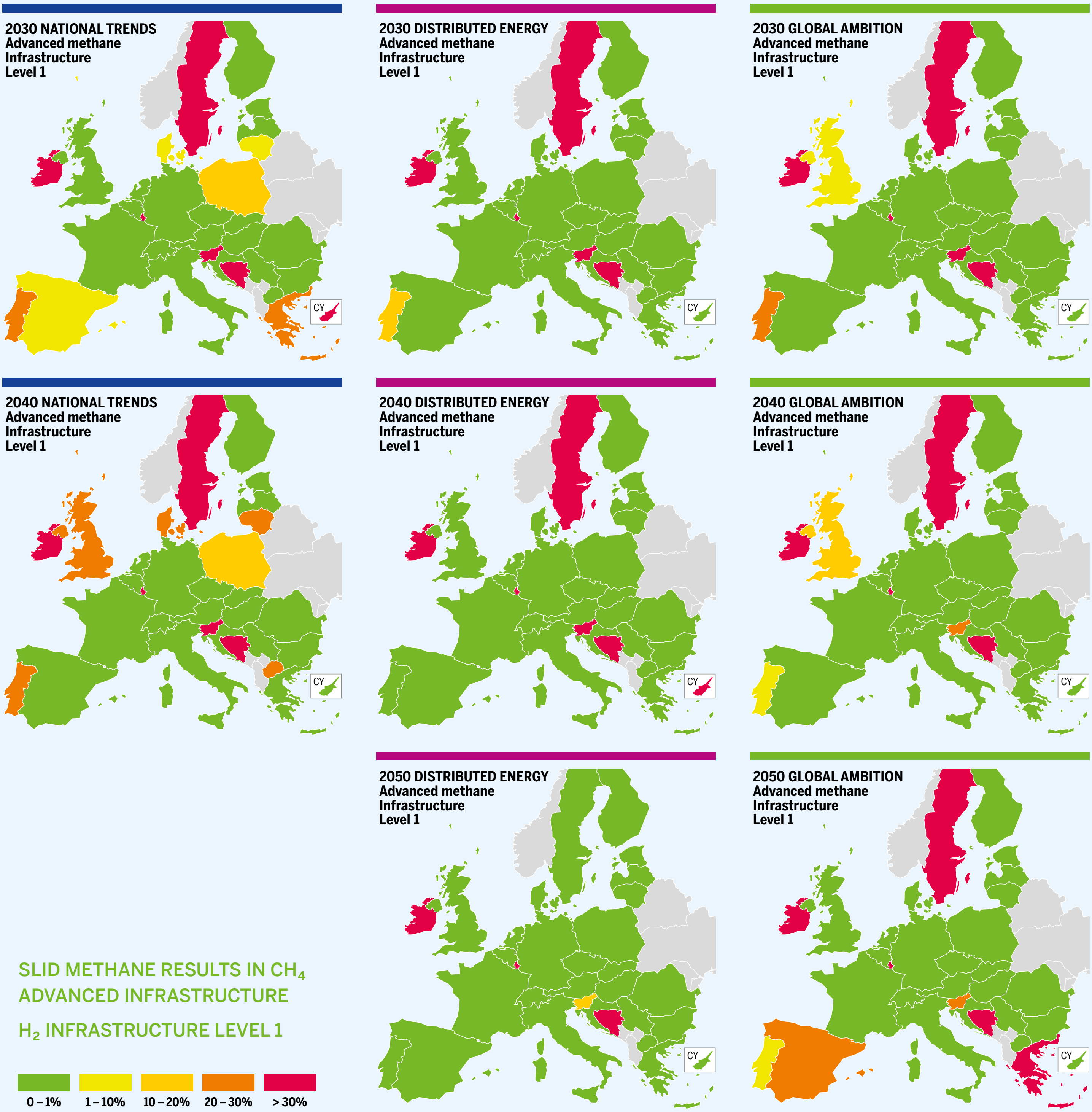


Figure 13.3 Methane SLID Results for Peak Demand in Advanced CH_4 Infrastructure with H_2 Level 1

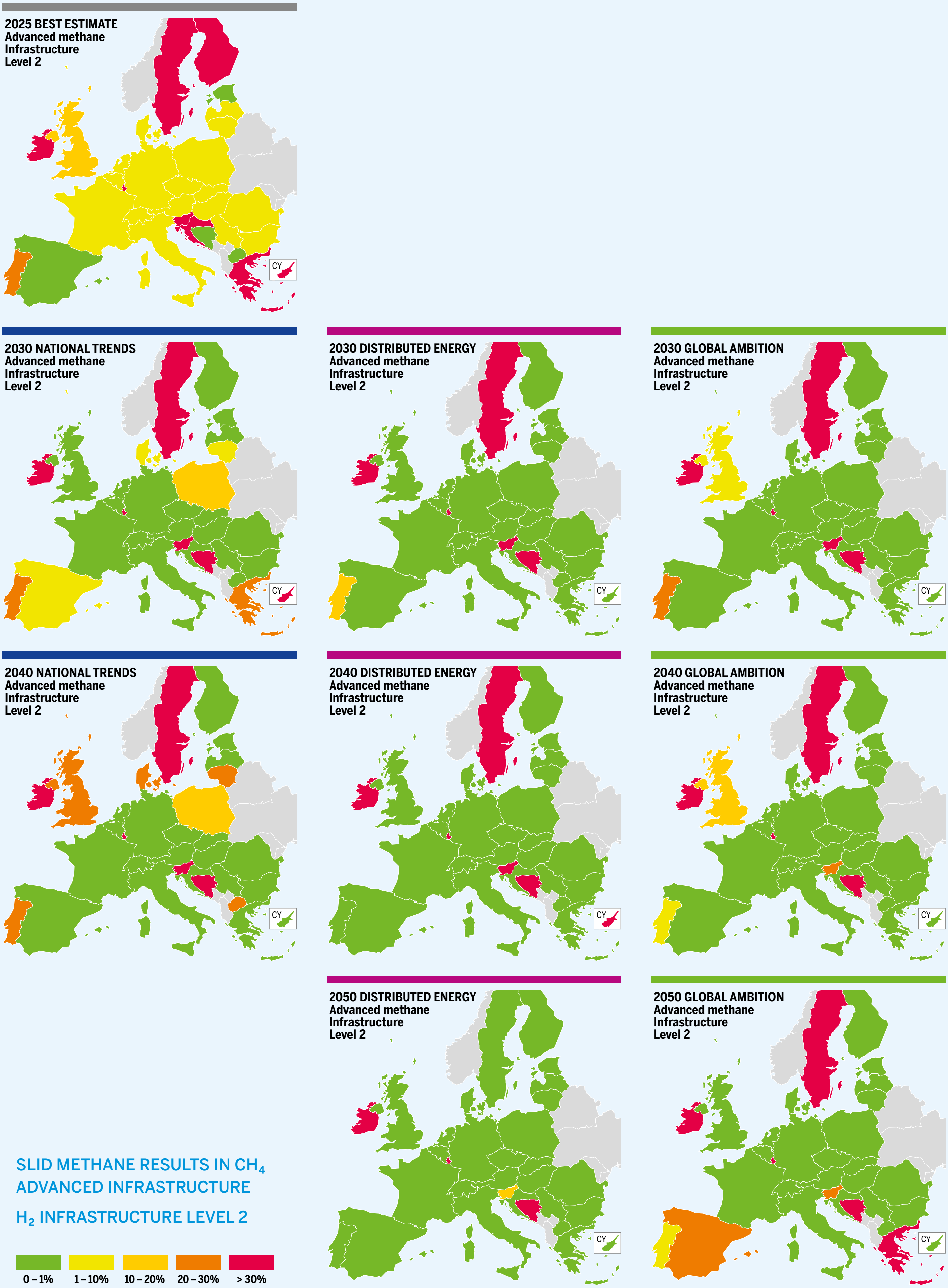


Figure 13.4 Methane SLID Results for Peak Demand in Advanced CH_4 Infrastructure with H_2 Level 2

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

In **Best Estimate** scenario, situation remains unchanged for some countries (Germany, Estonia, France, Italy, Portugal, Czech Republic, Poland, Serbia and Northern Ireland). In Advanced Infrastructure level, additional infrastructure and capacities mitigate demand curtailment in some countries (Denmark, Greece, Hungary, Lithuania, Latvia, North Macedonia and The Netherlands) and some countries increased their demand curtailment due to repurposed infrastructure (Austria, Belgium, Bulgaria, Switzerland, Finland, Croatia, Ireland, Luxembourg, Romania, Sweden, Slovenia, Slovakia and United Kingdom).

H_2 INFRASTRUCTURE LEVEL 2

In **Best Estimate** scenario, situation remains unchanged for most of the countries, only Bulgaria fully mitigates its demand curtailment and Germany, Hungary and The Netherlands decrease by 1 % their demand curtailment due to more hydrogen production using methane.

2030

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, all countries mitigate their demand curtailment except for Bosnia and Herzegovina (+6 %), Luxembourg (+6 %), Sweden (+6 %) and Slovenia (+5 %). These countries have no benefits in advanced and cooperate more with other countries.

In **Distributed Energy** scenario, situation worsens in Bosnia and Herzegovina with more impact for the SLID Bosnia. Most of the countries are not impacted by the Advanced Infrastructure level and some countries fully mitigate their demand curtailment due to additional flexibility (Bulgaria, Estonia, Finland, Greece, Lithuania, Latvia, North Macedonia, Romania and Serbia).

In **Global Ambition** scenario, situation worsens in Bosnia and Herzegovina with more impact for the SLID Bosnia. Most of the countries are not impacted by the Advanced Infrastructure level and many countries fully mitigate their demand curtailment due to additional flexibility (Bulgaria, Czech Republic, Germany, Denmark, Estonia, Finland, Greece, Croatia, Hungary, Lithuania, Italy, Latvia, The Netherlands, North Macedonia, Poland, Romania, Slovakia, United Kingdom and Serbia) due to the projects in advanced and additional flexibility.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, situation remains unchanged compared to H_2 Infrastructure level 1.

In **Distributed Energy** scenario, situation remains unchanged compared to H_2 Infrastructure level 1.

In **Global Ambition** scenario, situation remains unchanged compared to H_2 Infrastructure level 1.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, for most of the countries, the situation remains unchanged. Some countries improved the situation due to the additional flexibility in Advanced Infrastructure level: Bulgaria, Greece, Croatia and Serbia fully mitigate demand curtailment. Some countries partially mitigate their demand curtailment: Denmark, Lithuania and North Macedonia.

In **Distributed Energy** scenario, the situation remains unchanged for most of the countries. Situation worsens in Bosnia and Herzegovina with more impact for the SLID Bosnia. Bulgaria, Greece, Croatia, Lithuania, North Macedonia, Romania and Serbia fully mitigate their demand curtailment due to the additional flexibility in advanced.

In **Global Ambition** scenario, the situation remains unchanged for most of the countries. Situation worsens in Bosnia and Herzegovina with more impact for the SLID Bosnia. Bulgaria, Denmark, Greece, Croatia, Lithuania, North Macedonia, Poland, Romania and Serbia fully mitigate their demand curtailment due to the additional flexibility in advanced.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, situation remains unchanged compared to H_2 Infrastructure level 1.

In **Distributed Energy** scenario, situation remains unchanged compared to H_2 Infrastructure level 1.

In **Global Ambition**, situation remains unchanged compared to H_2 Infrastructure level 1 except for in Portugal now exposed to 2 % demand curtailment due to infrastructure limitation with Spain and additional hydrogen production using methane.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, the situation remains unchanged for most of the countries. Situation worsens in Bosnia and Herzegovina with more impact for the SLID Bosnia. Croatia, and North Macedonia fully mitigate demand curtailment due to the additional flexibility in advanced.

In **Global Ambition** scenario, the situation remains unchanged for most of the countries. Situation worsens in Bosnia and Herzegovina with more impact for the SLID Bosnia. Croatia, and North Macedonia fully mitigate demand curtailment due to the additional flexibility in advanced.

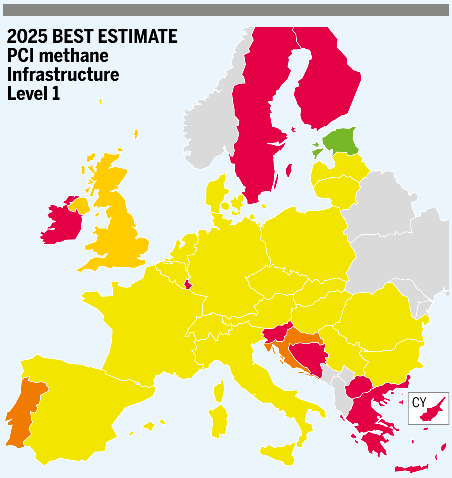
H_2 INFRASTRUCTURE LEVEL 2

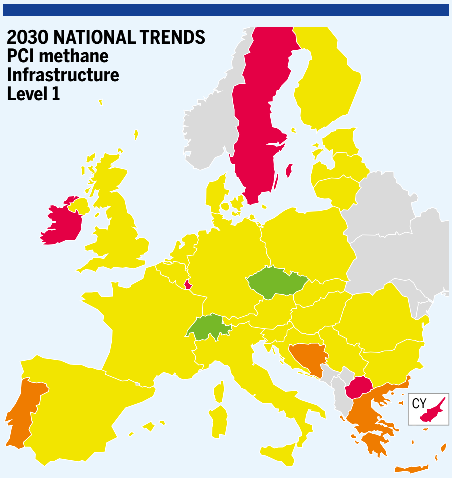
In **Global Ambition** scenario, situation remains unchanged compared to H_2 Infrastructure level 1.

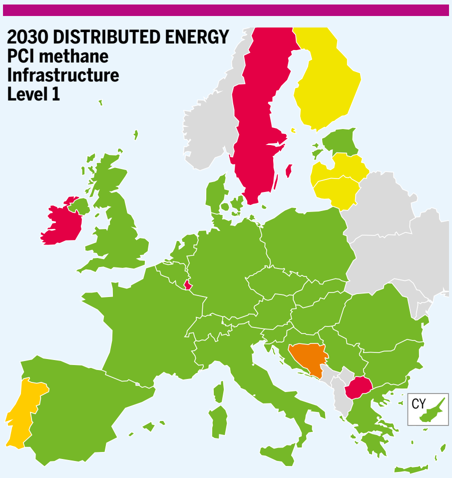
In **Distributed Energy** scenario, situation also remains unchanged.

