TYNDP 2022

The Hydrogen and Natural Gas TYNDP

25/04/2023 Workshop

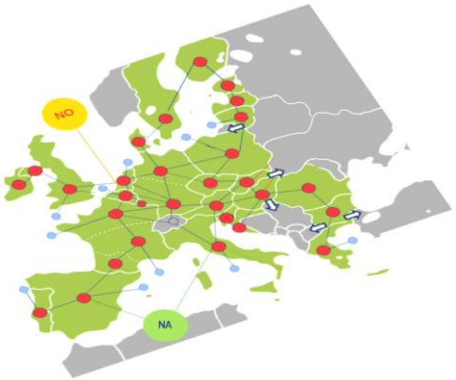
Agenda

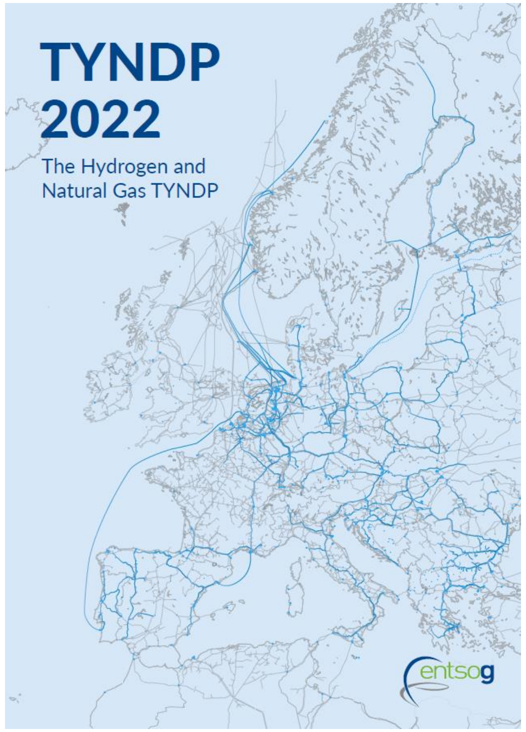
10:00 – 10:15	Welcome by ENTSOG General Director, Piotr Kuś
10:15 – 11:00	Scenario Report and REPowerEU Update
11:00 – 11:45	Infrastructure Report ○ Project Collection and Submitted Projects ○ Infrastructure Levels
11:45 – 12:55	System Assessment ○ ENTSOG Model ○ Results: Security of Supply ○ Sustainability
12:55 - 13:00	Closing

Draft TYNDP 2022

– Draft TYNDP was published on 11 April 2023
  – All chapters and annexes are available at: https://tyndp2022.entsog.eu/

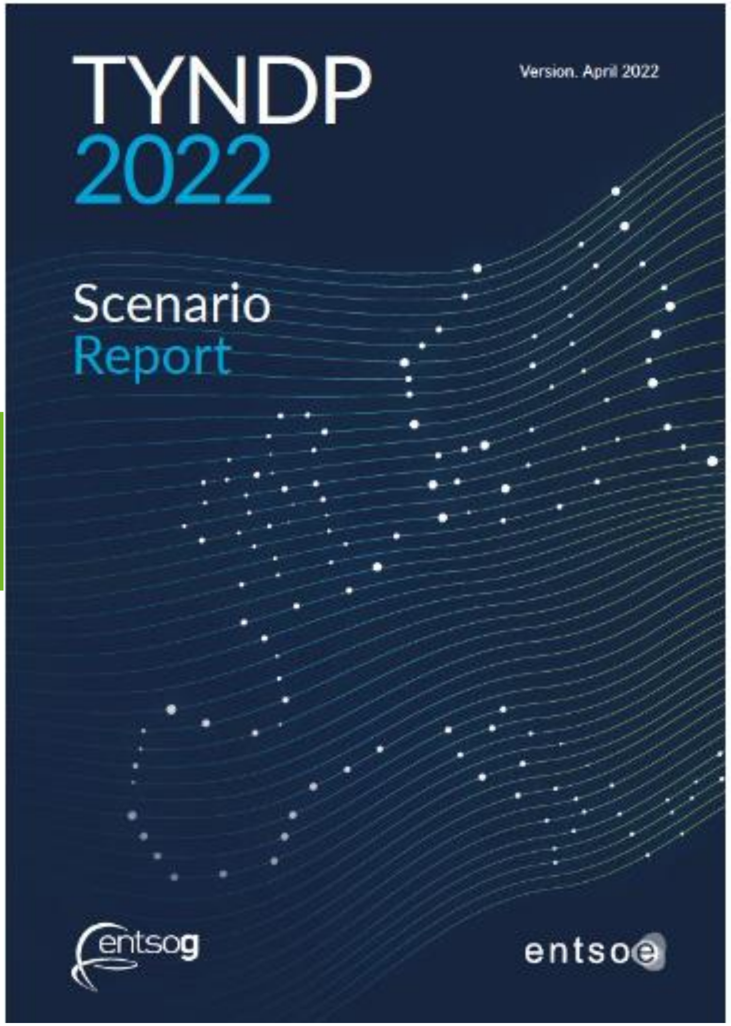
– Public consultation open until 19 May 2023
  – Available via this event site or
  – Public Consultation (office.com)





Scenario Report

and REPowerEU Update



10:15-11:00

Development of TYNDP 2022 scenarios

Purpose of TYNDP scenarios

TYNDP scenarios are designed for TYNDP infrastructure assessment

What will be the impact of decentralized energy production?
How to be sure that infrastructure supports RES development?
Is it ready for the Green Deal to materialize?
Can it deliver in terms of Security of Supply, Market Integration and Competition?

TYNDP scenarios are meant for analysis and information
- not for predictions/forecasting

TYNDP scenarios complementary to EC's **Impact Assessment** scenarios – with focus on assessment of infrastructure readiness vis-à-vis possible - **contrasted** - futures

TYNDP 2022 scenarios

National energy and climate plans (NECPs), national hydrogen strategies

2 x COP 21 scenarios

+1.5°C target with 66.7 % probability

At least -55% GHG reduction in 2030; Carbon neutrality by 2050

Benchmarked with EC Long-Term Strategy

National Trends 2030 - 2040

Policy Scenario **in line with national energy and climate policies**

Distributed Energy 2030 - 2050

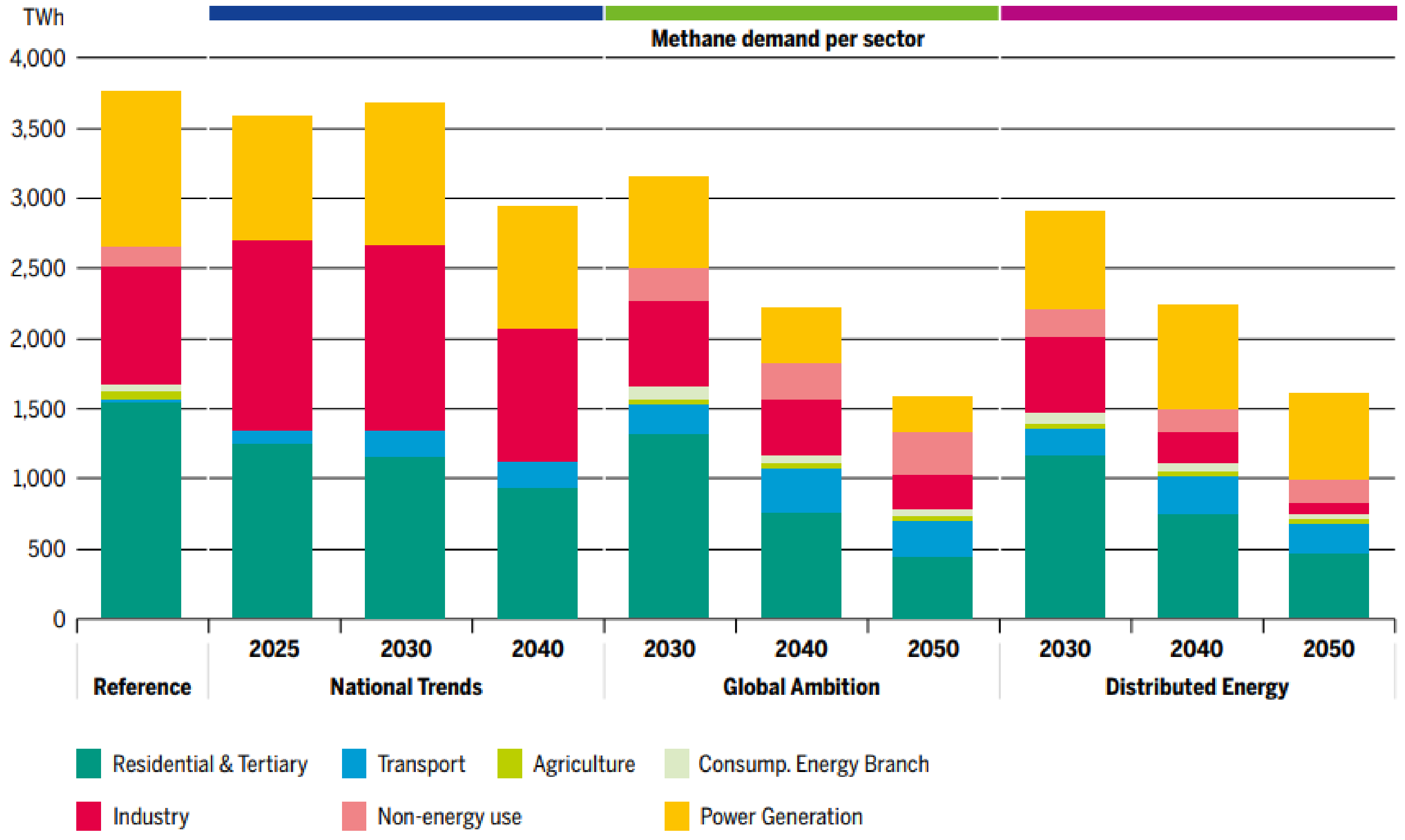
De-centralised approach: higher European energy autonomy, small-scale solutions, Prosumer

Global Ambition 2030 - 2050

Centralised approach: imports, large-scale renewables and decarbonisation

Please not: All figures of the TYNDP 2022 scenario report are expressed in NCV.