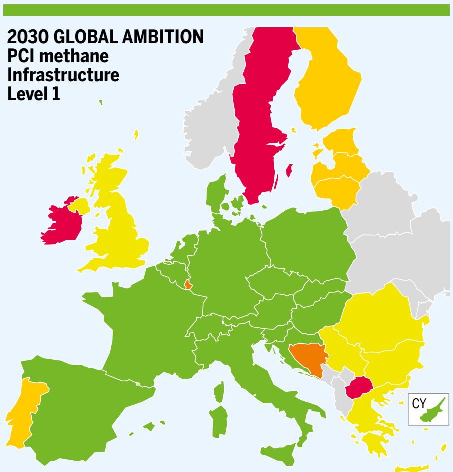

Picture courtesy of Gas Connect Austria

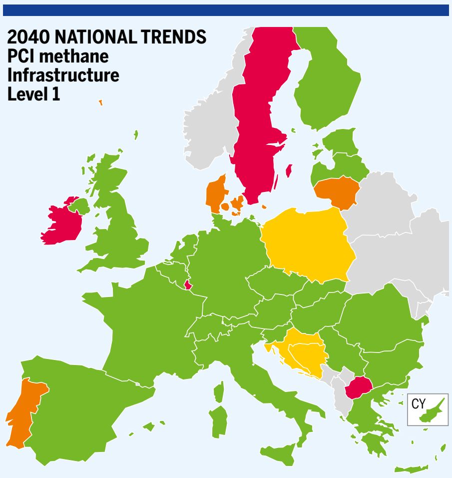
13.3 PCI INFRASTRUCTURE (METHANE RESULTS)

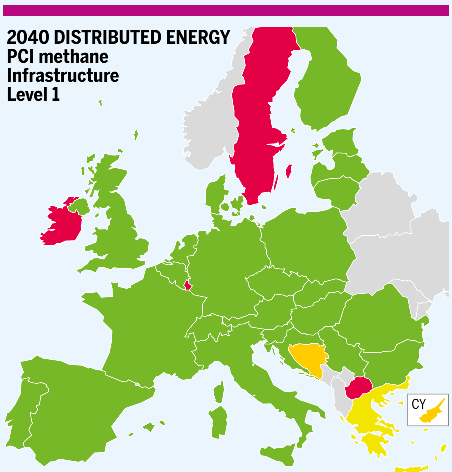


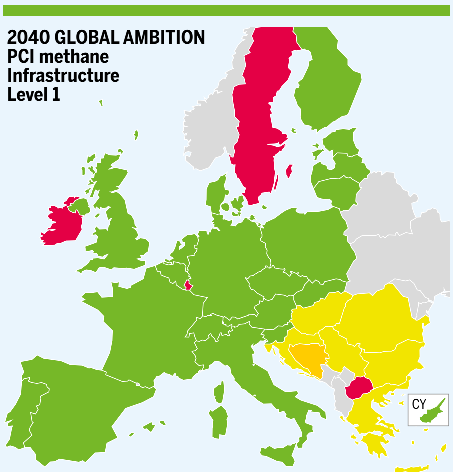






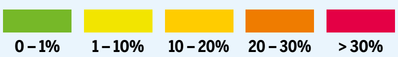


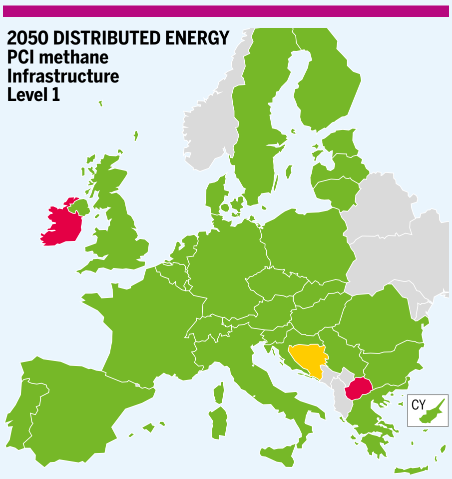




SLID METHANE RESULTS IN CH_4
PCI INFRASTRUCTURE

H_2 INFRASTRUCTURE LEVEL 1





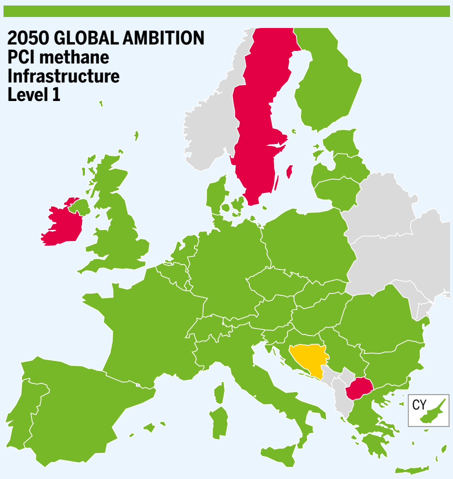


Figure 13.5 Methane SLID Results for Peak Demand in PCI CH_4 Infrastructure with H_2 Level 1

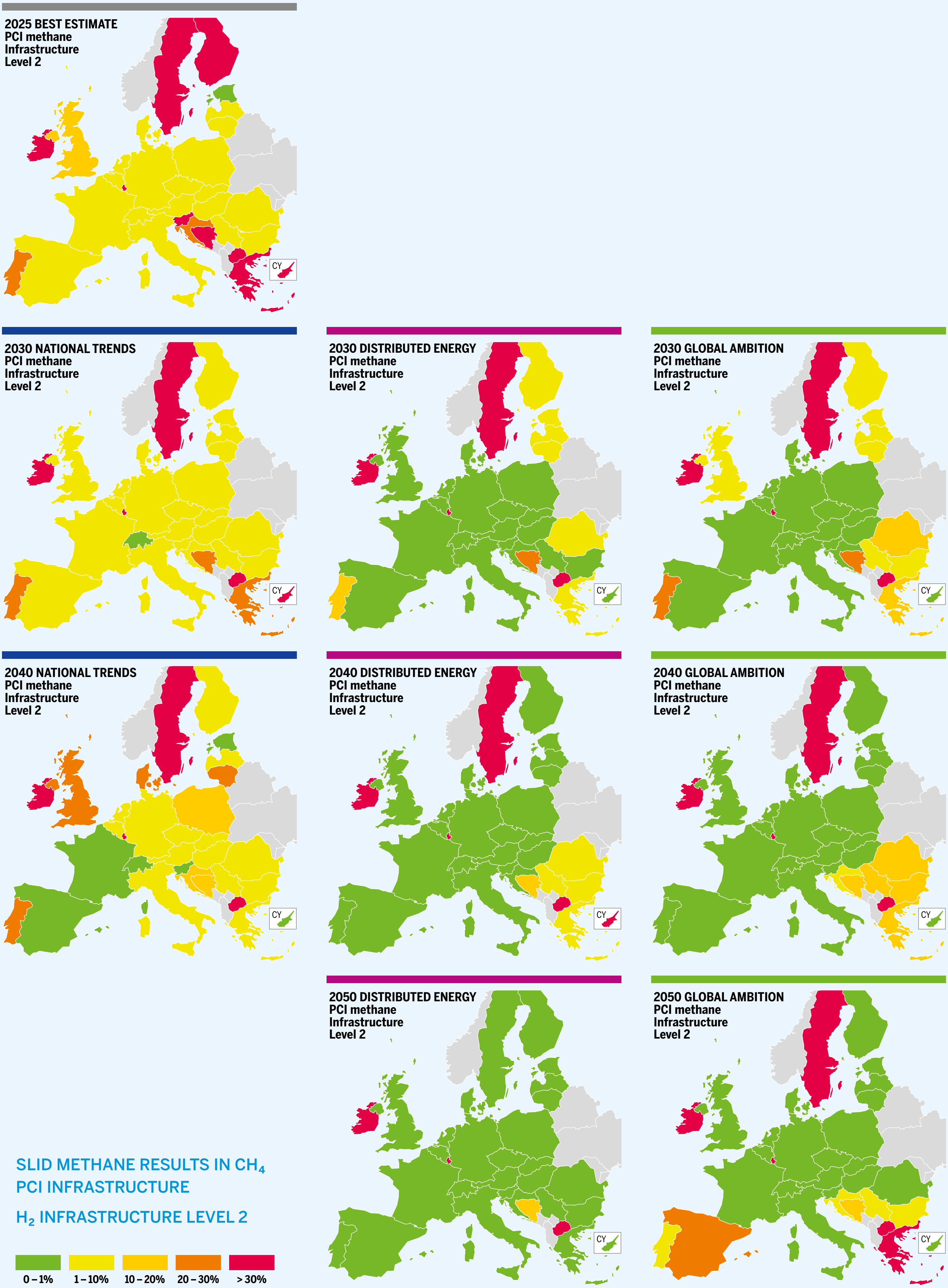


Figure 13.6 Methane SLID Results for Peak Demand in PCI CH_4 Infrastructure with H_2 Level 2

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

In **Best Estimate** scenario, situation remains unchanged for most of the countries. In PCI Infrastructure level, additional infrastructure and capacities mitigate demand curtailment in some countries (Greece, Hungary and Lithuania) and some countries increase their demand curtailment due to repurposed infrastructure (Finland, Croatia, Ireland, Luxembourg, Sweden, Slovenia and United Kingdom).

H_2 INFRASTRUCTURE LEVEL 2

In **Best Estimate** scenario, situation remains unchanged for all countries.

2030

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, most of the countries decrease their demand curtailment, some countries are stable (Bosnia and Herzegovina, Switzerland, Ireland, The Netherlands, Portugal and Northern Ireland). Finland, France, Luxembourg, North Macedonia and Sweden increased their curtailment dur to more cooperation.

In **Distributed Energy** scenario, all countries show same results or some improvement except for North Macedonia.

In **Global Ambition** scenario, all countries show same results or some improvement except for North Macedonia.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, situation remains unchanged or Demand curtailment is increased by 1–2 % due to more hydrogen production using methane.

In **Distributed Energy** scenario, situation remains unchanged or Demand curtailment is increased by 1–2 % due to more hydrogen production using methane.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, all countries show same results or some improvement.

In **Distributed Energy** scenario, all countries show same results or some improvement except for North Macedonia.

In i**Global Ambition** scenario, all countries show same results or some improvement except for North Macedonia.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, most of the countries show same results and some countries show increased curtailment, due to more hydrogen production using methane, except for in Hungary and Sweden with repurposed infrastructure.

In **Distributed Energy** scenario, situation remains unchanged.

In **Global Ambition** scenario, situation remains unchanged.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, all countries show same results or some improvement.

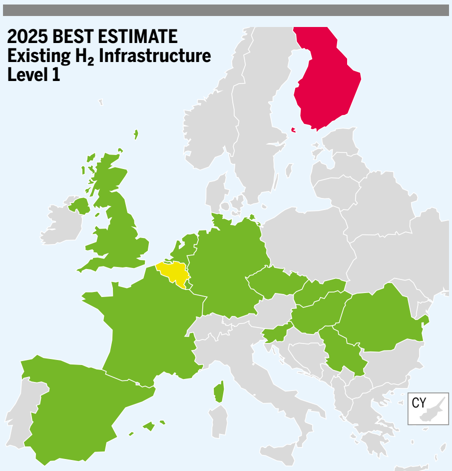
In **Global Ambition** scenario, all countries show same results or some improvement except for North Macedonia.

H_2 INFRASTRUCTURE LEVEL 2

In **Global Ambition** scenario, situation remains unchanged.

In **Distributed Energy** scenario, situation remains unchanged.

13.4 EXISTING INFRASTRUCTURE LEVEL (HYDROGEN RESULTS)



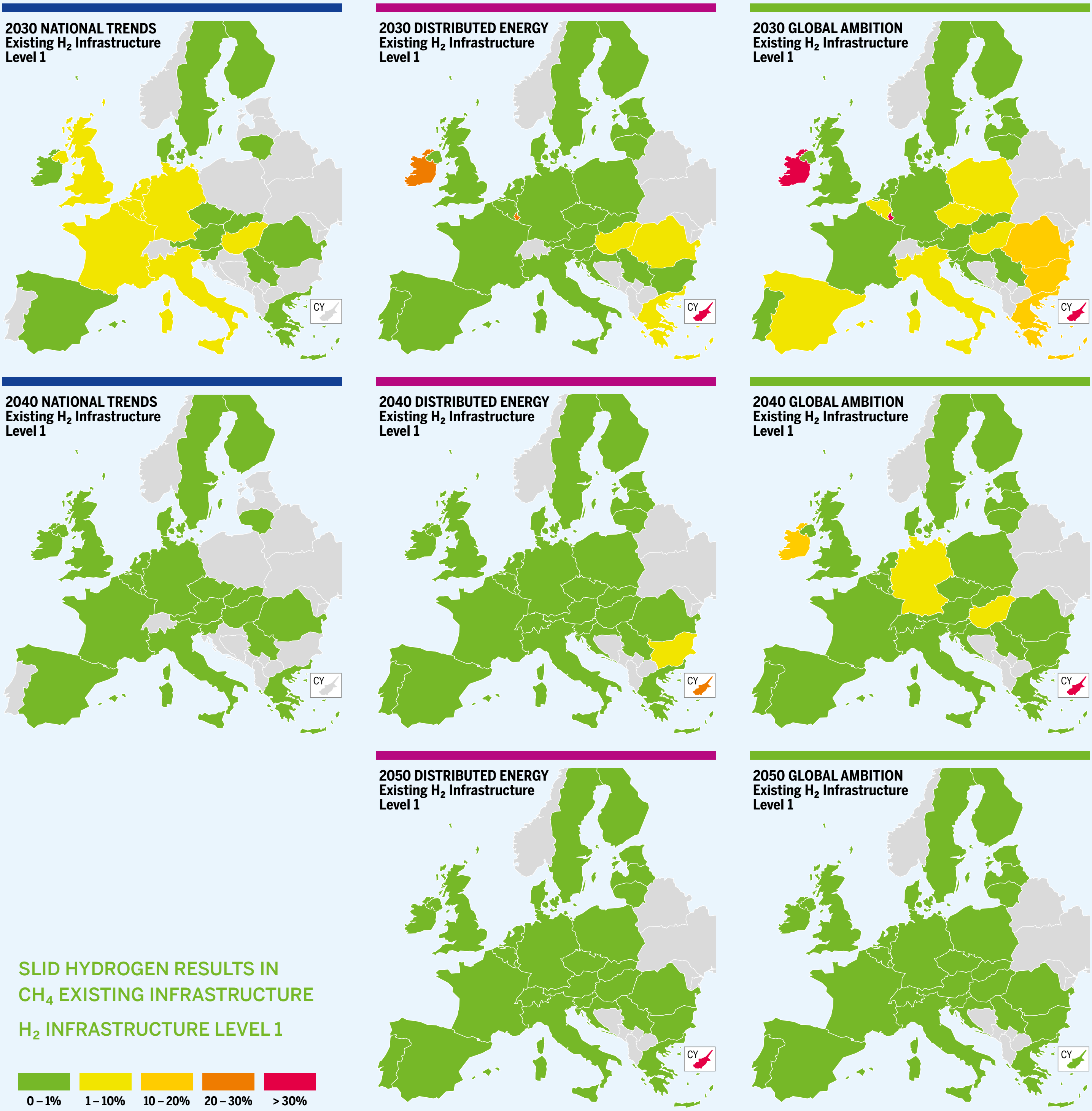


Figure 13.7 Hydrogen SLID Results for Peak Demand in Existing CH_4 Infrastructure with H_2 Level 1

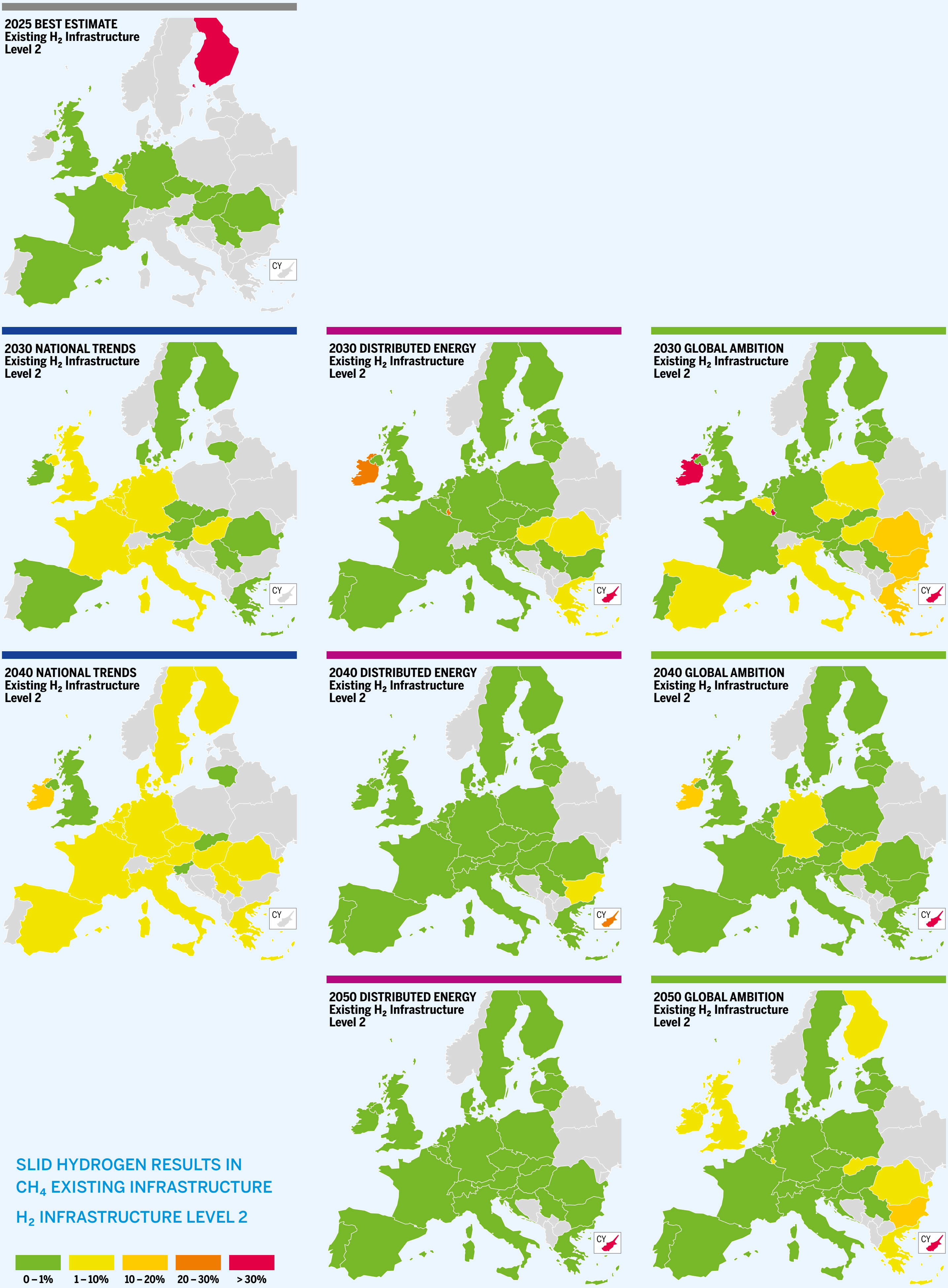


Figure 13.8 Hydrogen SLID Results for Peak Demand in Existing CH_4 Infrastructure with H_2 Level 2

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 1

In **Best Estimate** scenario, all countries show no impact on demand curtailment as there is no hydrogen production using methane.

H_2 INFRASTRUCTURE LEVEL 2

In **Best Estimate** scenario, only Belgium and Finland show respectively 3 % and 33 % demand curtailment due to more hydrogen production using methane.

2030

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** all countries show no impact on demand curtailment as there in no hydrogen production using methane in this scenario.

In **Distributed Energy** scenario, all countries show no impact on demand curtailment except for Germany with 1 % more due to higher hydrogen production using methane.

In **Global Ambition** scenario, most of the countries show no demand curtailment. Some countries show demand curtailment (Germany, Italy, Poland, Belgium) 1 %, (Greece, Hungary, Romania and Bulgaria) due to hydrogen production using methane.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, most of the countries show same results. Some countries increase their demand curtailment due to higher hydrogen production using methane (Italy, Hungary, Germany, The Netherlands, Belgium, France) 2 %, United Kingdom 7 % and Luxembourg 17 %.

In **Distributed Energy** scenario, most of the countries show same results. Some countries increase their demand curtailment due to higher hydrogen production using methane (Germany, Sweden, The Netherlands, Hungary, Greece, Romania) 2 %, Luxembourg 16 % and Ireland 28 %.

In **Global Ambition** scenario, most of the countries show no demand curtailment. Some countries show demand curtailment (France, Austria, Germany, The Netherlands, Poland, Czech Republic, Belgium, Spain, Italy) 1 %, Hungary 9 %, (Romania, Greece, Bulgaria) 11 %, Luxembourg, 21 % and Ireland 34 % due to more hydrogen production using methane.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, all countries show no impact on demand curtailment due to no hydrogen production using methane.

In **Distributed Energy** scenario, all countries show no impact on demand curtailment except for in Greece and France with 1 % due to hydrogen production using methane.

In **Global Ambition** scenario, all countries show no impact on demand curtailment.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, most of the countries show demand curtailment except for United Kingdom, Lithuania, Slovenia and Slovakia. Some countries increase their demand curtailment due to hydrogen production using methane (Serbia, Denmark, Greece, Finland, Italy, Czech Republic, Hungary, Sweden, Austria, Belgium, Germany, The Netherlands, Spain, Romania, France) 3 %, Ireland 12 % and Luxembourg 13 %.

In **Distributed Energy** scenario, most of the countries show same results (no curtailment). Some countries increase their demand curtailment due to higher hydrogen production using methane (Czech Republic, Spain, Greece, Bulgaria) 1 %.

In **Global Ambition** scenario, most of the countries show same results (no curtailment). Some countries increase their demand curtailment due to higher hydrogen production using methane (Germany and Hungary) 1 % and Ireland 19 %.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, all countries show no impact on demand curtailment.

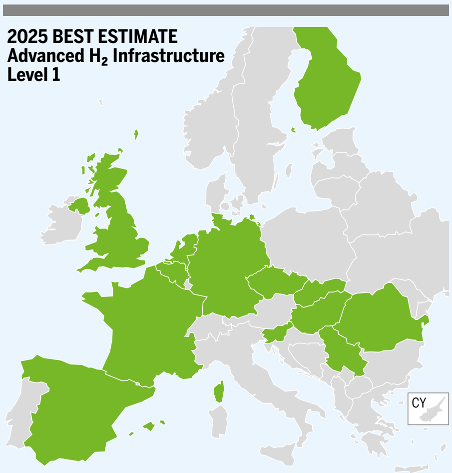
In **Global Ambition** scenario, all countries show no impact on demand curtailment.

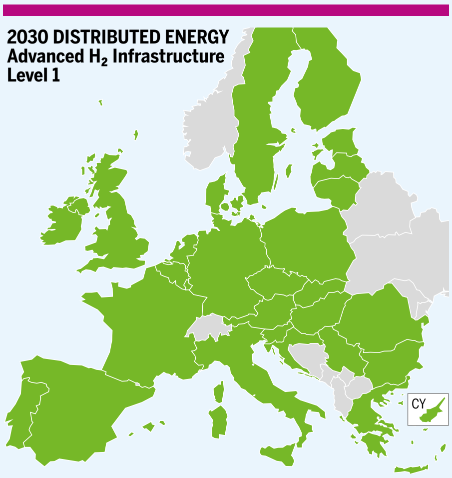
H_2 INFRASTRUCTURE LEVEL 2

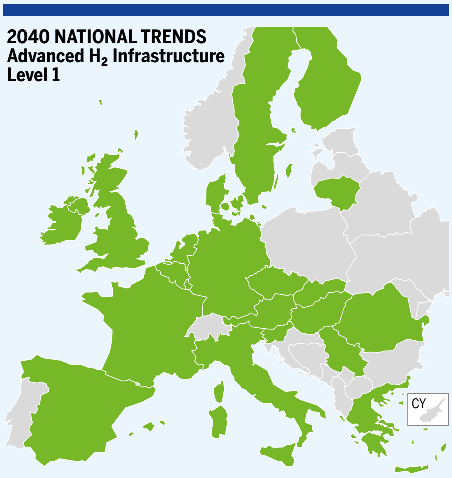
In **Distributed Energy** scenario, results remain unchanged.

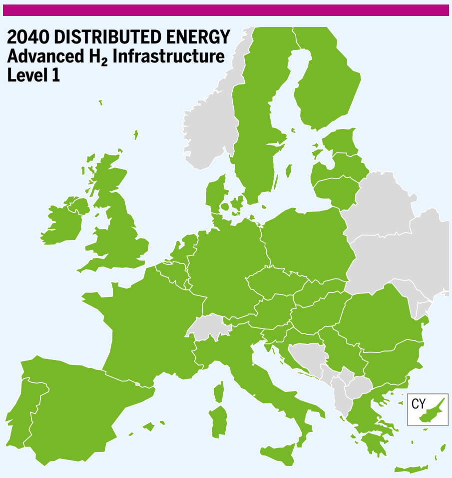
In **Global Ambition** scenario, most of the countries show same results (no curtailment). Some countries increase their demand curtailment due to higher hydrogen production using methane (The Netherlands, Slovakia, Finland, United Kingdom) 1 %, Ireland 5 %, Luxembourg 7 %, Greece and Bulgaria 10 %.

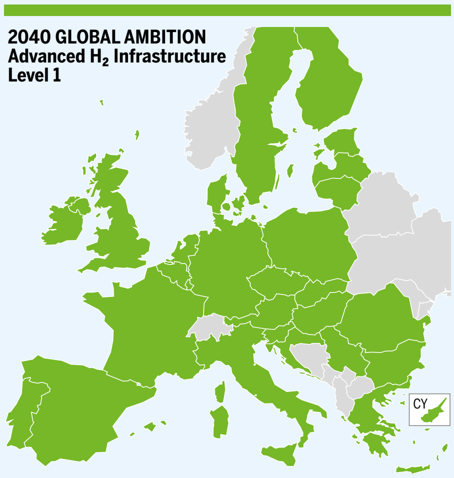
13.5 ADVANCED INFRASTRUCTURE LEVEL (HYDROGEN RESULTS)







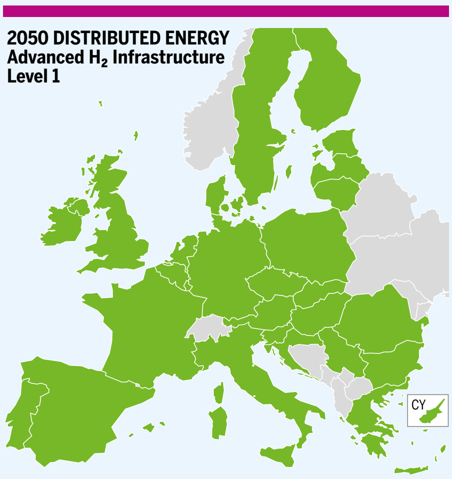




SLID HYDROGEN RESULTS IN CH_4 ADVANCED INFRASTRUCTURE

H_2 INFRASTRUCTURE LEVEL 1

0–1% | 1–10% | 10–20% | 20–30% | > 30%



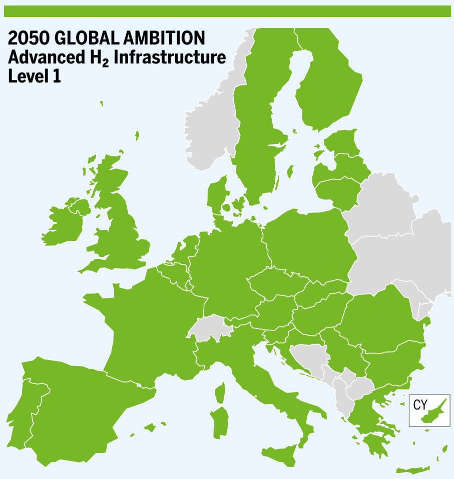


Figure 13.9 Hydrogen SLID Results for Peak Demand in Advanced CH_4 Infrastructure with H_2 Level 1

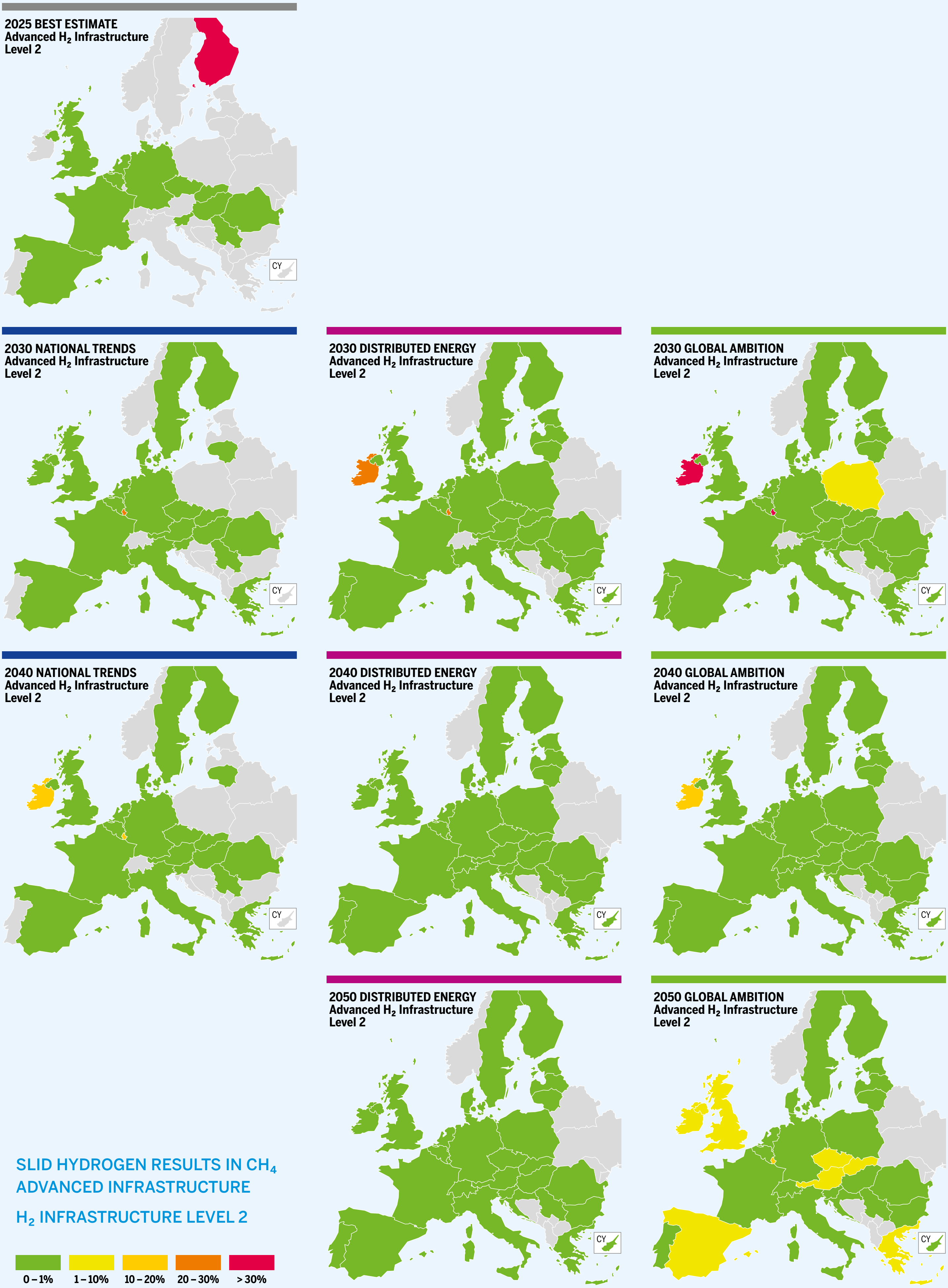


Figure 13.10 Hydrogen SLID Results for Peak Demand in Advanced CH_4 Infrastructure with H_2 Level 2

H_2 INFRASTRUCTURE LEVEL 1

In **infrastructure level 1**, situation is improved in all scenarios and Years. Only Spain shows 1 % demand curtailment in 2030 in **Global Ambition** scenario.