Methane demand (natural gas, synthetic methane and biomethane) per sector for EU 27*

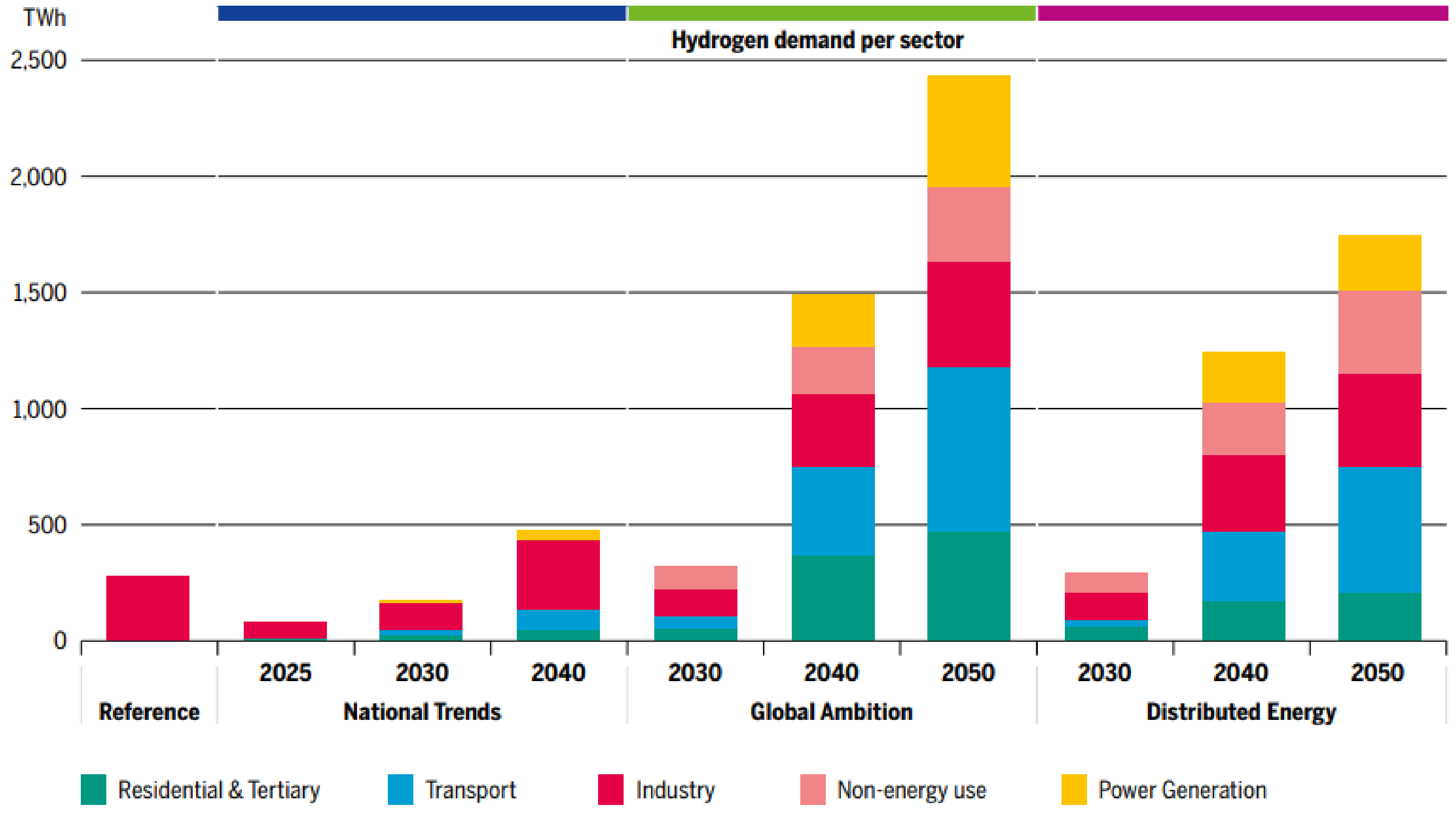


National policies rely more on methane until 2040, whilst hydrogen kicks in after 2030.

COP 21 scenarios: methane demand decreases and decarbonises over time

*before REPowerEU update for Global Ambition and Distributed Energy for 2030

Hydrogen demand for EU27*

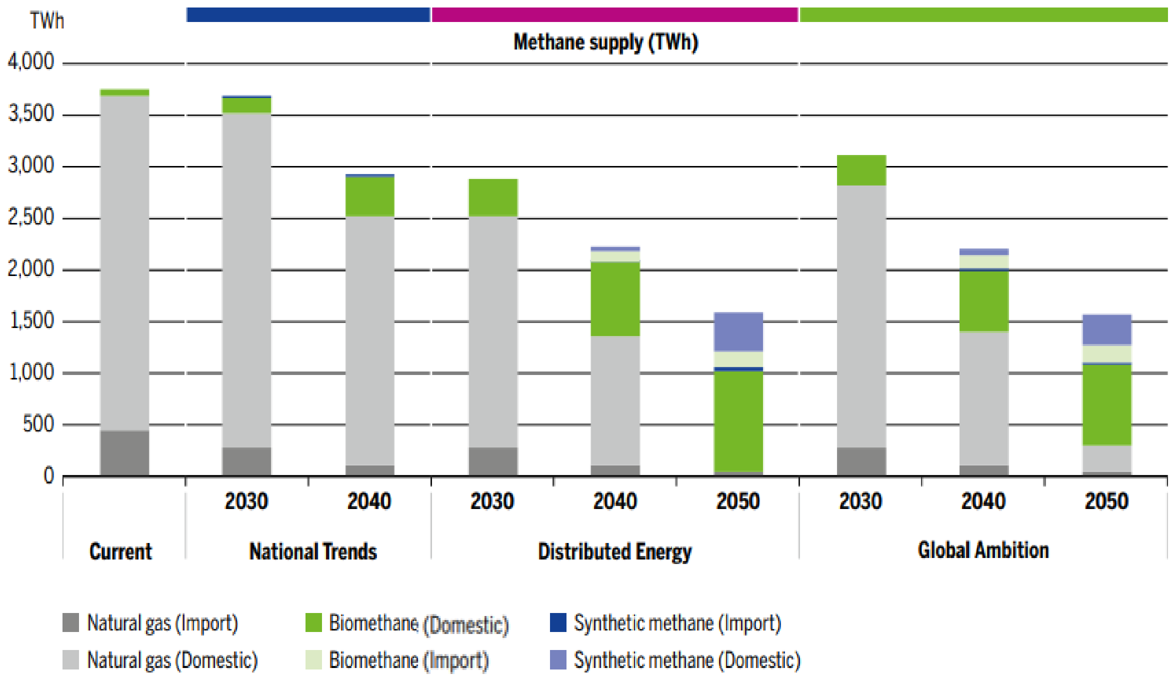


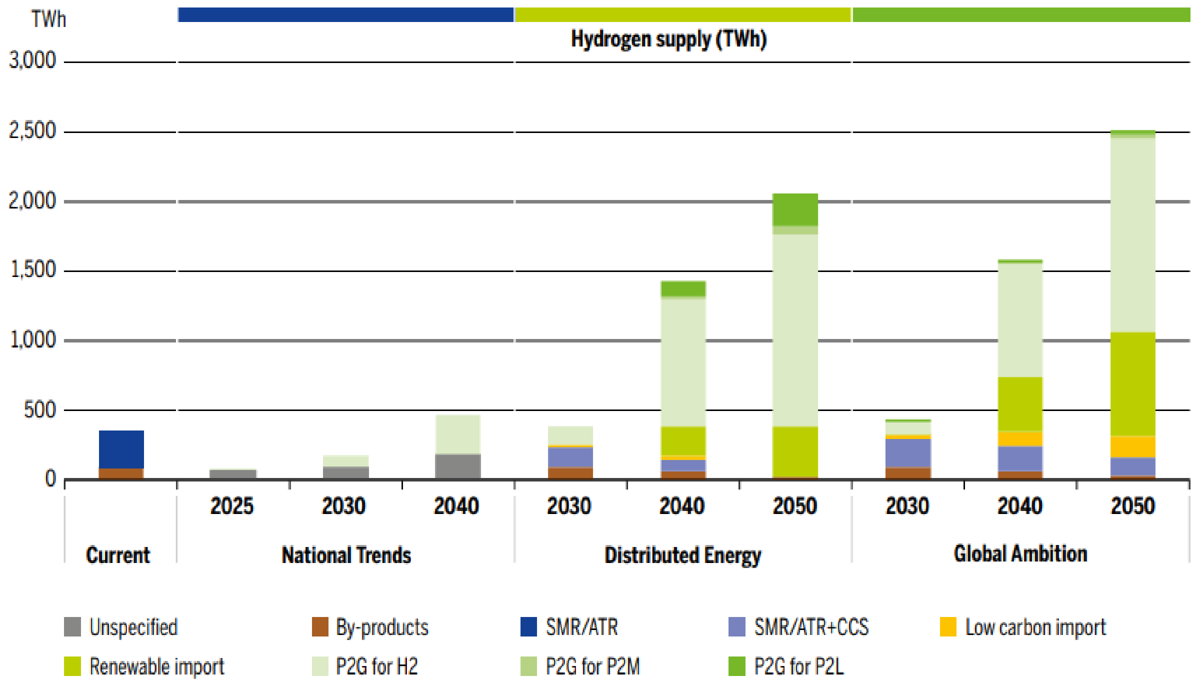
National Trends reflects contrasted policies across the different Member States.

Distributed Energy and Global Ambition: Hydrogen as a key element to reach carbon neutrality.