2030

H_2 INFRASTRUCTURE LEVEL 2

In **infrastructure level 2**, situation remains unchanged for most scenarios and Years.

In **Distributed Energy** scenario, Ireland and Luxembourg show 28 % and 16 % demand curtailment due to higher hydrogen production using methane.

In **Global Ambition** scenario, Ireland, Luxembourg and Poland show respectively 34 %, 21 % and 1 % demand curtailment due to higher hydrogen production using methane.

2040

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, Ireland shows 13 % demand curtailment due to higher hydrogen production using methane.

In **Global Ambition** scenario, Ireland shows 19 % demand curtailment due to higher hydrogen production using methane.

2050

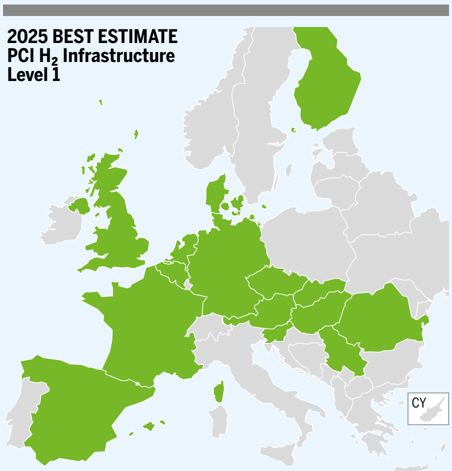
H_2 INFRASTRUCTURE LEVEL 2

In **Global Ambition** scenario, some countries show 1 % demand curtailment (Greece, Hungary, Austria, Czech Republic and Spain) United Kingdom 2 % and Ireland 7 % due to higher hydrogen production using methane.

.

Picture courtesy of TAP

13.6 PCI INFRASTRUCTURE LEVEL (HYDROGEN RESULTS)



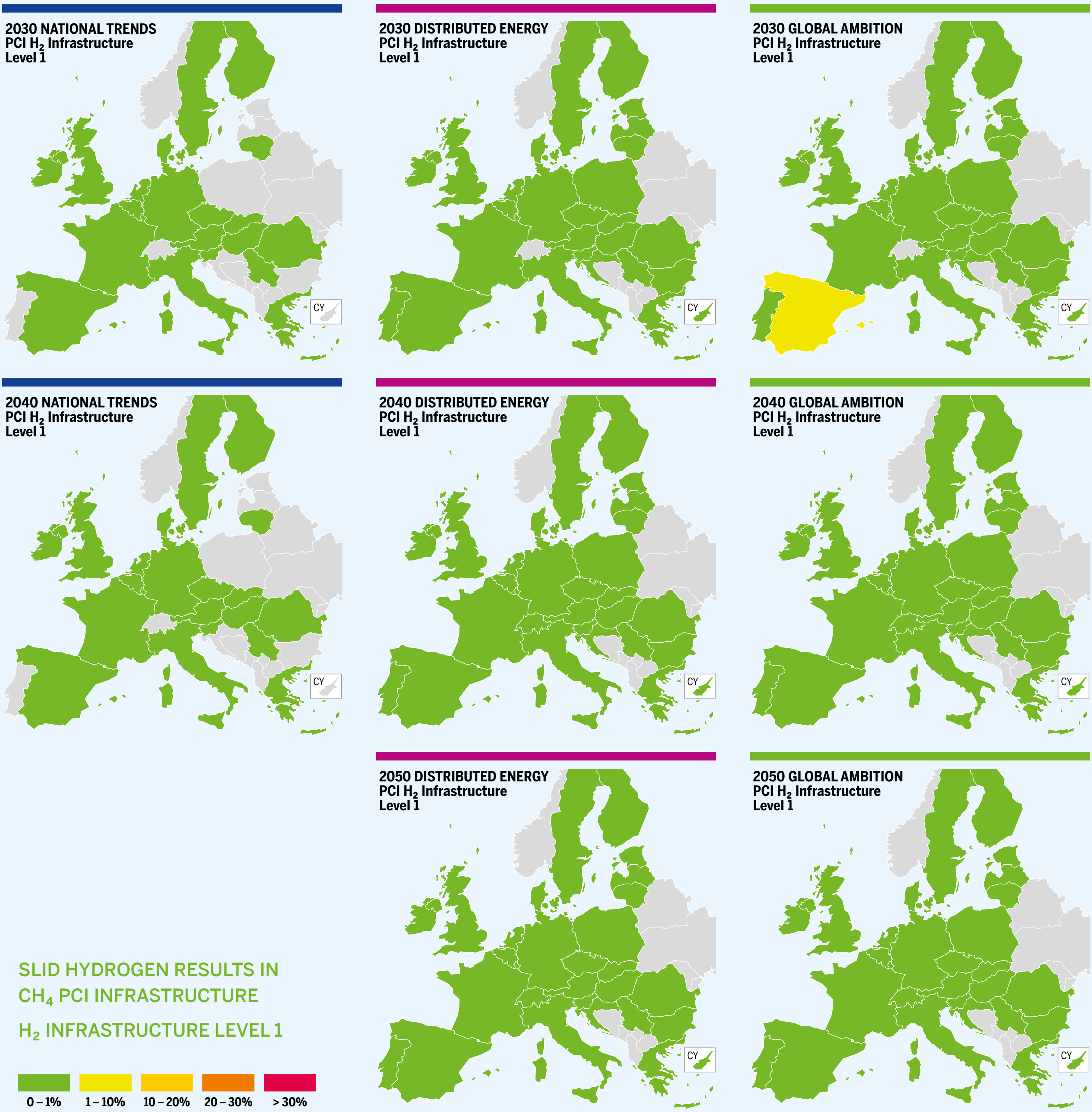


Figure 13.11 Hydrogen SLID Results for Peak Demand in PCI CH_4 Infrastructure with H_2 Level 1

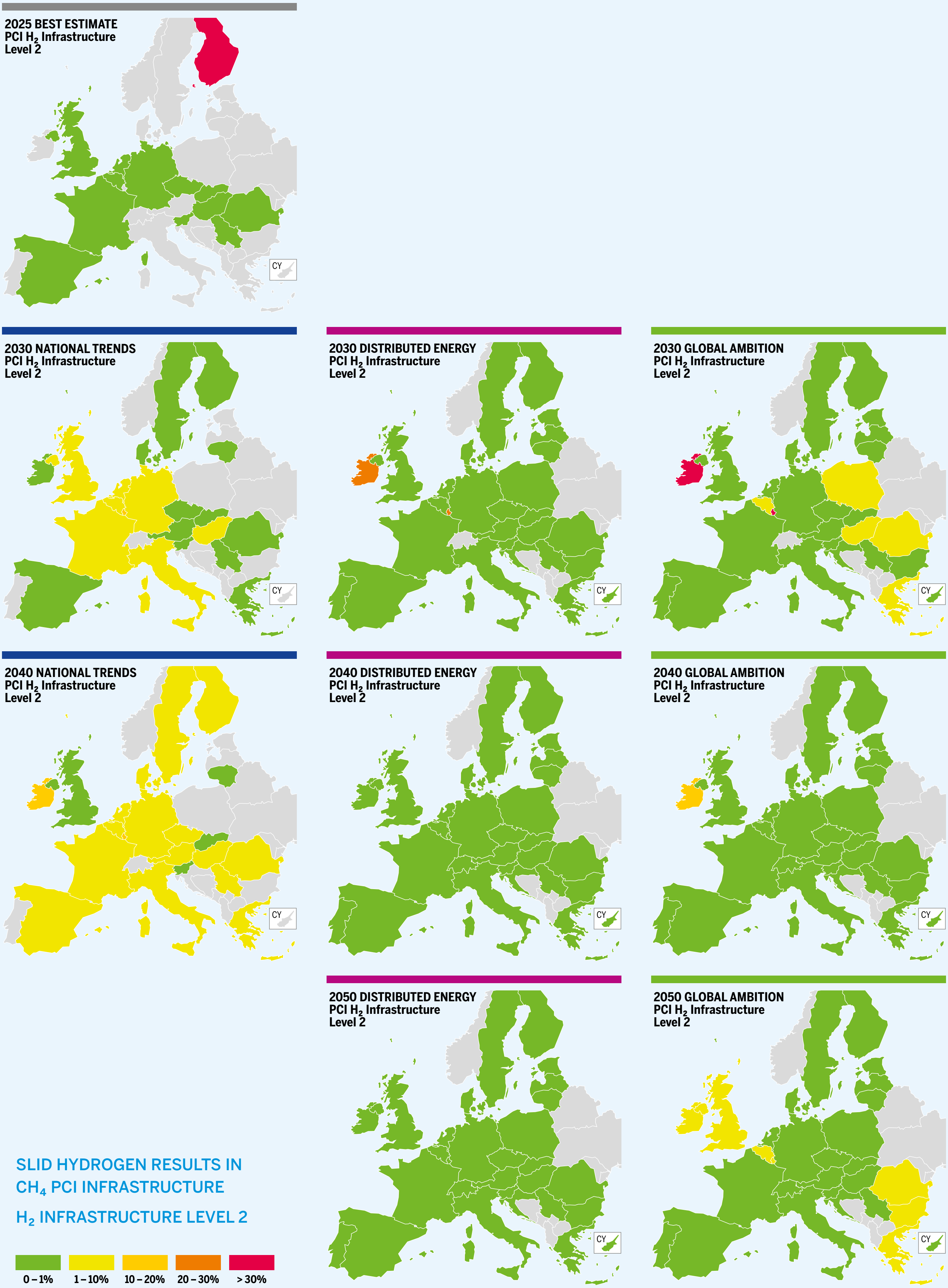


Figure 13.12 Hydrogen SLID Results for Peak Demand in PCI CH_4 Infrastructure with H_2 Level 2

H_2 INFRASTRUCTURE LEVEL 1

In H_2 Infrastructure level 1, situation is improved in all scenarios and years. Only Spain shows 1 % demand curtailment in 2030 in **Global Ambition** scenario.

2025 – Best Estimate

H_2 INFRASTRUCTURE LEVEL 2

In **Best Estimate** scenario, only Finland shows now 33 % demand curtailment due to higher hydrogen production using methane and infrastructure limitation.

2030

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, results remain unchanged for most of the countries. Due to higher hydrogen production using methane, some countries increase their demand curtailment (Belgium, Hungary, Germany, The Netherlands, Italy, France) 2 %, United Kingdom 6 % and Luxembourg 17 %.

In **Distributed Energy** scenario, Ireland and Luxembourg show 28 % and 16 % demand curtailment due to higher hydrogen production using methane.

In **Global Ambition** scenario, Ireland and Luxembourg show respectively 34 % and 21 % demand curtailment and Belgium, Poland, Hungary, Romania and Greece show 1 % demand curtailment, due to higher hydrogen production using methane.

2040

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, most of the countries show now 4 % demand curtailment and Ireland 13 %. Situation remains unchanged for Lithuania, Slovakia, Slovenia and United Kingdom.

In **Distributed Energy** scenario, situation remains unchanged (no demand curtailment).

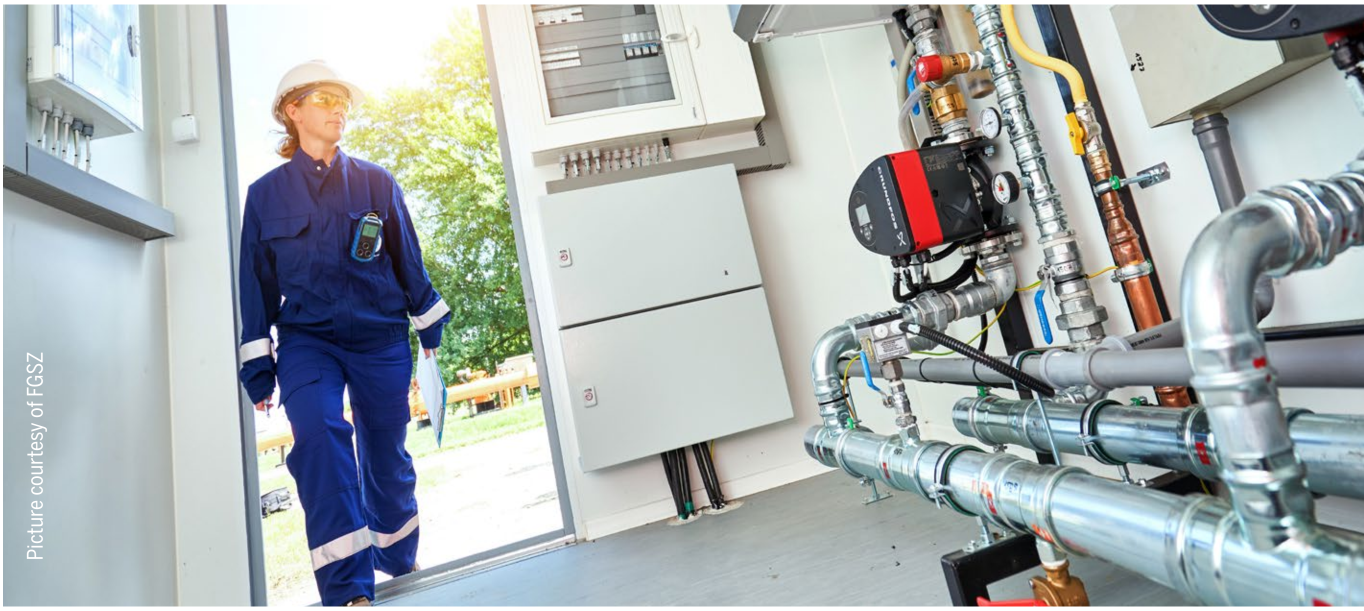
In **Global Ambition** scenario, Ireland shows now 19 % demand curtailment.

2050

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, situation remains unchanged (no demand curtailment).

In **Global Ambition** scenario, some countries show 3 % demand curtailment (Greece, Romania and Bulgaria), Belgium 1 %, United Kingdom 2 % and Ireland 7 % due to higher hydrogen production using methane.


Picture courtesy of FGSZ

14 SINGLE LARGEST CAPACITY DISRUPTION (SLCD) – HYDROGEN

This section investigates the impact of the Single Largest Capacity Disription (SLCD) of a country during a Peak day. The SLCD measures the curtailed demand following the disruption of this capacity in a given country (including storage and national production). For each country, the Single Largest Capacity depends on the year and the infrastructure level.

The table with the Single Largest Capacity considered for each country can be found in Annex D. The results presented correspond to the possible additional curtailment for a country in case of disruption of its Single Largest Capacity, and its impact on other countries, compared to the climatic stress in peak day. The demand curtailment in Peak Day without any disruption is not represented in this chapter (see Climatic Stress chapter).

SLCD is not calculated in Best Estimate scenario because in 2025 there is not hydrogen infrastructure. In National Trends scenario, H_2 infrastructure level 1, there is no impact on the methane side as there is no hydrogen production using methane (no link between the 2 infrastructures).

Picture courtesy of Reganosa

14.1 EXISTING INFRASTRUCTURE LEVEL (METHANE RESULTS)

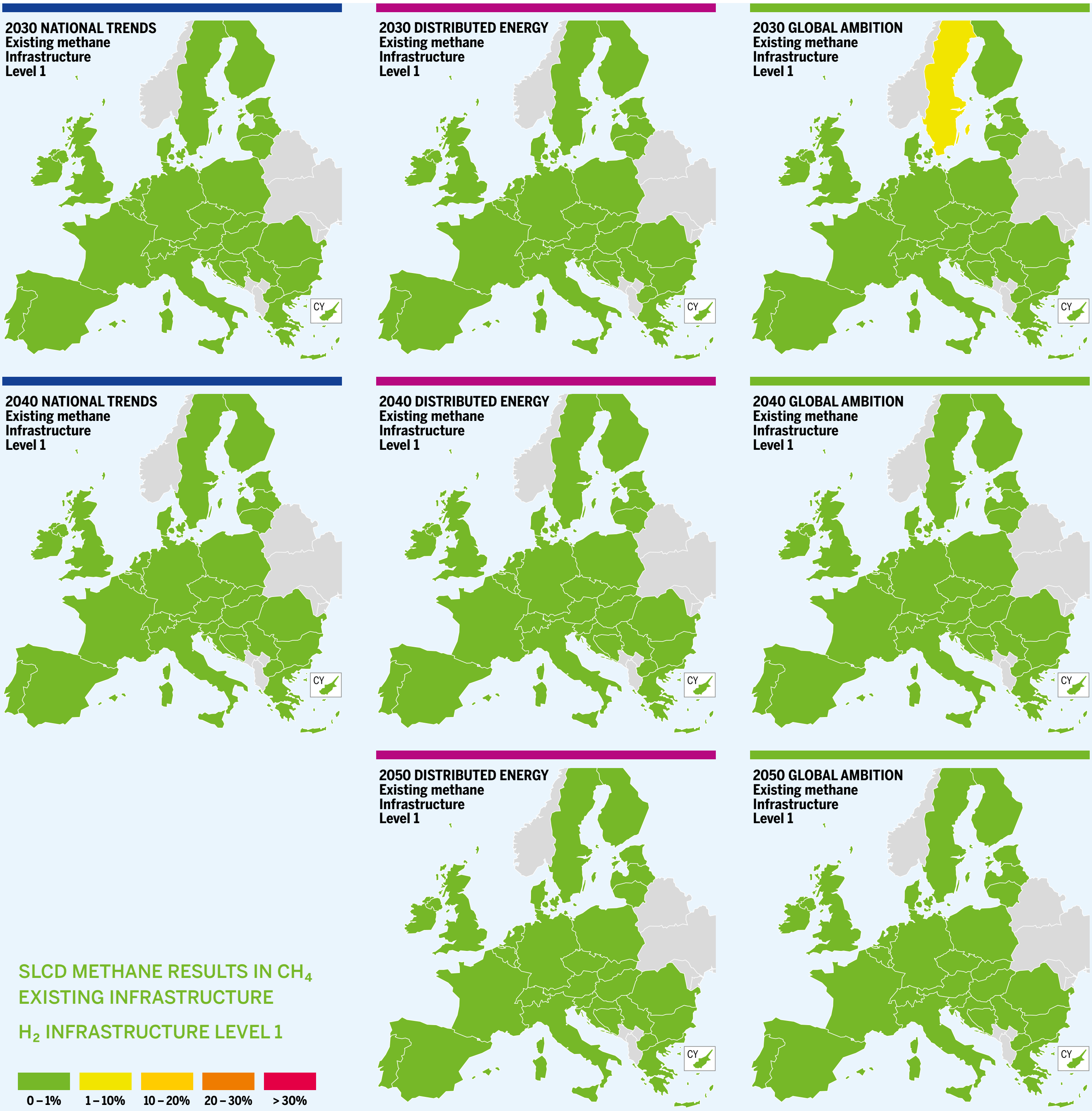


Figure 14.1 Methane SLCD Results for Peak Demand in Existing CH_4 Infrastructure with H_2 Level 1

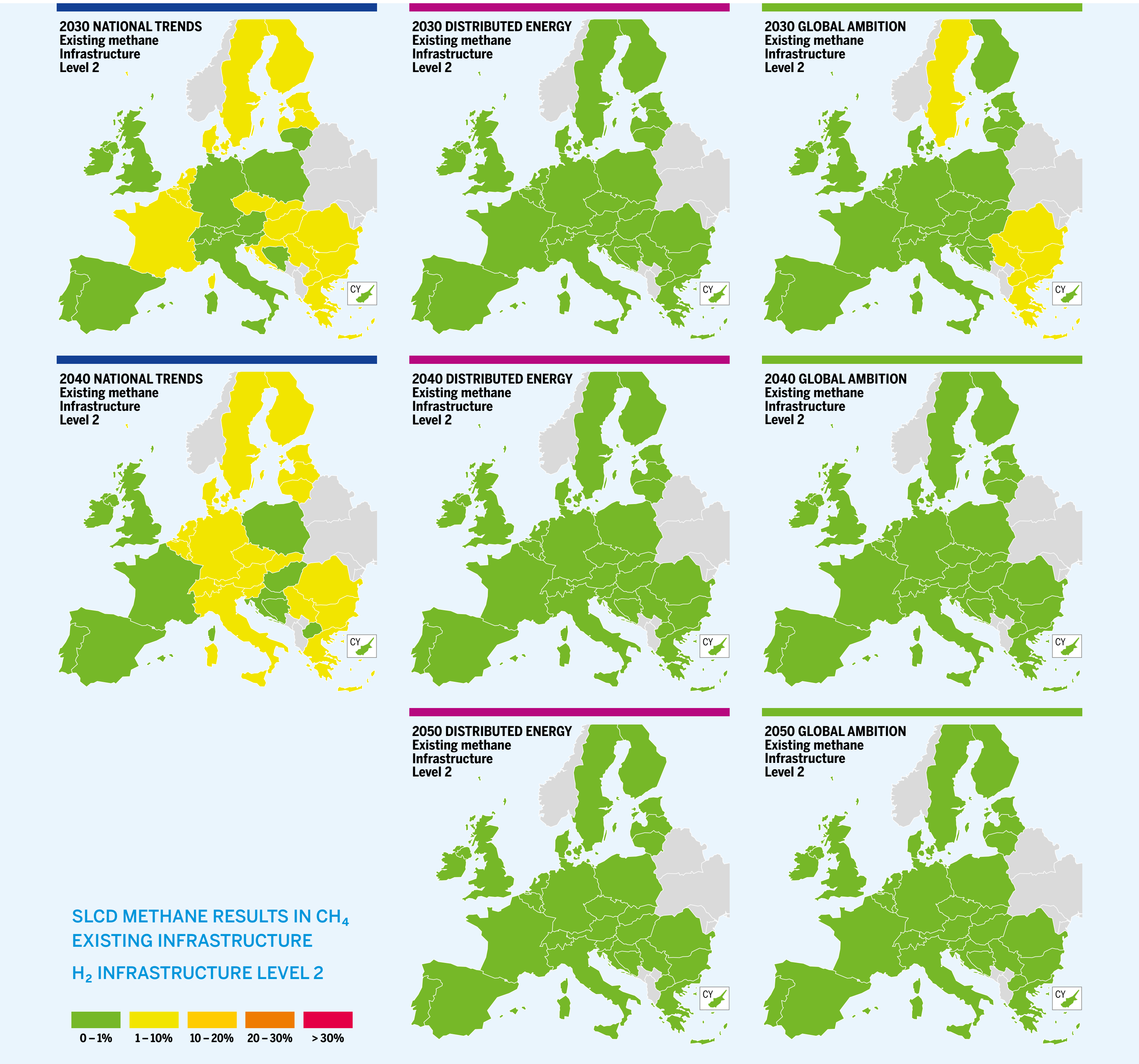


Figure 14.2 Methane SLCD Results for Peak Demand in Existing CH_4 Infrastructure with H_2 Level 2

H_2 INFRASTRUCTURE LEVEL 1

In **H_2 Infrastructure level 1**, only Sweden shows 4 % demand curtailment in **Global Ambition** scenario, due to infrastructure limitations between Denmark and Sweden and hydrogen production using methane.

2030

H_2 INFRASTRUCTURE LEVEL 2

In Infrastructure H_2 level 2 **National Trends** scenario, due to higher hydrogen production using methane, some countries show now 1 % demand curtailment (2 % in the Netherlands).

In **Distributed Energy** scenario, situation remains unchanged (without demand curtailment).

In H_2 Infrastructure level 2 **Global Ambition** scenario, most of the countries show no impact (no demand curtailment). Serbia, North Macedonia, Bulgaria and Romania show now 3 % demand curtailment due to higher hydrogen production and bottlenecks on the methane infrastructure. Sweden shows 6 % demand curtailment in Global Ambition scenario, due to infrastructure limitations between Denmark and Sweden and hydrogen production using methane.

2040

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, some countries show now demand curtailment (3 %) due to hydrogen production using methane and infrastructure limitations.

In **Distributed Energy and Global Ambition** scenarios, situation remains unchanged (without demand curtailment).

2050

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy and Global Ambition** scenarios, situation remains unchanged (without demand curtailment).

14.2 ADVANCED INFRASTRUCTURE LEVEL (METHANE)

H_2 INFRASTRUCTURE LEVEL 1

In H_2 Infrastructure level 1, situation remains unchanged compared to Existing Infrastructure.

H_2 INFRASTRUCTURE LEVEL 2

In H_2 Infrastructure level 2, demand curtailment is fully mitigated in all scenarios and years (except for in **Global Ambition scenario, in 2030**) compared to infrastructure level 1 Existing infrastructure level due to increase flexibility on the methane side. In 2030, Global Ambition scenario, Sweden shows 5 % demand curtailment due to infrastructure limitations between Denmark and Sweden and higher hydrogen production using methane.

14.3 PCI INFRASTRUCTURE LEVEL (METHANE RESULTS)

H_2 INFRASTRUCTURE LEVEL 1

In **H_2 Infrastructure level 1**, situation remains unchanged compared to Existing Infrastructure.

2030

H_2 INFRASTRUCTURE LEVEL 2

In **H_2 Infrastructure level 2 National Trends** scenario, most of the countries fully mitigate demand curtailment due to additional flexibility on the methane infrastructure. Belgium, the Netherlands, Denmark and Sweden still show 1 % demand curtailment.

In **Distributed Energy** scenario, situation remains unchanged (no demand curtailment).

In **Global Ambition** scenario, curtailed countries in the east fully mitigate their demand curtailment and Sweden decrease its demand curtailment by 1 %.

2040

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, all curtailed countries decrease their demand curtailment by 1 % due to additional flexibility in PCI Infrastructure level. Luxembourg increased its demand curtailment rate to 12 % due to repurposed infrastructure and a bottleneck with Germany.

Both **Distributed Energy and Global Ambition** scenarios remain without demand curtailment.

2050

H_2 INFRASTRUCTURE LEVEL 2

Both **Distributed Energy** and **Global Ambition** scenarios remain without demand curtailment.