*before REPowerEU update for Global Ambition and Distributed Energy for 2030

Methane and hydrogen supply for EU27*



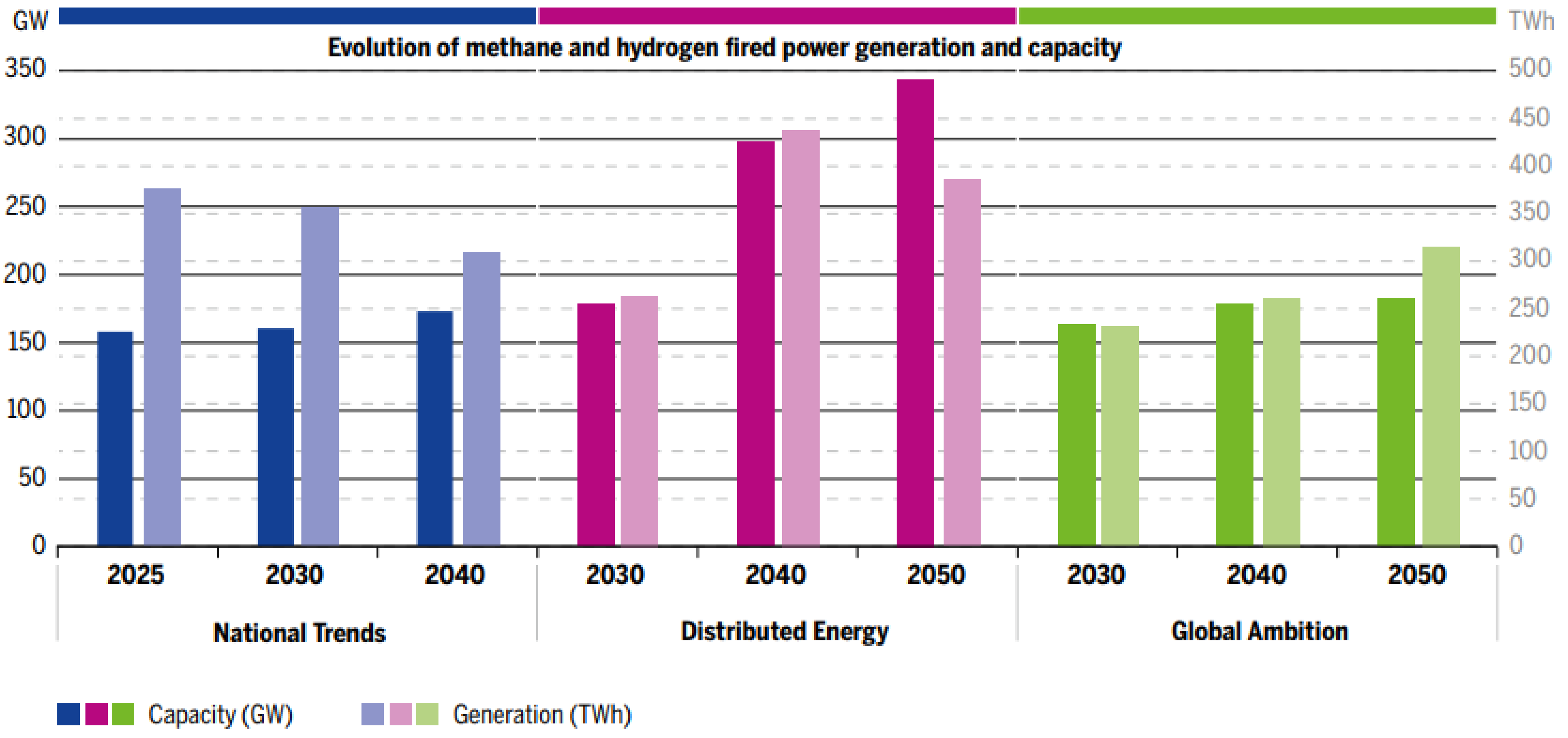


Production of methane declines over time. Biomethane becomes the main source between 2040 and 2050

Production of hydrogen increases substantially. Role of SMR/ATR reduces over time, electrolysis and imports increase. Hydrogen becomes the main gaseous energy carrier by 2050

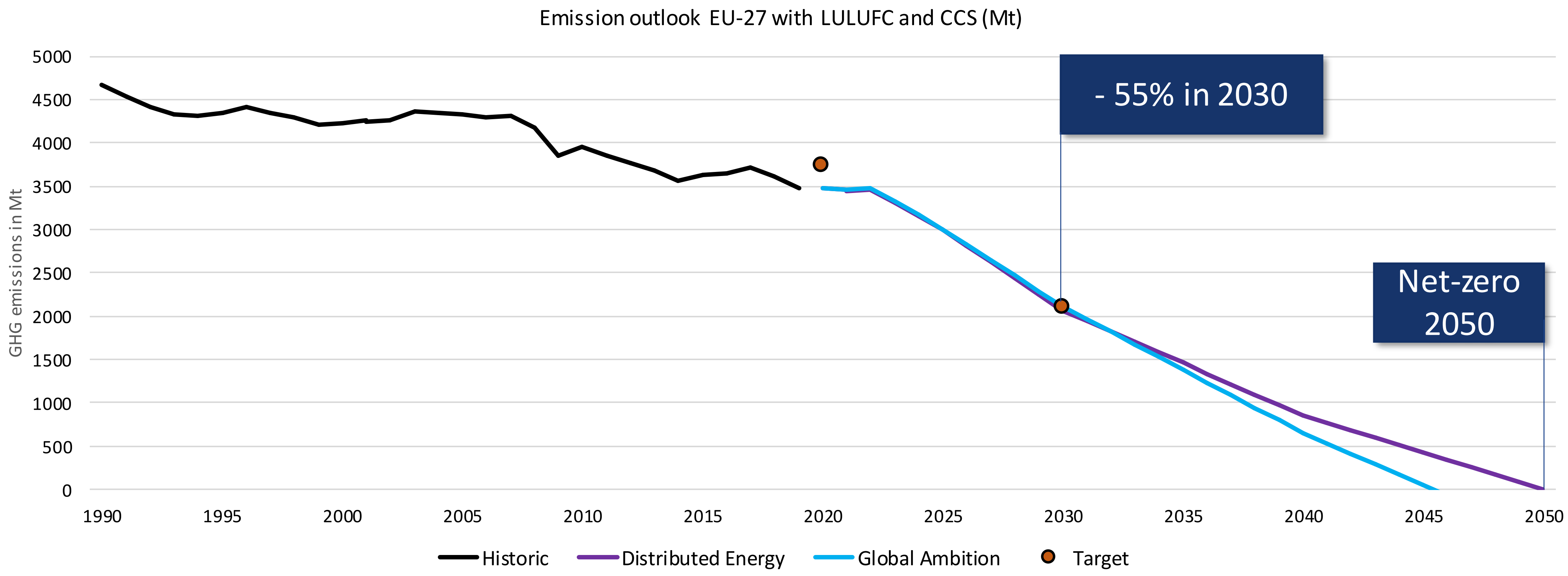
* before REPowerEU update for Global Ambition and Distributed Energy for 2030

Evolution of gas fired power generation



With electrification, gas demand for power becomes more seasonal and critical

COP 21 scenarios meet the 2030 targets and reach carbon neutrality by 2050*



Net zero can be achieved by 2050

* before REPowerEU update for Global Ambition and Distributed Energy for 2030

REPowerEU adjustment

Motivation

- 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 COP21 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.

TYNDP 2022 scenarios – after REPowerEU adjustment

National energy and climate plans (NECPs), national hydrogen strategies

National Trends 2030 - 2040

Policy Scenario **in line with national energy and climate policies**

2 x COP 21 scenarios

Benchmarked with EC Long-Term Strategy

+1.5°C target with 66.7 % probability

At least -55% GHG reduction in 2030; Carbon neutrality by 2050

Consideration of REPowerEU for 2030 (only H2+CH4)

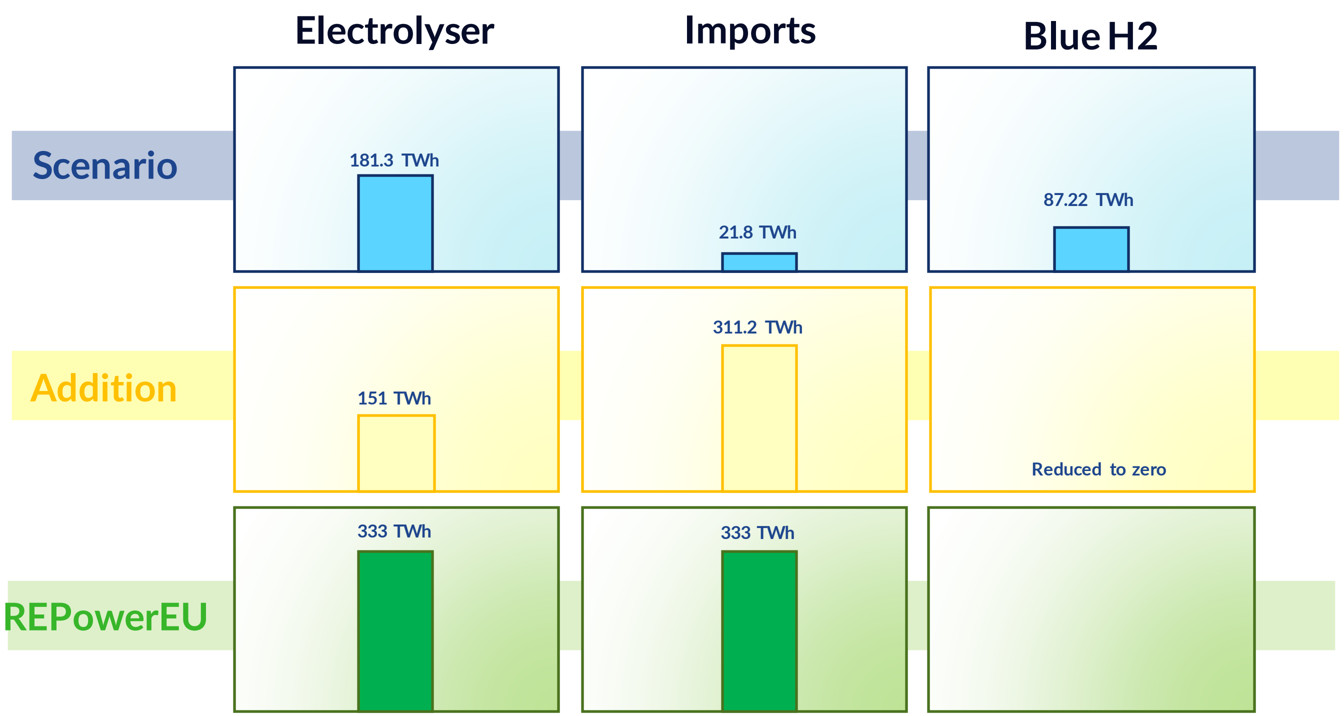
Distributed Energy 2030 - 2050

De-centralised approach: higher European energy autonomy, small-scale solutions, Prosumer