14.4 EXISTING INFRASTRUCTURE LEVEL (HYDROGEN RESULTS)

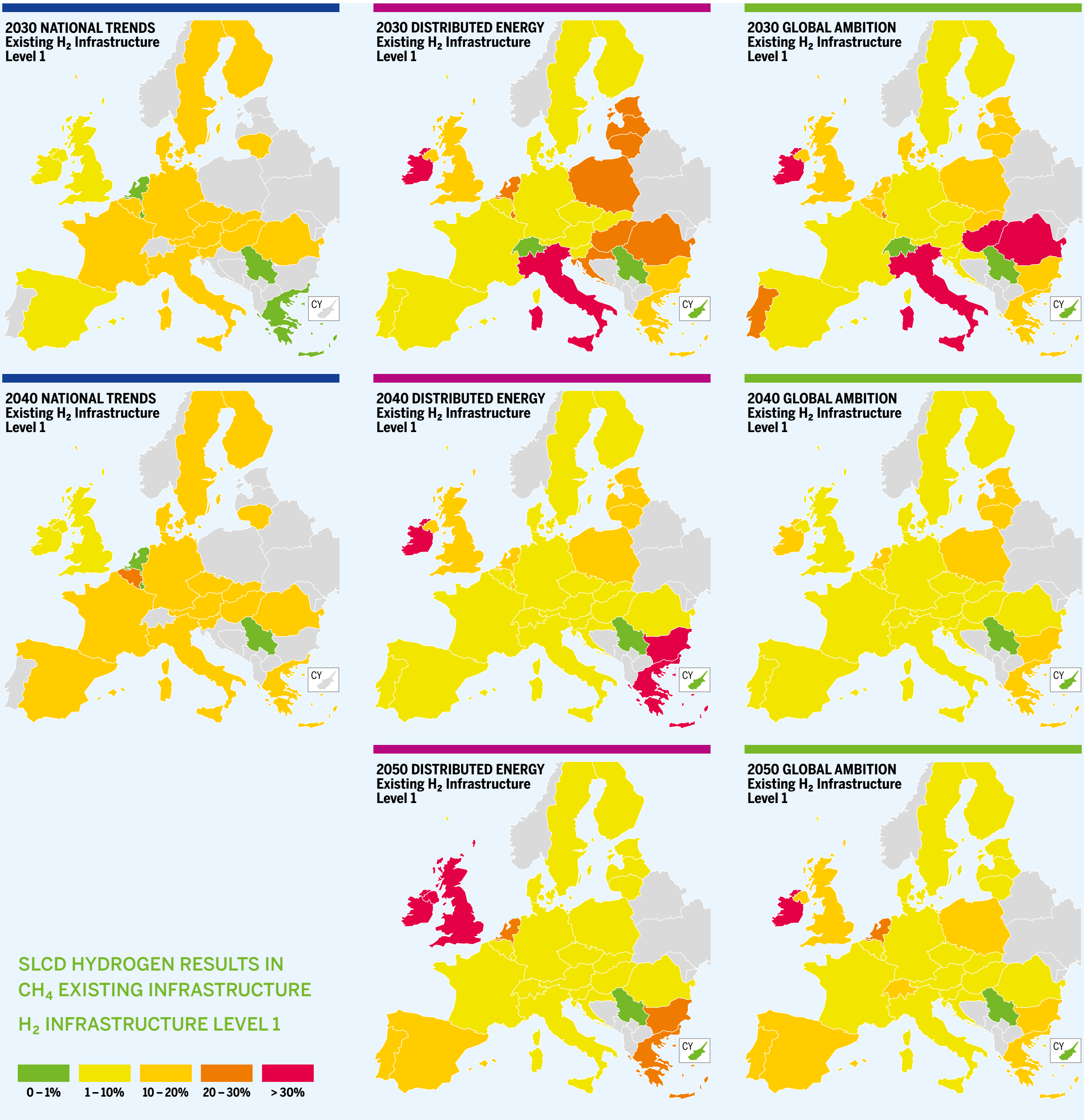


Figure 14.3 Hydrogen SLCD Results for Peak Demand in Existing CH_4 Infrastructure with H_2 Level 1

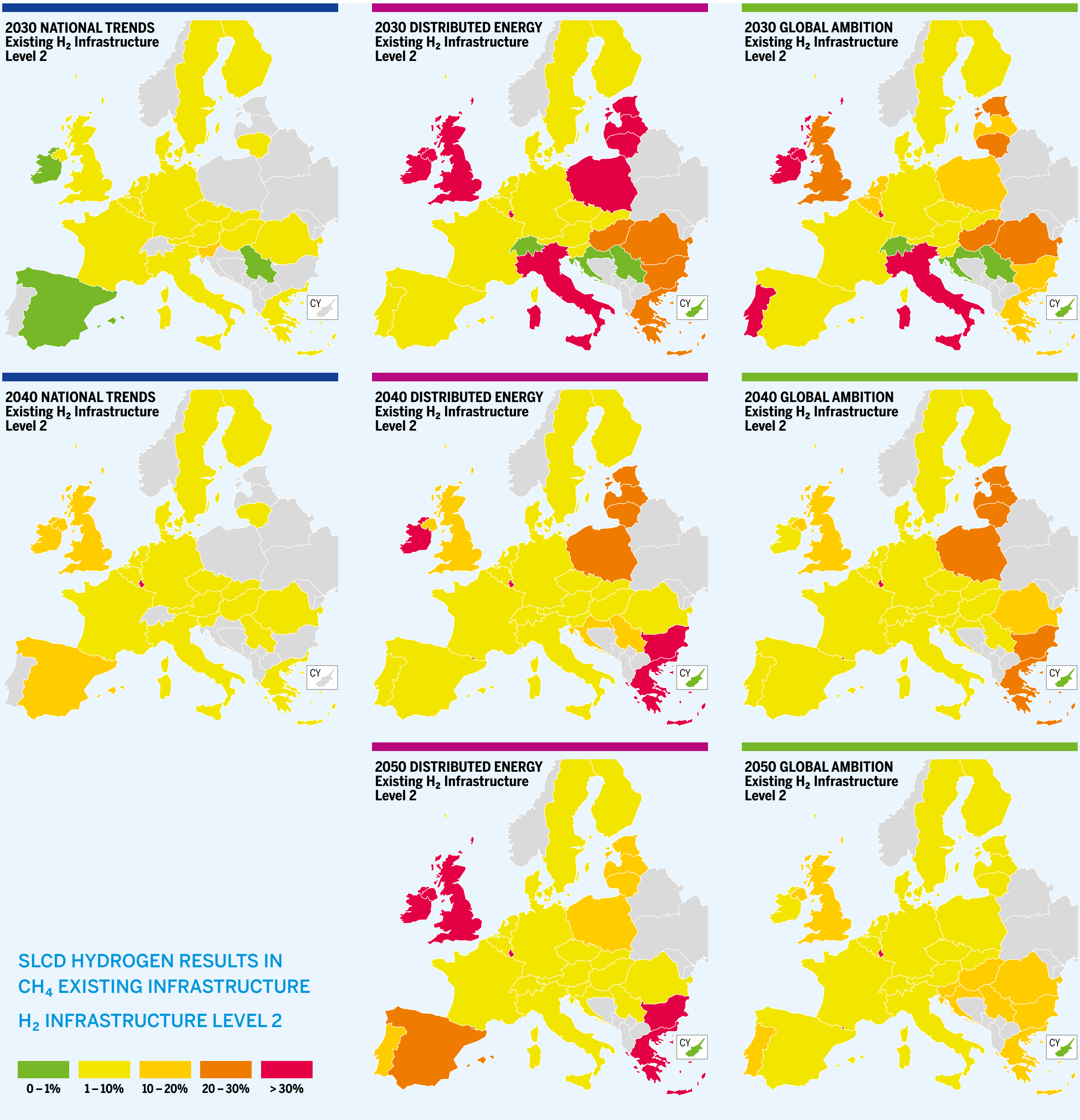


Figure 14.4 Hydrogen SLCD Results for Peak Demand in Existing CH_4 Infrastructure with H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, without any hydrogen production using methane, some countries show demand curtailment.

- Ireland shows 2 % demand curtailment as SLCD is national production and there are no interconnections with neighbouring countries.
- Luxembourg shows 3 % demand curtailment as SLCD is national production and there are no interconnections with neighbouring countries.
- Spain shows 3 % demand curtailment, SLCD is the interconnection with France and there is a bottleneck with Portugal.
- United Kingdom shows 9 % demand curtailment as SLCD is national production and there are no interconnections with neighbouring countries.
- The rest of the countries show 14 % to 15 % curtailment rate due to SLCD but good cooperation sharing demand curtailment.

In **Distributed Energy** scenario, most of the countries are impacted by SLCD. Sweden, Finland, Slovenia, Germany, Portugal, Spain, Slovakia, Denmark, Czech Republic, Austria, France and Belgium show 9 % demand curtailment. Greece, United Kingdom and Bulgaria show 16 % demand curtailment. The Netherlands, Poland, Latvia, Estonia, Lithuania and Croatia show 20 % to 23 % demand curtailment. Luxembourg shows 26 % demand curtailment and Romania and Hungary show 29 % demand curtailment. Italy and Ireland show respectively 34 % and 38 % demand curtailment. For each SLCD, infrastructure limitations or no interconnections due to SLCD or not interconnected countries do not allow to mitigate more the curtailment rates.

In **Global Ambition** scenario, most of the countries are impacted by SLCD. Croatia and Slovenia show 3 % and 6 % demand curtailment. Sweden, Finland, Germany, Spain, Czech Republic, France, Austria and Slovakia show 9 % demand curtailment. Poland, Latvia, Estonia, Lithuania, Greece, Denmark, United Kingdom, and Bulgaria show 13 % demand curtailment. The Netherlands, Belgium, Portugal and Luxembourg show respectively 17 %, 19 %, 27 % and 29 %curtailment. Italy, Romania, Hungary and Ireland show respectively 32 %, 36 %, 37 % and 39 %. Infrastructure limitations, or no interconnections due to SLCD, or not interconnected countries do not allow to mitigate more demand curtailments.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, most of the countries mitigate their demand curtailment to 1–2 % due to additional hydrogen production using methane and better cooperation in H_2 Infrastructure level 2. Slovenia and Luxembourg keep their demand curtailment due to infrastructure limitations with neighbouring countries. Some countries (The Netherlands and Greece) show now demand curtailment due to more cooperation in H_2 Infrastructure level 2.

In **Distributed Energy** scenario, most of the countries reduce their demand curtailment to 1–3 % (11 % in The Netherlands) due to additional hydrogen production using methane and more flexibility in H_2 Infrastructure level 2. Some countries increase their demand curtailment (from 5 % to 10 %) due to more cooperation between countries in H_2 Infrastructure level 2.

In **Global Ambition** scenario, most of the countries reduce their demand curtailment to 1–3 % due to additional hydrogen production using methane and more flexibility in H_2 Infrastructure level 2. Some countries increase their demand curtailment (from 4 % to 15 %) due to more cooperation between countries in H_2 Infrastructure level 2.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, infrastructure limitations, or no interconnections due to SLCD, or not interconnected countries do not allow to mitigate demand curtailment. United Kingdom, Luxembourg and Ireland show 3 % to 7 % demand curtailment. Most of the countries show 19 % demand curtailment. Belgium shows 26 % demand curtailment.

In **Distributed Energy** scenario, infrastructure limitations, or no interconnections due to SLCD, or not interconnected countries do not allow to mitigate demand curtailment. Most of the countries show 3 % to 6 % range of demand curtailment and some other countries show higher demand curtailment with 12 % to 14 % of SLCD impact. Greece, Bulgaria and Ireland show 32 % and Ireland 86 % demand curtailment.

In **Global Ambition** countries, infrastructure limitations, or no interconnections due to SLCD, or not interconnected countries do not allow to mitigate demand curtailment. Most of the countries show 2 % to 9 % range of demand curtailment and some other countries show higher demand curtailment with 12 % to 16 % of SLCD impact. Finally, Ireland shows 19 % demand curtailment.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, most of the countries mitigate their demand curtailment due to the additional hydrogen production using methane. Some countries keep their demand curtailment values due to not enough flexibility on the methane infrastructure. Ireland, Luxembourg, The Netherlands, Serbia and United Kingdom, increased their demand curtailment due to more cooperation in H_2 Infrastructure level 2 and repurposed methane infrastructure.

In **Distributed Energy** scenario, most of the countries mitigate their demand curtailment due to the additional hydrogen production using methane. Some countries keep their demand curtailment values due to not enough flexibility on the methane infrastructure. Bulgaria, Estonia, Croatia, Lithuania, Luxembourg, Latvia, Poland and Serbia, increase their demand curtailment due to more cooperation in H_2 Infrastructure level 2 and repurposed methane infrastructure.

In **Global Ambition** scenario, most of the countries mitigate their demand curtailment due to the additional hydrogen production using methane. Some countries keep their demand curtailment values due to not enough flexibility on the methane infrastructure. Bulgaria, Estonia, Greece, Croatia, Hungary, Lithuania, Luxembourg, Latvia, Poland, Romania, Serbia, Sweden, Slovakia and United Kingdom increase their demand curtailment due to more cooperation in H_2 Infrastructure level 2 and repurposed methane infrastructure.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, infrastructure limitations, or no interconnections due to SLCD, or not interconnected countries do not allow to mitigate demand curtailment. Most of the countries show 5 % to 9 % demand curtailment. Portugal and Spain show 12 % and 17 % demand curtailment. Greece, Bulgaria and The Netherlands show 20 %, 21 % and 27 %. United Kingdom and Ireland show respectively 32 % and 92 % demand curtailment.

In **Global Ambition** scenario, infrastructure limitations, or no interconnections due to SLCD, or not interconnected countries do not allow to mitigate demand curtailment. Most of the countries show 4 % to 9 % demand curtailment. Italy, Switzerland, Portugal, Spain, Poland, Greece and Bulgaria show 12 % to 18 % demand curtailment. United Kingdom, The Netherlands and Ireland show respectively 20 %, 21 % and 31 % demand curtailment.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, most of the countries mitigate their demand curtailment. Bulgaria, Estonia, Greece, Croatia, Hungary, Lithuania, Luxembourg, Latvia, Poland, Romania, Serbia, Sweden, Slovakia and United Kingdom increase their demand curtailment rate due to more flexibility on the hydrogen infrastructure and higher cooperation.

In **Global Ambition** scenario, most of the countries mitigate their demand curtailment. Croatia, Hungary, Luxembourg, Romania, Serbia and Slovenia increase their demand curtailment rate due to more flexibility on the hydrogen infrastructure and higher cooperation.

14.5 ADVANCED INFRASTRUCTURE LEVEL (HYDROGEN RESULTS)

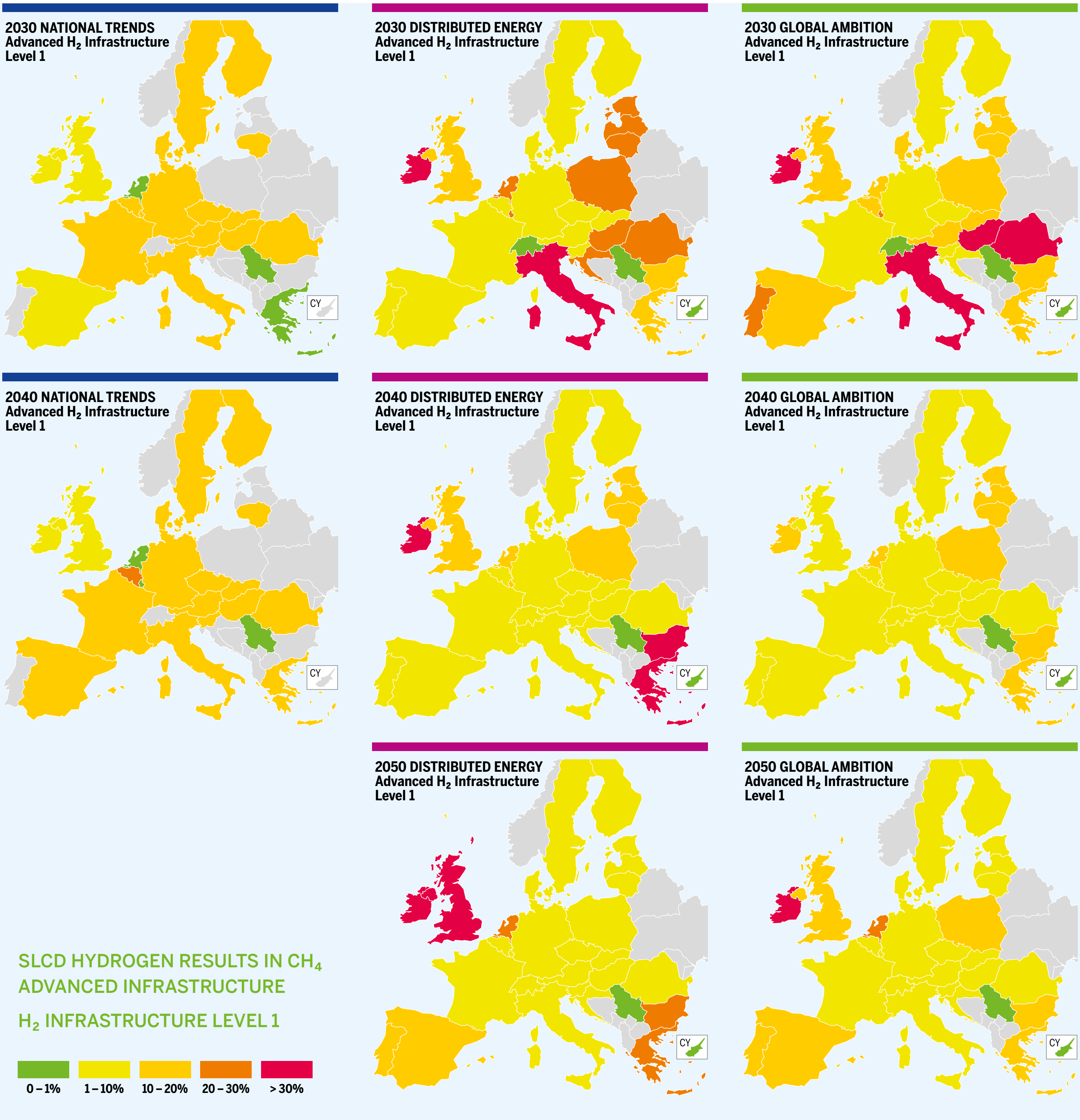


Figure 14.5 Hydrogen SLID Results for Peak Demand in Advanced CH_4 Infrastructure with H_2 Level 1

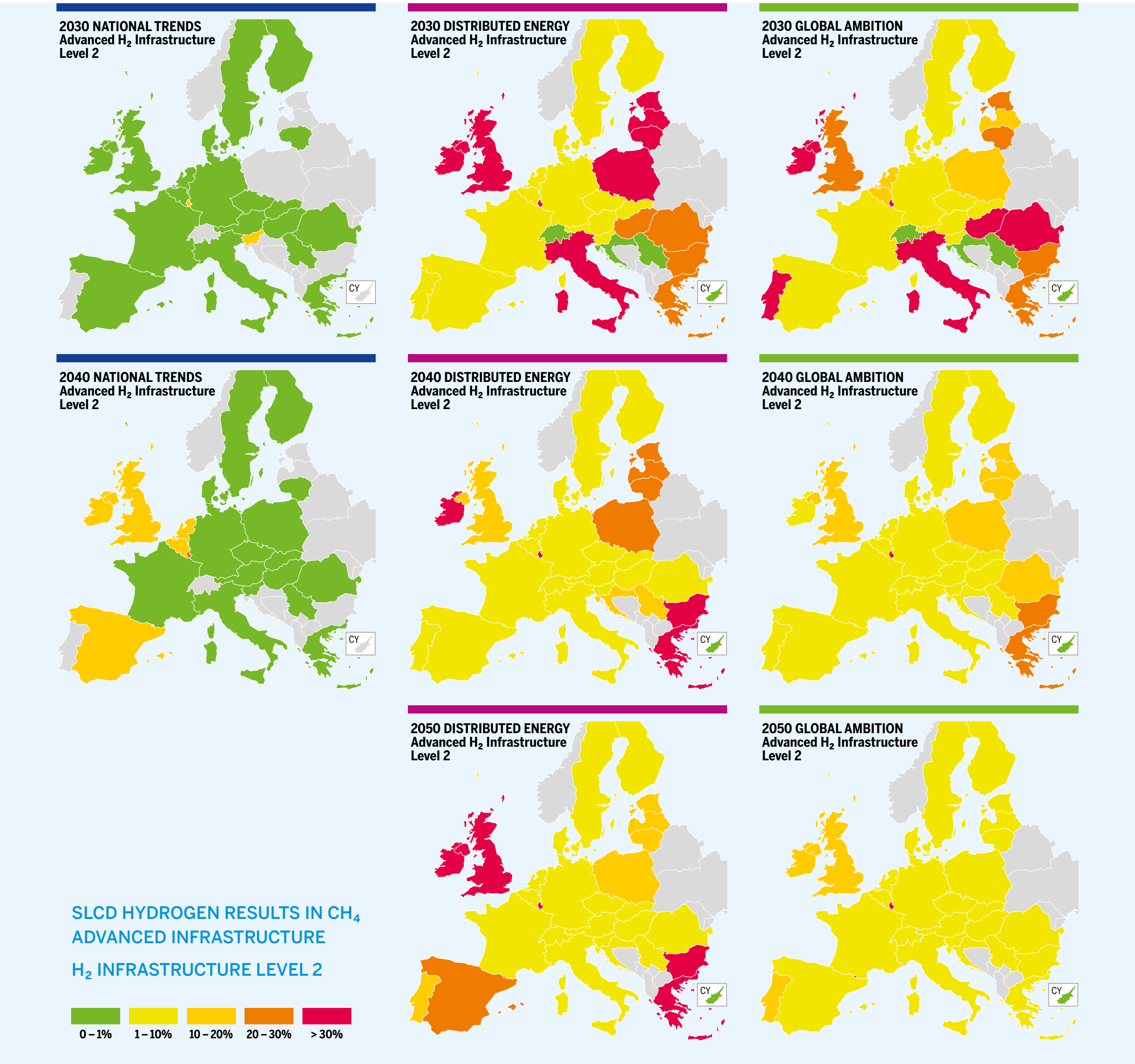


Figure 14.6 Hydrogen SLID Results for Peak Demand in Advanced CH_4 Infrastructure with H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, situation remains unchanged compared to Existing Infrastructure as there is no hydrogen production using methane in this scenario.

In **Distributed Energy** scenario, situation remains unchanged compared to Existing Infrastructure due to no more hydrogen production using methane available.

In **Global Ambition** scenario, situation remains unchanged compared to Existing Infrastructure due to no more hydrogen production using methane available .

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, most of the countries fully mitigate demand curtailment. Only Luxembourg and Slovenia results remain unchanged due to infrastructure limitations on the methane infrastructure.

In **Distributed Energy** scenario, situation remains unchanged. Countries show the same demand curtailment due to infrastructure limitations on the methane infrastructure.

In **Global Ambition** scenario, most of the countries show the same results. Bulgaria, Greece, Hungary and Romania increase their demand curtailment due to more flexibility on the methane infrastructure allowing for a better cooperation.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, situation remains unchanged compared to Existing Infrastructure as there is no hydrogen production using methane in this scenario.

In **Distributed Energy** scenario, situation remains unchanged due to no more hydrogen production using methane available.

In **Global Ambition** scenario, situation remains unchanged due to no more hydrogen production using methane available.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, most of the countries fully mitigate demand curtailment. Some countries (Romania, Serbia, Sweden, Slovenia, Slovakia and United Kingdom) increase demand curtailment due to more flexibility on the methane infrastructure allowing for a better cooperation.

In **Distributed Energy** scenario, most of the countries mitigate demand curtailment some countries increase demand curtailment due to more flexibility and better cooperation (Belgium, Finland, France, Hungary, Sweden, Slovenia and United Kingdom).

In **Global Ambition** scenario, most of the countries mitigate demand curtailment. Some countries (Belgium, Denmark, Finland, Hungary, Lithuania, Romania, Serbia, Sweden, Slovenia, Slovakia and United Kingdom) increase demand curtailment due to more flexibility on the methane infrastructure allowing for a better cooperation.

2050

H_2 INFRASTRUCTURE LEVEL 1

In **Distributed Energy** scenario, situation remains unchanged due to no more hydrogen production using methane available.

In **Global Ambition** scenario, situation remains unchanged due to no more hydrogen production using methane available.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, most of the countries mitigate demand curtailment due to the additional flexibility to increase hydrogen production with methane in the CH_4 Advanced level. Some countries increase their demand curtailment due to more flexibility on the methane infrastructure allowing for a better cooperation (Belgium, Denmark, Finland, Hungary, Lithuania, Romania, Serbia, Sweden, Slovenia, Slovakia and United Kingdom).

In **Global Ambition** scenario, most of the countries mitigate demand curtailment due to the additional flexibility to increase hydrogen production with methane in the CH_4 Advanced level. Some countries increase their demand curtailment due to more flexibility on the methane infrastructure allowing for a better cooperation (Denmark, Lithuania, Poland, Sweden, Slovenia and United Kingdom).

14.6 PCI INFRASTRUCTURE LEVEL (HYDROGEN RESULTS)

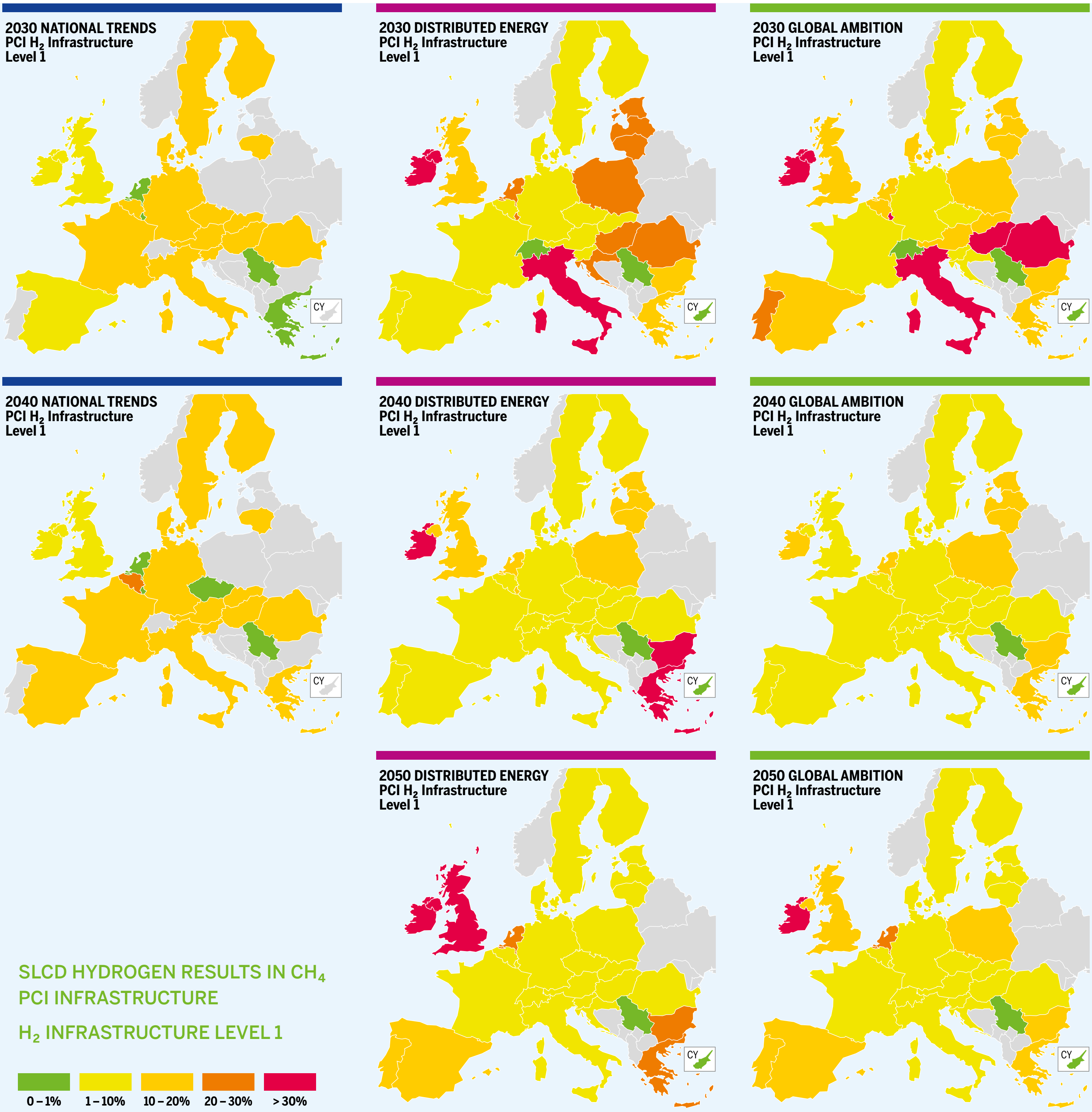


Figure 14.7 Hydrogen SLCD Results for Peak Demand in PCI CH_4 Infrastructure with H_2 Level 1

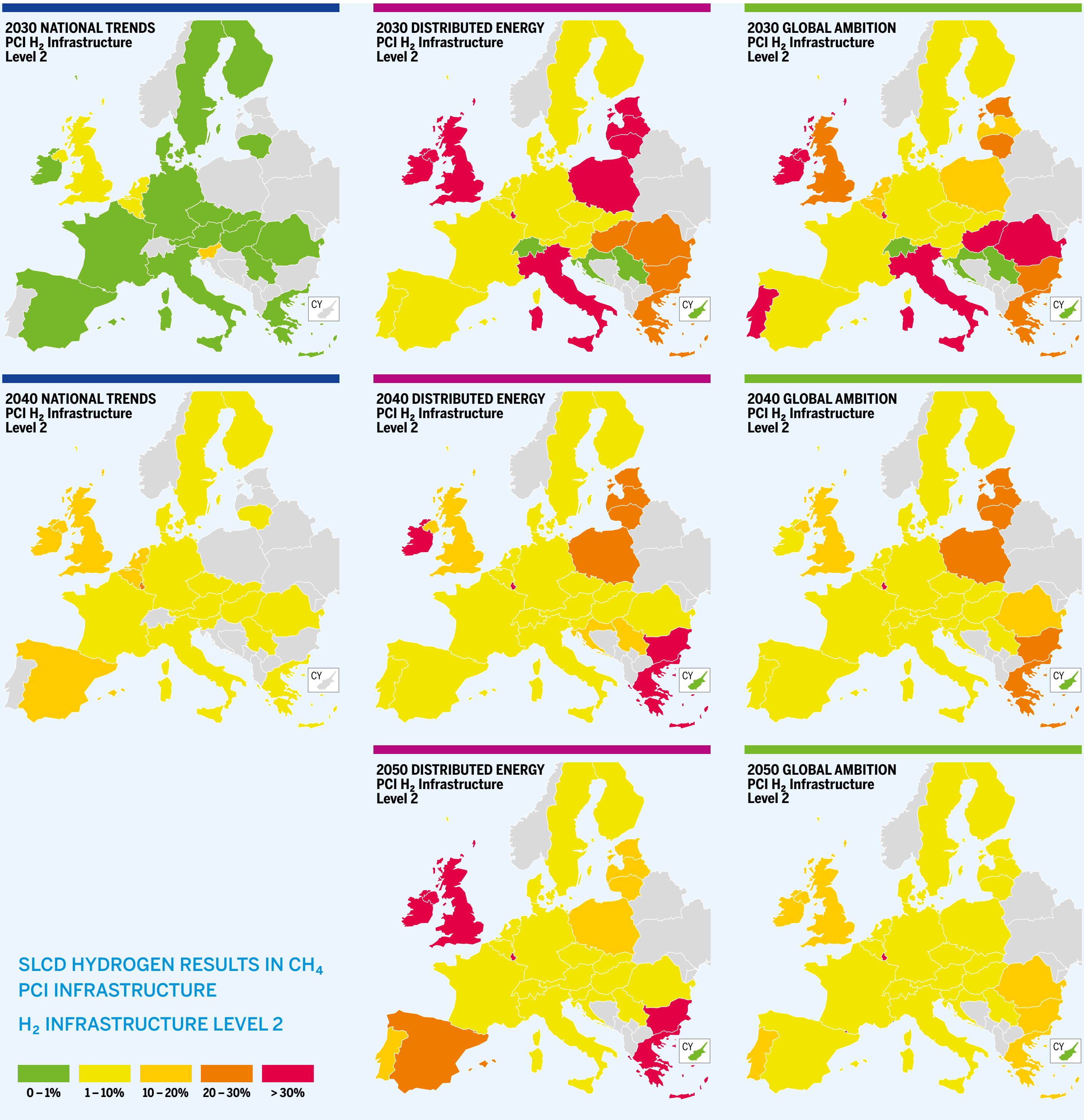


Figure 14.8 Hydrogen SLCD Results for Peak Demand in PCI CH_4 Infrastructure with H_2 Level 2

2030

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, situation remains unchanged compared to Existing infrastructure as there is no hydrogen production using methane in this scenario.