Global Ambition 2030 - 2050

Centralised approach: imports, large-scale renewables and decarbonisation

Reconstruction of hydrogen supply – Distributed Energy as example



First step: Adjustment of domestic H2 supply

REPowerEU Alignment: Domestic Supply

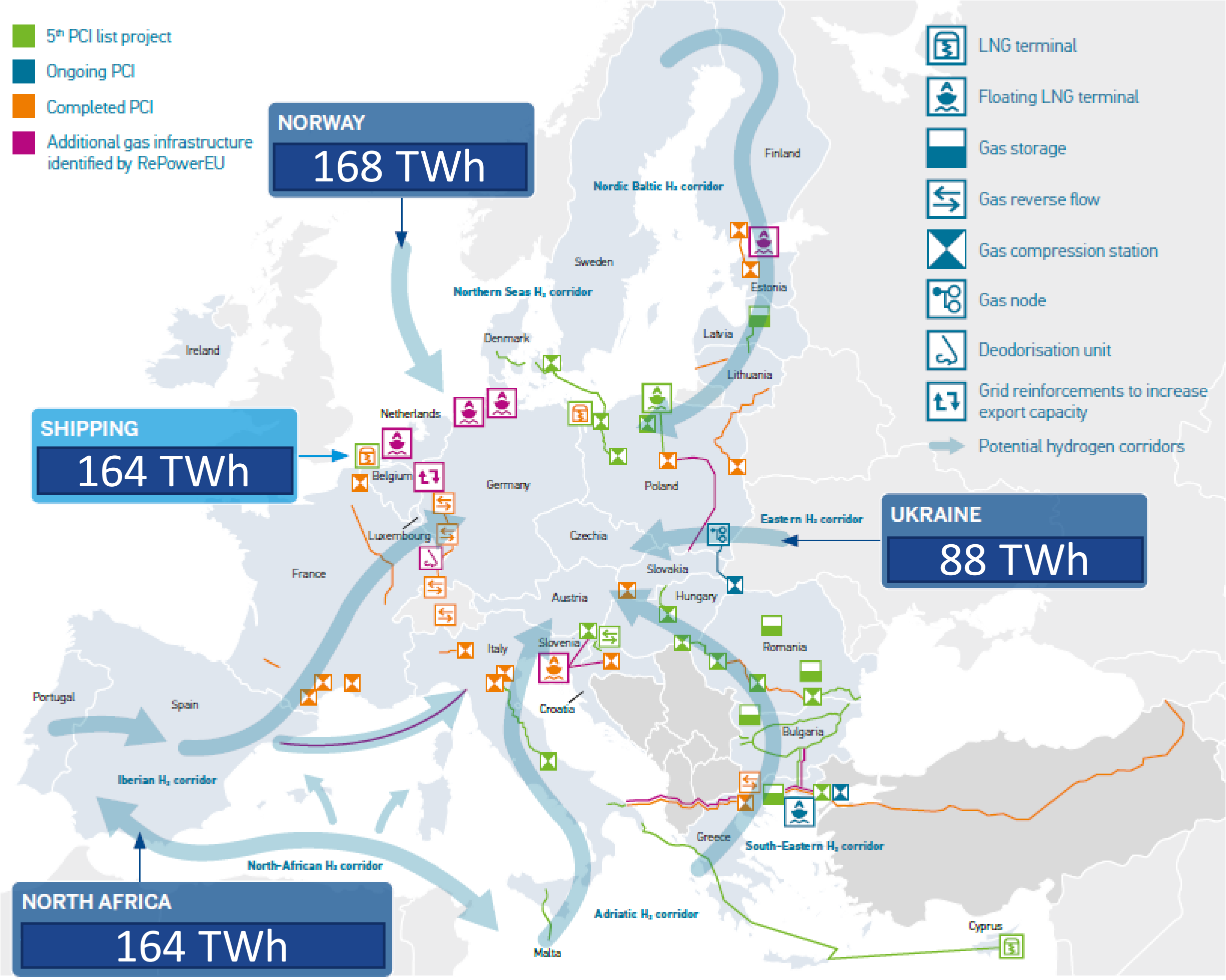
- This domestic supply adjustment aims to explore how to supply the 10 million tonnes of domestic renewable hydrogen
- This is done by
  - Building electrolysers through economic modelling
  - Building renewables (Onshore Wind, Offshore Wind, Solar PV) through economic modelling
- To keep the impact on the electricity system minimal, the additional hydrogen production was added via electrolysers producing renewable hydrogen connected to dedicated renewables only. The electrolyser capacity in 2040 sets the limit of the expansion.
- The renewables necessary are taken from the upper expansion limit per country for 2040 to maintain a consistent development of the RES deployment.

Second step: Adjustment of H2 import

Updated potential extra EU H2 supply in 2030 I/II

- The extra EU supply for the TYNDP 2022 scenarios was developed in mid-2021
- The methodology to assess the import potentials mainly assumed a conversion of methane pipelines with a certain conversion rate
- The assessed potential is not sufficient to comply with REPowerEU targets
- The project collection for the TYNDP 2022 showed submission of several projects linked to extra EU H2 import
- These projects align with the REPowerEU H2 import corridors
- **Updated TYNDP 2022 scenarios will rely on the project collection for TYNDP 2022**

Updated potential extra EU H2 supply in 2030 II/II

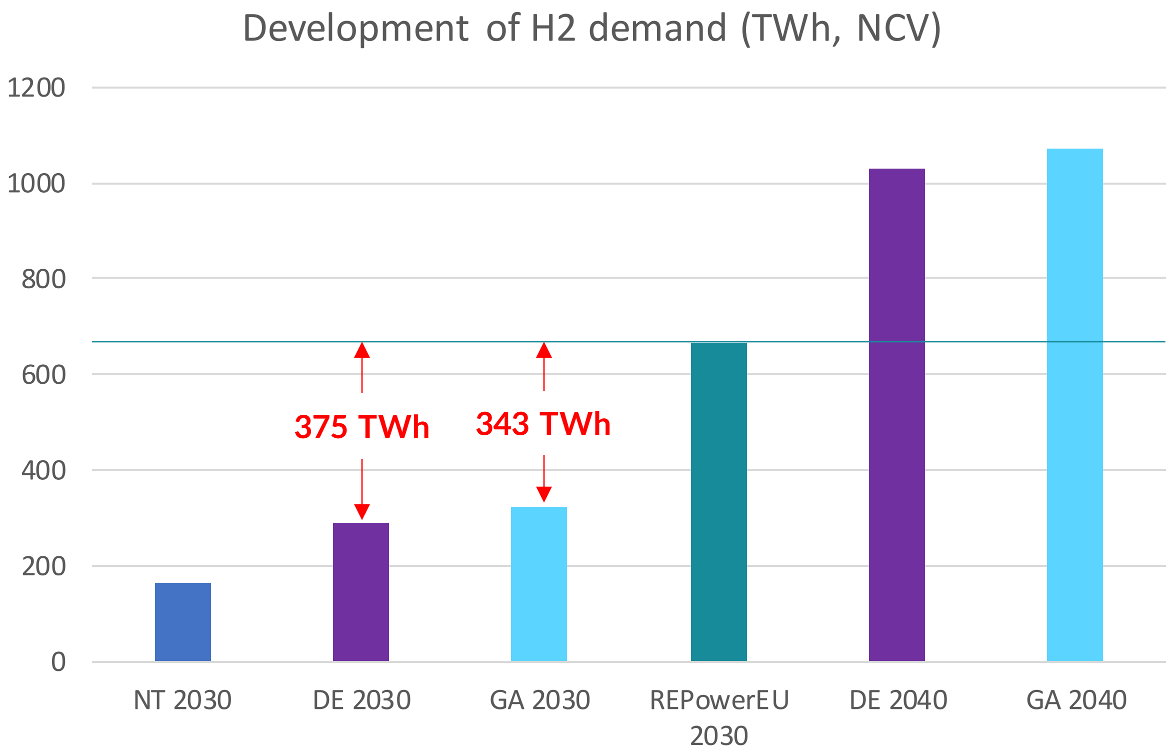


2022 scenarios: H_2 potential before adjustment to RePowerEU
Project collection: H_2 projects collected for TYNDP 2022

REPowerEU 2030 Target	
Pipeline	200 TWh
Shipping	133 TWh

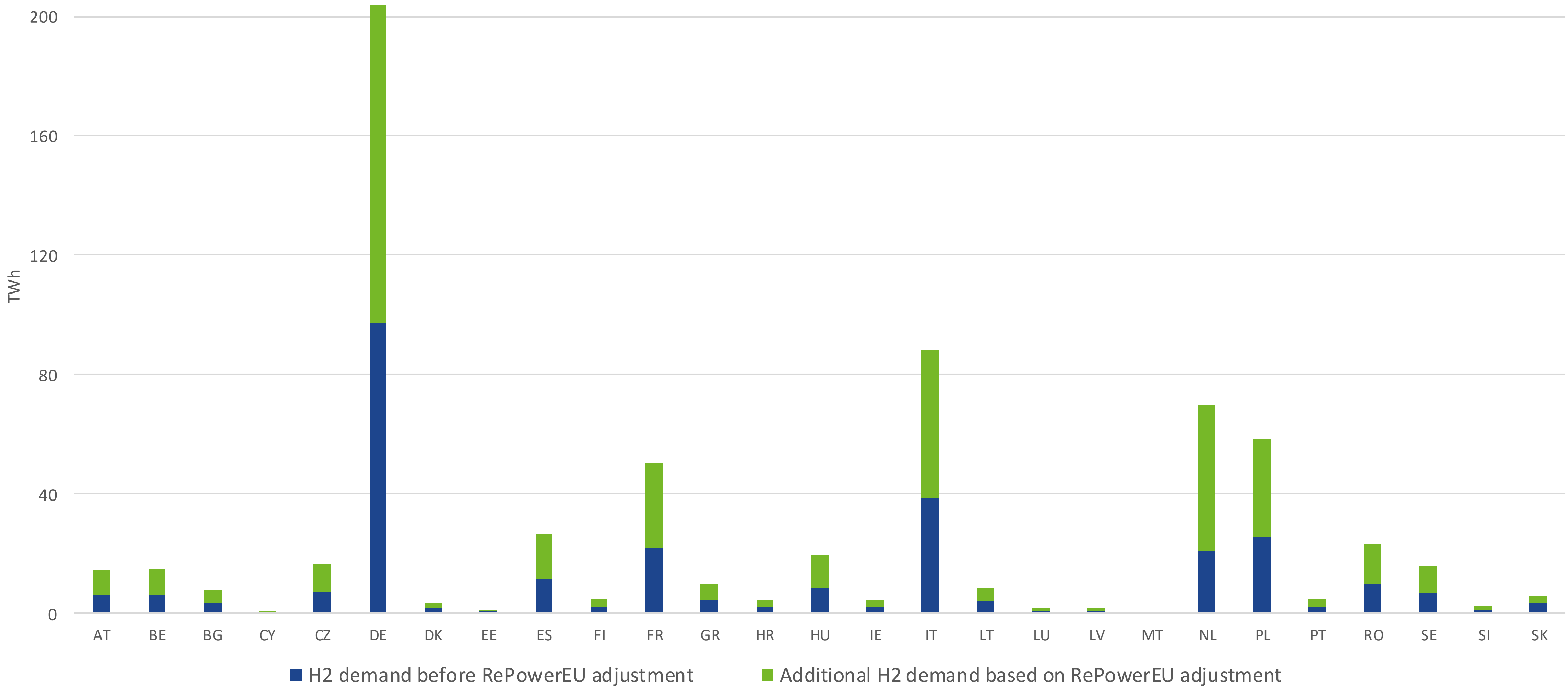
Third and last step: Adjustment of H2 demand