In **Distributed Energy** scenario, situation remains unchanged due to no more hydrogen production using methane available.

In **Global Ambition** scenario, situation remains unchanged due to no more hydrogen production using methane available.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, all countries mitigate their demand curtailment.

In **Distributed Energy** scenario, situation remains unchanged due to no more hydrogen production using methane available.

In **Global Ambition** scenario, situation remains unchanged due to no more hydrogen production using methane available.

2040

H_2 INFRASTRUCTURE LEVEL 1

In **National Trends** scenario, situation remains unchanged compared to Existing infrastructure as there is no hydrogen production using methane in this scenario.

In **Distributed Energy** scenario, situation remains unchanged due to no more hydrogen production using methane available.

In **Global Ambition** scenario, situation remains unchanged due to no more hydrogen production using methane available.

H_2 INFRASTRUCTURE LEVEL 2

In **National Trends** scenario, some countries increase demand curtailment due to more flexibility on the hydrogen infrastructure which allows for higher cooperation (Belgium, Spain and The Netherlands).

In **Distributed Energy** scenario, situation remains unchanged due to no more hydrogen production using methane available.

In **Global Ambition** scenario, situation remains unchanged due to no more hydrogen production using methane available.

2050

H_2 INFRASTRUCTURE LEVEL 1

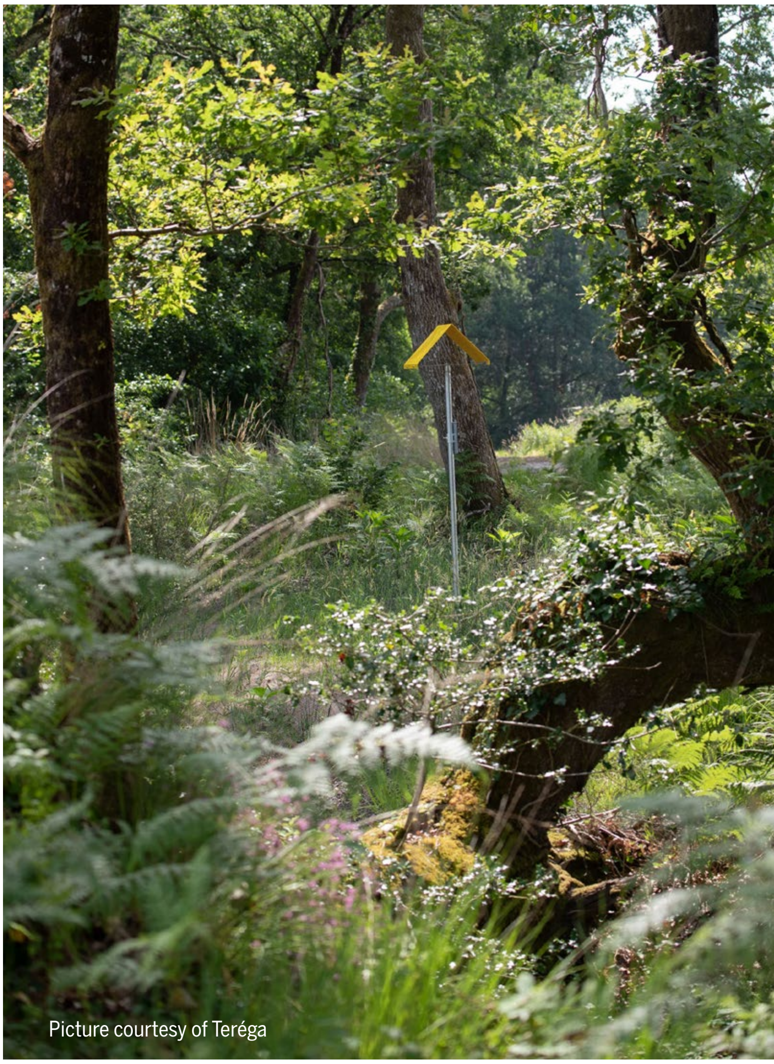
In **Distributed Energy** scenario, situation remains unchanged due to no more hydrogen production using methane available.

In **Global Ambition** scenario, situation remains unchanged due to no more hydrogen production using methane available.

H_2 INFRASTRUCTURE LEVEL 2

In **Distributed Energy** scenario, situation remains unchanged due to no more hydrogen production using methane available.

In **Global Ambition** scenario, situation remains unchanged due to no more hydrogen production using methane available.



Picture courtesy of Teréga

15 SUPPLY ADEQUACY IN NORTH-WEST EUROPE: THE CHALLENGE OF L-GAS AREAS

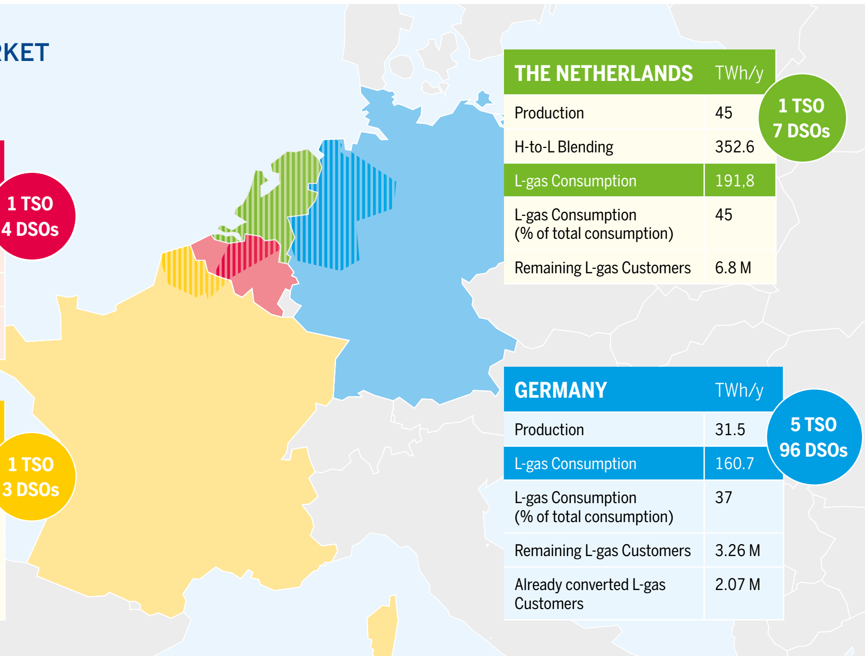
Historically, the main supplier of L-gas in North West Europe was the Groningen gas field in the Netherlands. Since 2012 Belgium, France, Germany and the Netherlands have been working together to phase-out L-gas.

Initially, the phase-out was motivated by the natural decline of the capacity of the Groningen field. After an earthquake, which occurred on 8 January 2018 near Zeerijp, the government of the Netherlands announced in March 2018 its decision to terminate natural gas production from the Groningen field as soon as possible, in order to guarantee safety in the area of Groningen against the risk of earthquakes resulting from natural gas extraction. Due to various measures to reduce the dependency on the Groningen gas, the Groningen field has a back-up role in gas year 2022/2023. The production locations will produce at a minimum flow in order to ensure availability in case of extreme cold weather, unexpected (out of spec) qas qualities, transportation limitations, a shortage of H-gas or an outage in the L-gas system.

The decline of L-gas production is causing a pressing investment requirement. As the only region where L-gas is produced and consumed, the phasing out of the Groningen field and the decline of German L-gas production requires considerable infrastructure investments, which are already well underway, to allow L-to-H market conversion in large parts of Belgium, France and Germany. A detailed overview of the current status of the L-gas markets and the ongoing associated infrastructure adaptations that are required for a successful market conversion and integration into the H-gas system is presented in the latest North West Gas Regional Investment Plan (NW-GRIP)[19].

EUROPEAN L-GAS MARKET

Rounded figures



BELGIUM	TWh/y
L-gas Consumption	37.7
L-gas Consumption (% of total consumption)	9
Remaining L-gas Customers	0.83 M
Already converted L-gas Customers	0.75 M

1 TSO, 4 DSOs

FRANCE	TWh/y
L-gas Consumption	38.8
L-gas Consumption (% of total consumption)	9
Remaining L-gas Customers	1.2 M
Already converted L-gas Customers	0.2 M

1 TSO, 3 DSOs

THE NETHERLANDS	TWh/y
Production	45
H-to-L Blending	352.6
L-gas Consumption	191.8
L-gas Consumption (% of total consumption)	45
Remaining L-gas Customers	6.8 M

1 TSO, 7 DSOs

GERMANY	TWh/y
Production	31.5
L-gas Consumption	160.7
L-gas Consumption (% of total consumption)	37
Remaining L-gas Customers	3.26 M
Already converted L-gas Customers	2.07 M

5 TSO, 96 DSOs

Figure 15.1 European L-gas market in 2022. In Germany, the L-gas market is measured in number of appliances rather than number of customers. L-gas consumptions are relevant for GY 2021–2022 and are partly estimates. (Source: L-gas Market conversion review, NW GRIP TSOs)

19 https://www.entsog.eu/gas-regional-investment-plans-grips#north-west

Picture courtesy of GRTgaz

THE KEY CONCLUSIONS IN THE NW-GRIP ARE:

- There will be sufficient L-gas supply to cover security of supply (SoS) throughout the L-to-H market conversion program, according to the Task Force Monitoring L-Gas Market Conversion.
- The measures to increase conversion capacity and reduce L-gas demand in the Netherlands are ongoing.
- The L-to-H infrastructure conversion programs in France, Belgium, Germany are on track.
- The Task Force Monitoring L-Gas Market Conversion provides a good forum for international cooperation and alignment between the four concerned countries.

After the publication of the latest NW GRIP in December 2022, the GTS (Dutch TSO) advice[20] on security of supply for 2023/2024 concluded that the Groningen field should remain available to cover an extreme cold period during the winter, to ensure the gas storages reach the level required by the European regulation to ensure security of supply next gas year or unforeseen conditions. The need for back-up from the Groningen field arises due to current limitations on the supply of H-gas in North West Europe. The State Secretary for mining, who is responsible for setting the allowed production from the Groningen field, announced that six of the eleven production locations of the Groningen field will be closed, yet without taking irreversible steps until a final decision is being made on the allowed production before the start of the new gas year.

The impact of COVID-19 in Europe on the L-gas supply and demand projections is assessed in the latest winter briefing of the L-gas Market Conversion Monitoring Taskforce report[21], in which the participating countries concluded that due to COVID-19 the conversion was impacted to some degree during the year 2020 however this impact did not lead to a significant delay of the conversion.

20 Advice regarding required Groningen capacities and volumes for security of supply for gas year 2023/2024

21 https://open.overheid.nl/documenten/ronl-464612803aae5e15f645f8739c2a05172a06fbc4/pdf

LIST OF **FIGURES**

LIST OF **ABBREVIATIONS**

ACER	Agency for the Cooperation of Energy Regulators
Bcm/Bcma	Billion cubic meters/Billion cubic meters per annum
BIO	Biomethane Development Projects
CAPEX	Capital expenditure
CBA	Cost-Benefit Analysis
DAR	Demand Assessment Report
EC	European Commission
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSOG	European Network of Transmission System Operators for Gas
ETR	Energy Transition Projects
EU	European Union
FEED	Front End Engineering Design
FID	Final Investment Decision
GCV	Gross Calorific Value
GIE	Gas Infrastructure Europe
GHG	Greenhouse Gases
GRIP	Gas Regional Investment Plan
GWh	Gigawatt hour
e-GWh	Gigawatt hour electrical
GQO	Gas Quality Outlook
H-gas	High calorific gas
HYD	Hydrogen
IP	Interconnection Point
ktoe	A thousand tonnes of oil equivalent. Where gas demand figures have been calculated in TWh (based on GCV) from gas data expressed in ktoe, this was done on the basis of NCV and it was assumed that the NCV is 10 % less than GCV.
L-gas	Low calorific gas
LNG	Liquefied Natural Gas
mcm	Million cubic meters
MS	Member State

mtoe	A million tonnes of oil equivalents. Where gas demand figures have been calculated in TWh (based on GCV) from gas data expressed in mtoe, this was done on the basis of NCV and it was assumed that the NCV is 10 % less than GCV.
MWh	Megawatt hour
e-MWh	Megawatt hour electrical
NCV	Net Calorific Value
NDP	National Development Plan
NG	Natural Gas
NRA	National Regulatory Authority
OTH	Other Infrastructure-Related Projects
P2G	Power-to-Gas
PCI	Project of Common Interest
PID	Practical Implementation Document
REG-347	Regulation (EU) No 347/2013 of the European Parliament and of the council of 17 April 2013 on guidelines for trans-European energy infrastructure and repealing Decision No 1364/2006/EC and amending Regulations (EC) No 713/2009, (EC) No 714/2009 and (EC) No 715/2009
RES	Renewable Energy Sources
RET	Projects for Retrofitting Infrastructure to further integrate Hydrogen
SMR	Steam Methane Reforming
SoS	Security of Supply
Tcm	Tera cubic meter
TEN-E	Trans-European Networks for Energy
TSO	Transmission System Operator
TWh	Terawatt hour
e-TWh	Terawatt hour electrical
TYNDP	Ten-Year Network Development Plan
UGS	Underground Gas Storage (facility)
WI	Wobbe Index

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

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