Adjustment of the H2 demand for GA and DE 2030



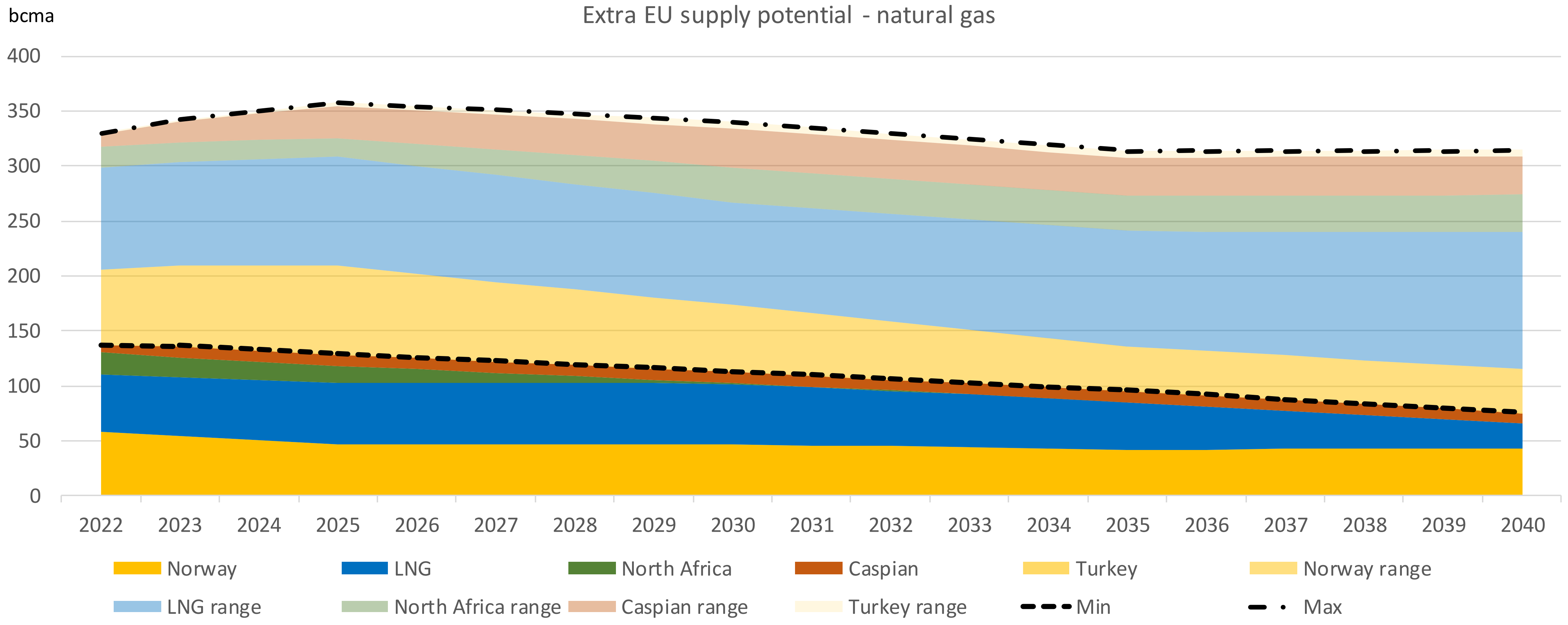
- The identified gap of the H2 demand is distributed proportionally among the countries, considering country specific views
- According to the REPowerEU plan, H2 will be used primarily in Industry and Transport. The added H2 demand is assigned to these two sectors with an 80/20 ratio (Industry/Transport)
- The added H2 demand is subtracted from the natural gas demand for these two sectors

Updated H2 demand - Distributed Energy 2030



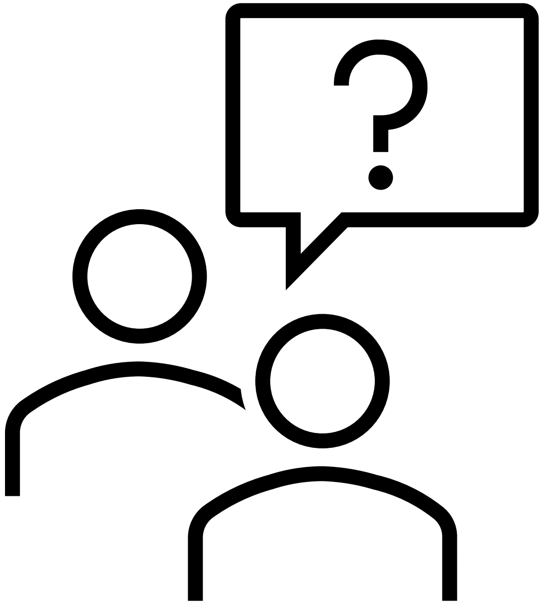
Furthermore: Adjustment of CH_4 import potential

TYNDP 2022 scenarios natural gas import potential (w/o Russia)

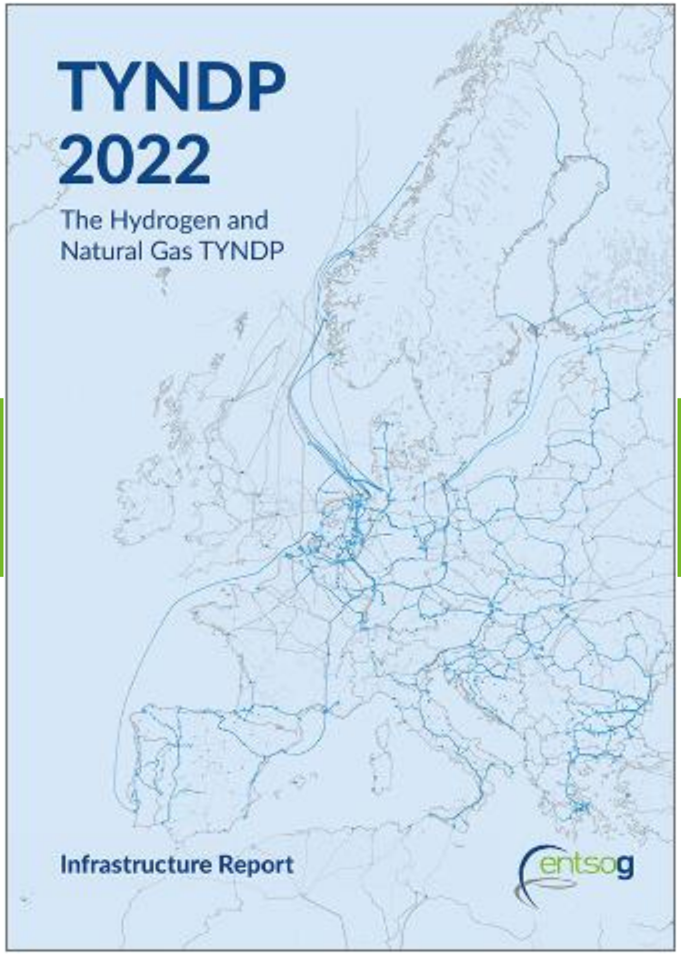


Supply potentials of TYNDP 2022 scenario are considered without Russia

Q&A



Infrastructure Report



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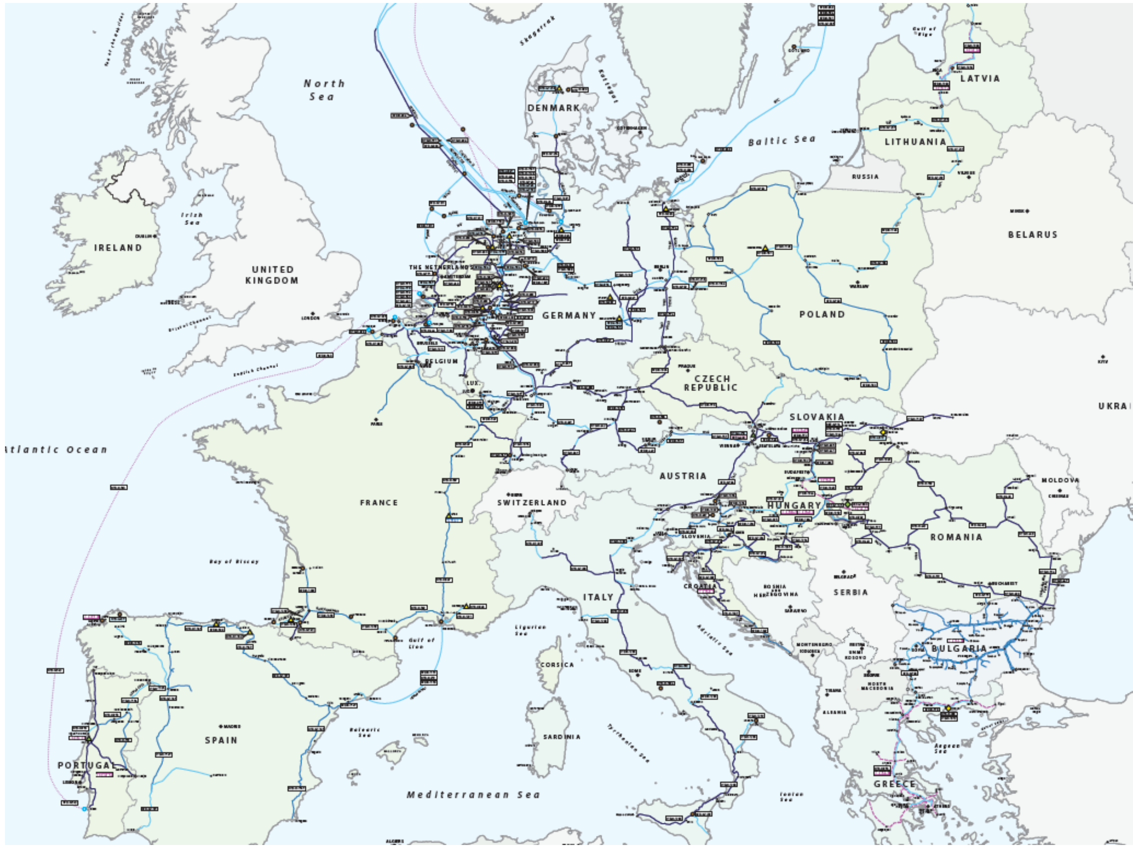
TYNDP 2022

TYNDP provides a view of the future gas developments, while also taking into account ongoing decarbonisation efforts and the need to reduce Russian gas supply dependence.



Following the TEN-E revision, published in June 2022. This TYNDP – for the first time ever – is providing a particular focus on the hydrogen network development

Projects

Project Collection TYNDP 2022

Project Collection Process and administrative and technical inclusion criteria as defined in the Practical Implementation Document (PID) for TYNDP 2022:

- Projects have been submitted under 7 projects categories
- Project falling under natural gas categories (TRA, UGS and LNG) needed to be H2-ready or contributing to the fuel switch within a country/area

Initial Project Collection phase:

- 18 October - 12 November 2021
- Followed by a comprehensive check and correction phase
- Coordinated precheck by ACER, NRA's and EC

Additional project collection:

- 30 May - 24 June 2022
- Include additional ad-hoc projects aiming to reduce Russian supply dependence

Complemented with new and updated projects from the first PCI/PMI call under the revised TEN-E

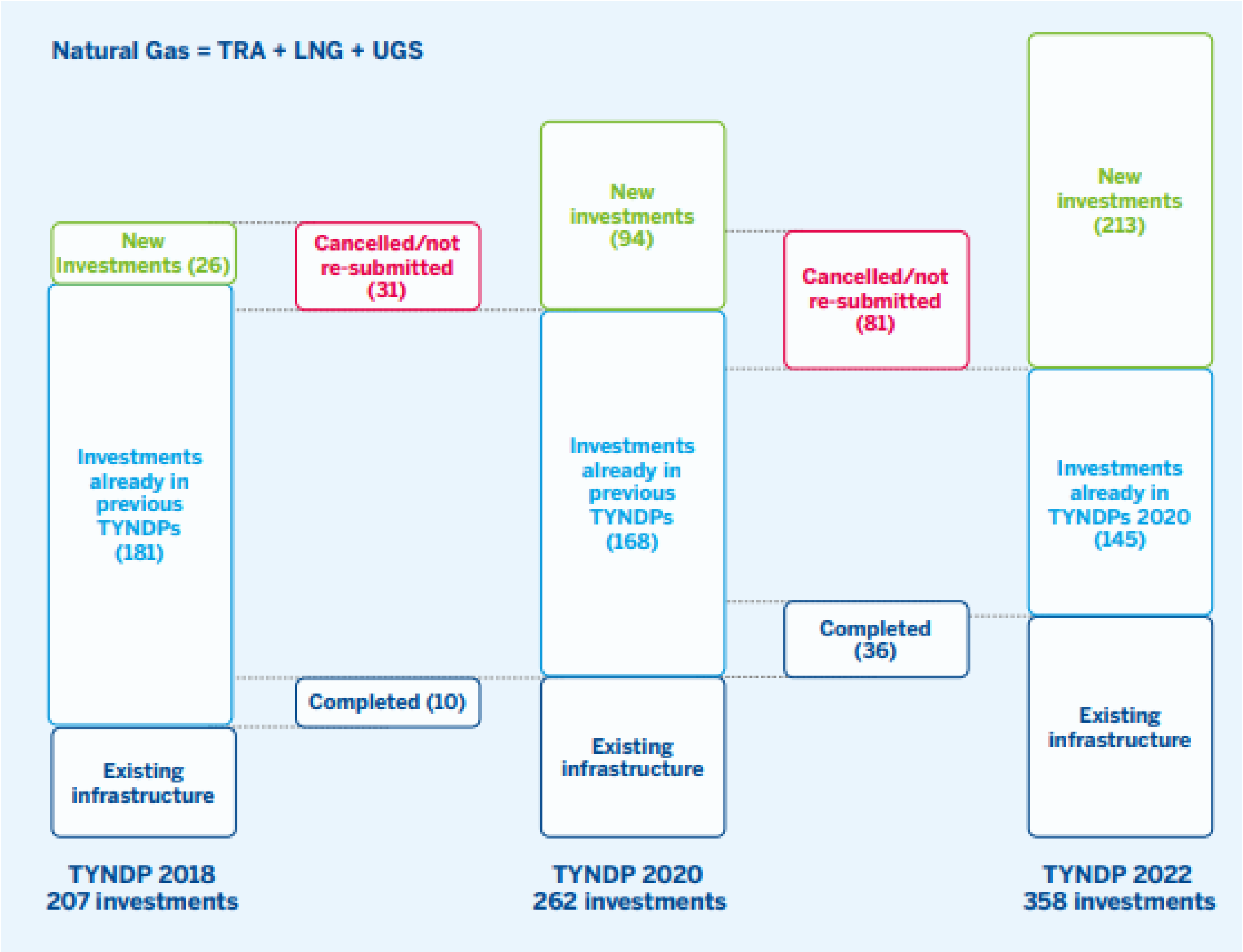
Eligible Project Categories TYNDP 2022

1. Gas Transmission pipeline including Compressor Stations (TRA)
2. Reception and storage and regasification or decompression facilities for liquified naturals gas or compressed natural gas (LNG)
3. Underground storage facility (UGS)
4. New or repurposed infrastructure to carry hydrogen (HYD)*
5. Projects for retrofitting infrastructure to further integrate hydrogen (RET)
6. Biomethane development projects (BIO)
7. Other infrastructure related projects (OTH)

(Items 4–7:) NEW
Replacing former ETR Category (TYNDP 20)

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

Evolution



81 Investments cancelled or not resubmitted

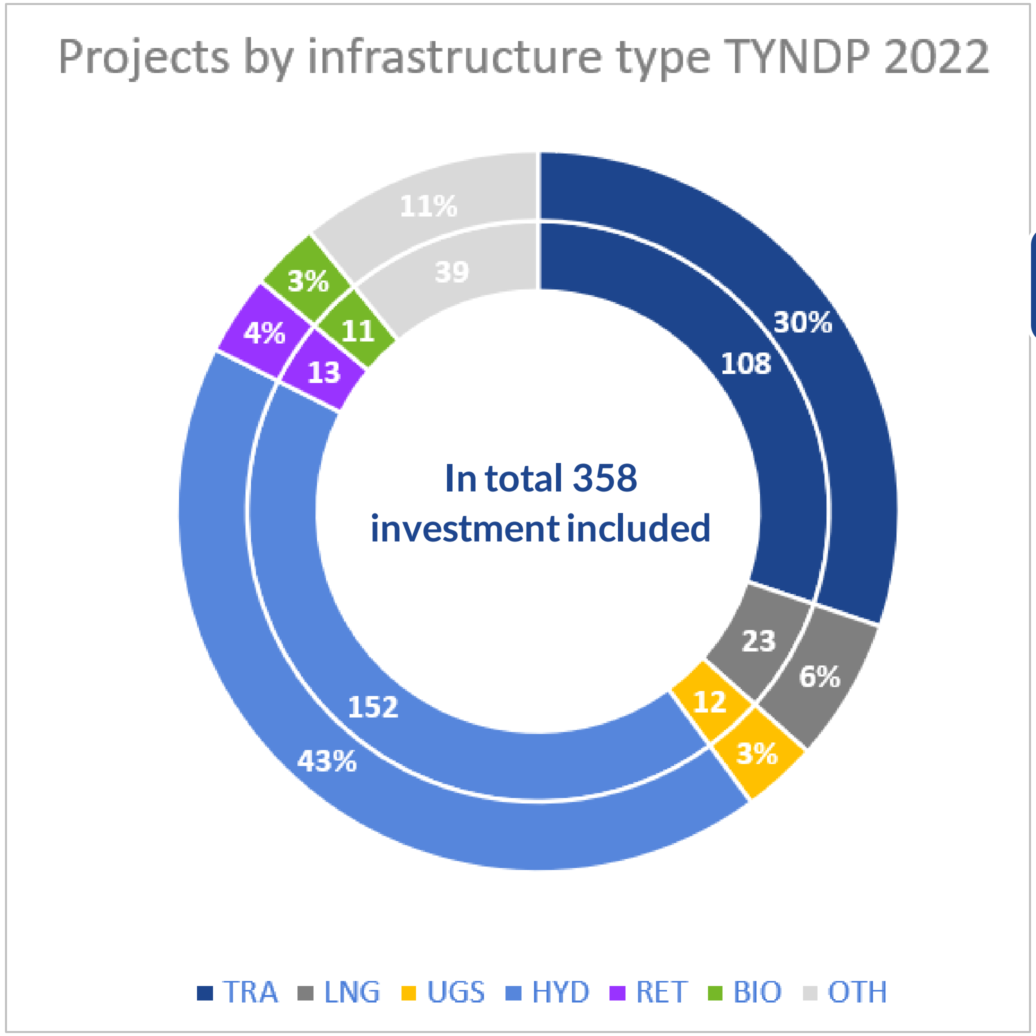
36 Investments completed in the meanwhile

213 new Investments

Commissioned Projects

36 Investments completed in the meanwhile + 25 investment with commissioning year 2023 (FID or advanced)

Overview Submissions

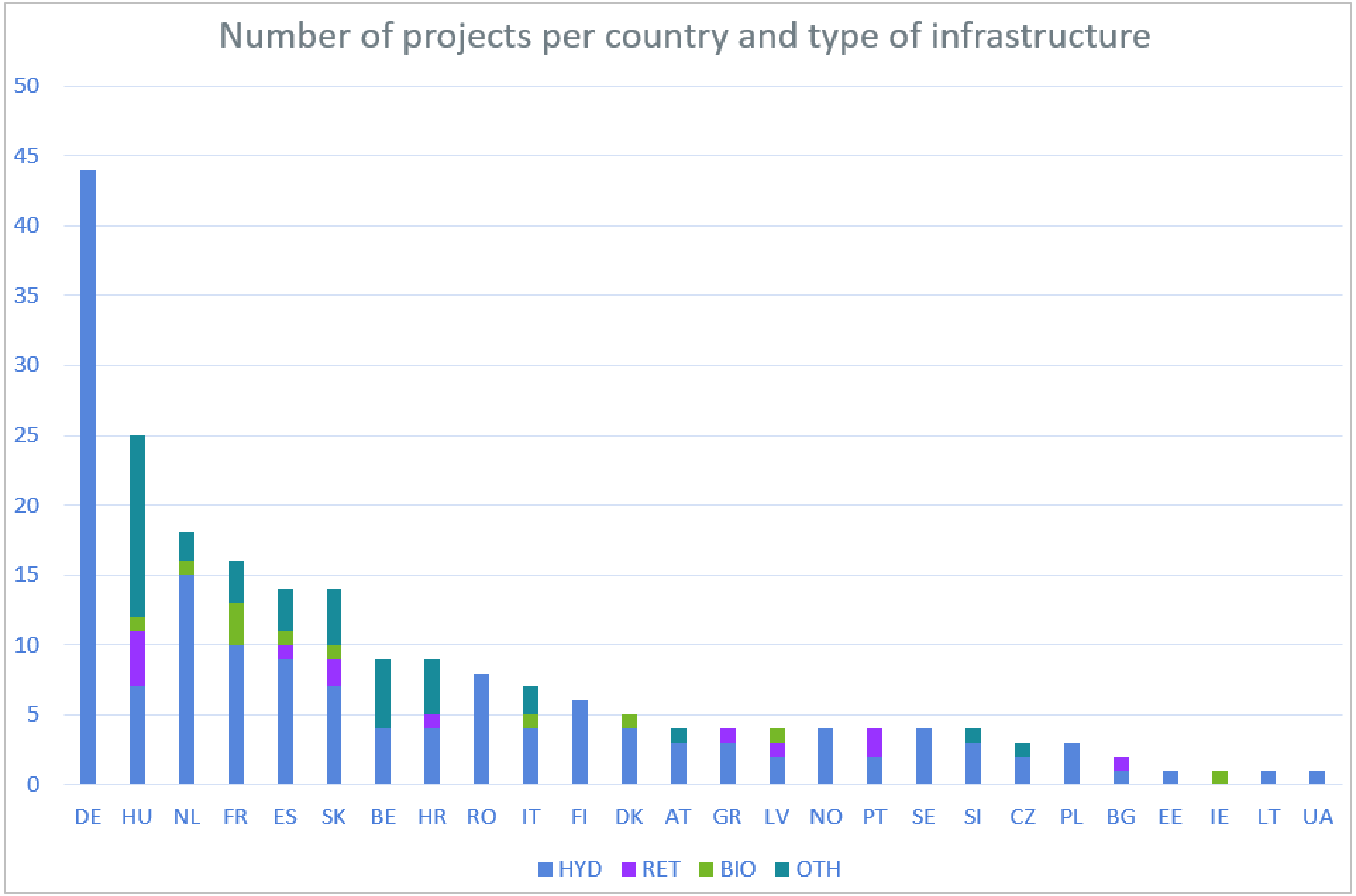


43 %

Highest share recorded in category HYD

H_2

Overview new categories per country



Infrastructure Levels

Infrastructure levels for Natural gas projects

Natural gas infrastructure levels based on **project maturity status**

- **3** Natural gas infrastructure levels
- Allows to consider the evolution of natural gas infrastructure in the TYNDP system assessment

Existing infrastructure level	Advanced infrastructure level	PCI infrastructure level
	Advanced non-FID projects	Non-FID projects with 5th PCI label
FID projects commissioning < 31/12/2022	FID projects	FID projects
Existing infrastructure	Existing infrastructure	Existing infrastructure

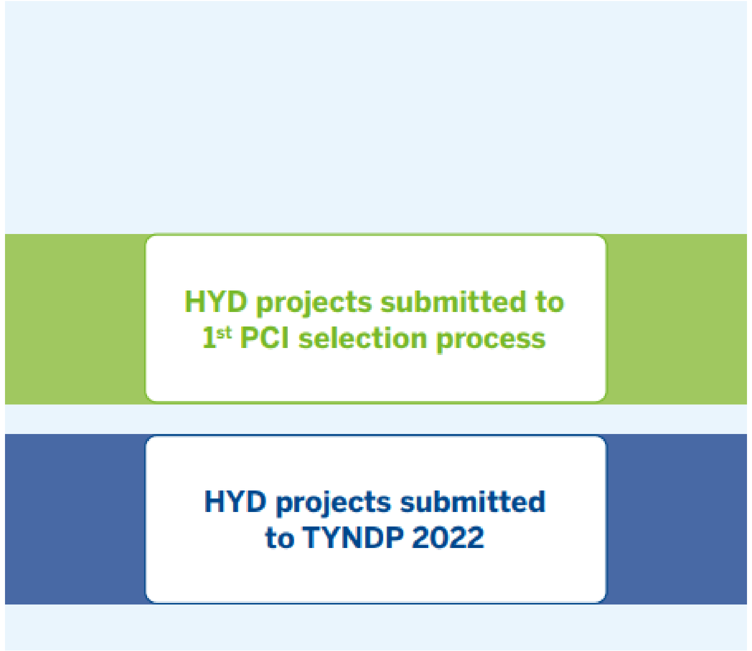
\+ Project maturity status –

Infrastructure levels for hydrogen infrastructure projects

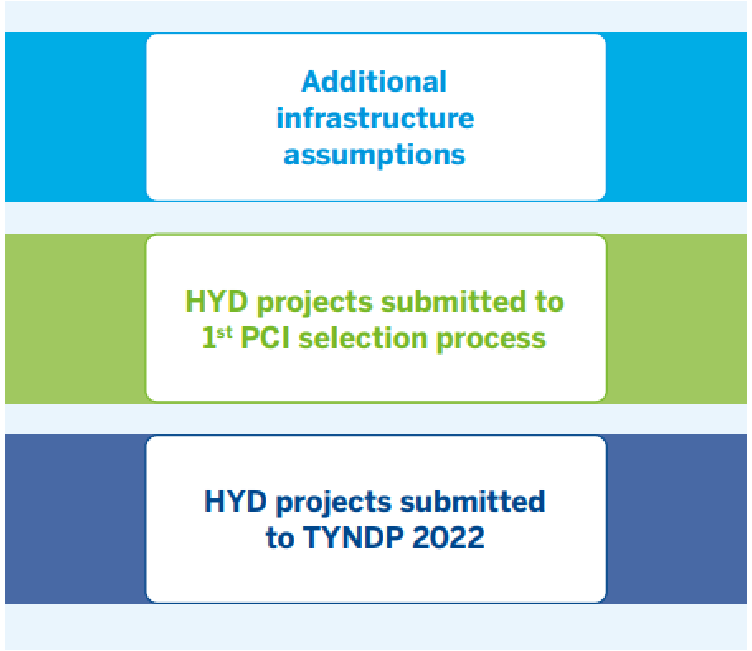
Hydrogen infrastructure levels were included **for the first time as part of TYNDP**

- **2 contrasted Hydrogen** infrastructure levels
- Considers **both new** hydrogen infrastructure and **repurposed** infrastructure from Natural gas

Hydrogen infrastructure level 1:



Hydrogen infrastructure level 2:

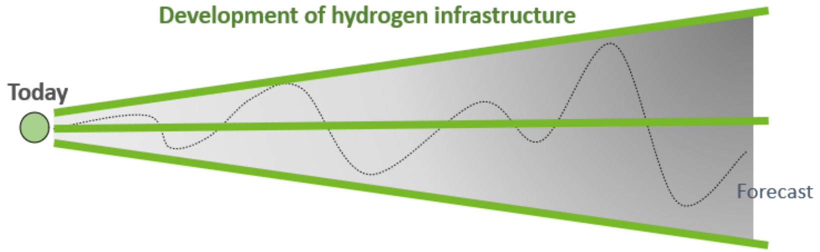


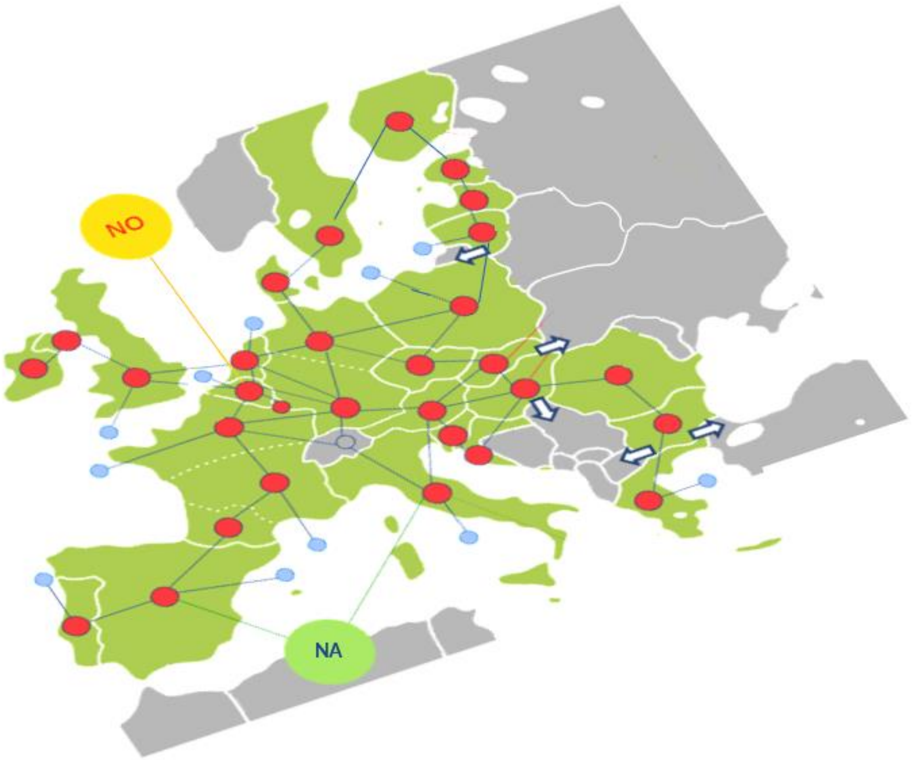
Infrastructure levels for hydrogen infrastructure projects

Contrasted infrastructure levels

Hydrogen ⟷ **Natural gas**

Impact of the repurposing of natural gas infrastructure to hydrogen is also considered in the infrastructure levels





Hydrogen infrastructure development is highly dependent on the evolution of hydrogen demand – supply

Infrastructure levels for hydrogen infrastructure projects

Type of hydrogen infrastructure considered within the infrastructure levels

- **Transmission infrastructure**
- **Storage infrastructure**
- **Hydrogen imports (via pipeline and liquefied imports)**

Infrastructure level 1:

- ✓ Lower extra-EU import capacities
- ✓ Lower LH2 import capacities
- ✓ Lower cross-border capacities for some EU countries
- ✓ Lower storage capacities

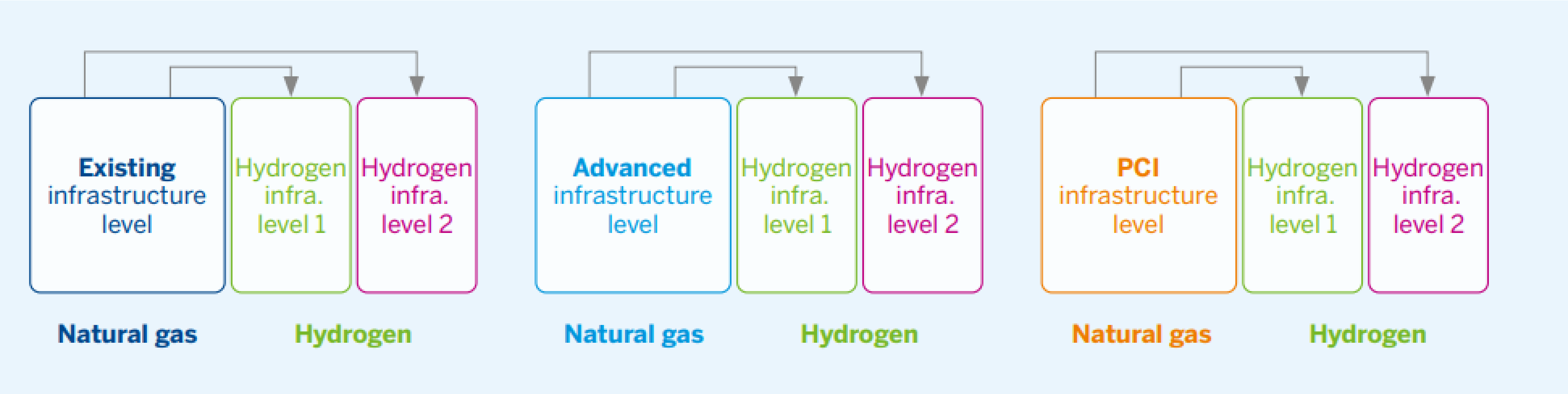
Infrastructure level 2:

- ✓ Higher extra-EU import capacities
- ✓ Higher LH2 import capacities
- ✓ Slightly higher cross-border capacities within some EU countries
- ✓ Higher storage capacities

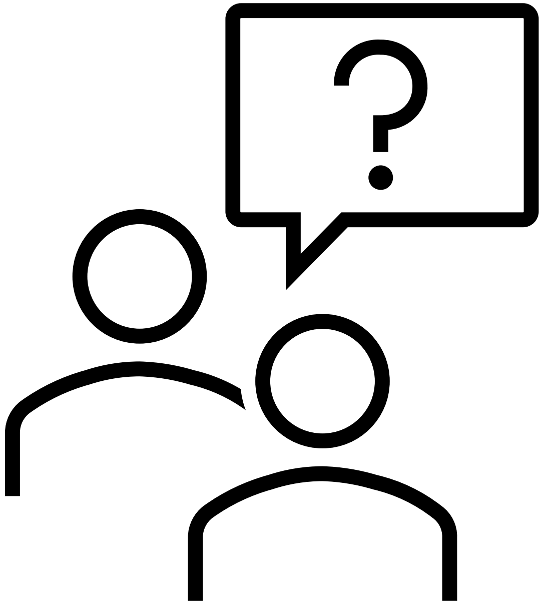
All information available in the **Annex C of TYNDP 2022**

Infrastructure levels in the TYNDP 2022

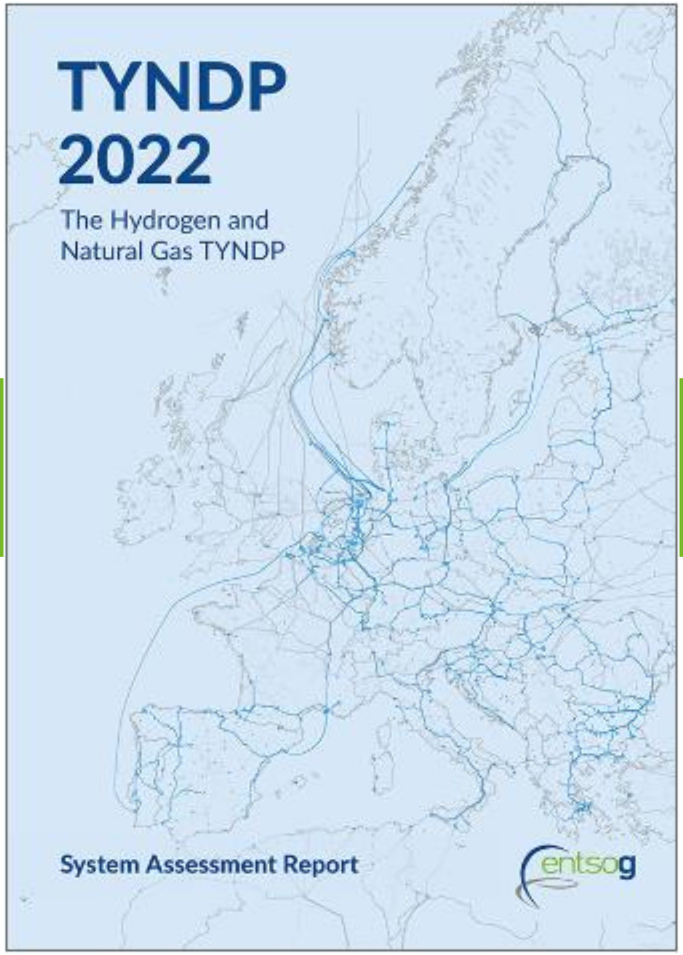
Each natural gas infrastructure level is combined with both hydrogen infrastructure levels, this allows for a broader and more robust analysis on the future evolution of natural gas and hydrogen infrastructure projects.



Q&A



System Assessment



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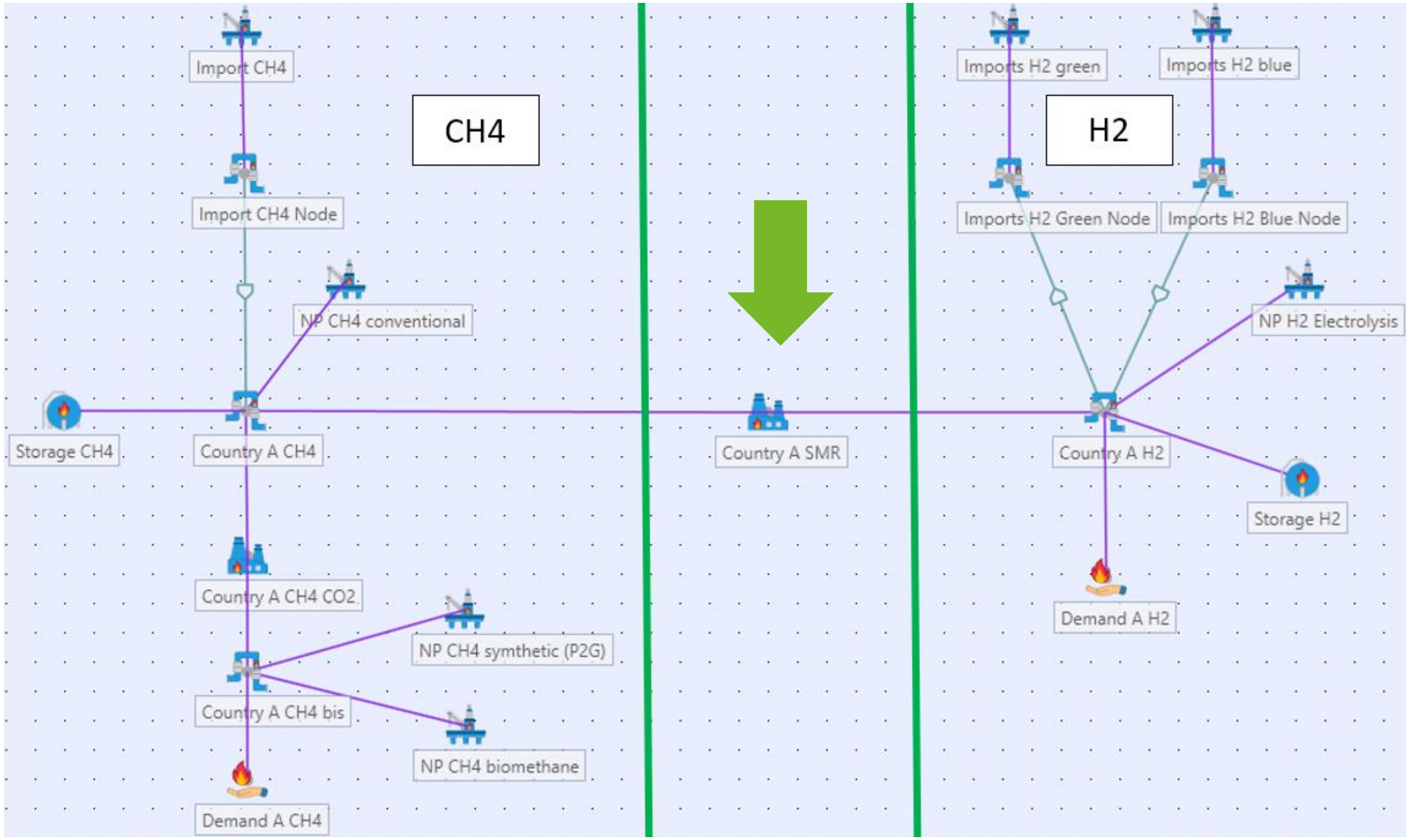
Topology

Dual gas infrastructure: Methane and Hydrogen

In TYNDP 2022 there is **only one, dual gas topology** used for the assessment of both Methane and Hydrogen. **The modelled Methane and Hydrogen grids are connected only though production of hydrogen from methane (named here SMR).**



Constraints & objective function

Constraints in the model

There are two types of constraints in the model:

- **Hard constraints**: constraints that the model has to respect whatever the consequences (even if it leads to the absence of solution)

Capacity, working gas volume, maximum supply potential…

- **Soft constraints**: parameters that the model will incorporate to find the "best" solution. They are "constraints" because they put some restrictions on what can be the best solution. But they are also "soft" because the model can still use the related quantity, even if it increases the cost of the solution. These soft constraints are price/cost related.

Cost of curtailment, storage target penalty, CO_2 cost, supply price, infrastructure residual costs…

The objective function

The **objective function** is defined, for a given simulation, as the **sum of all costs in the system**.

Objective function = ***SUM for all supplies (unitary cost of supply * related supply quantity)***

+ SUM for all arcs (unitary residual cost * related flow)

+ unitary CO2 cost * CO2 emissions

+ SUM for all countries (unitary curtailment cost * related curtailed quantity)

+ SUM for all storages (unitary target penalty* quantity below target)

Understand "SUM" as being a sum for all concerned objects and for all periods. Hence there is not one objective function per period, but only one objective function for the full simulation horizon.

The **parameters**, of which values are known before the simulation, are in **blue**.

The **variables**, of which values will be known after the simulation, are in **purple**.

Note: The objective function integrates all the soft constraints.

Results: optimization of the objective function

The “best” solution is found through the mathematical minimization of the objective function under constraints, which is formulated like this

Minimize (objective function) **subject to** (hard constraints)

- There is no closed-form formula that gives the solution. It is found through an optimization program.
- Most of the times **there is not 1 best solution but 1 best solution among many.** This is why it is important to understand which problem you are trying to solve (that is, **which question you are asking**), and not to extract the wrong results (flows) which could lead you to **over-interpret your answer**.

If you have one country A connected to two suppliers S1 and S2 with infinite capacity and the same price.

There is an infinity of different “best solutions”. The flows S1=>A and S2=>A are irrelevant.

The only information is that demand in country A can be satisfied.

Merit Order

Merit order

The way to create a merit order is to affect different costs/prices to soft constraints, and hence to weigh differently the quantities in the objective function.

(The problem “Minimize (10x+y)” will not produce the same result as “Minimize (x+10y)”)

There are 5 categories of costs in the following ranking:

(1) Curtailment
(2) Storage target penalty
(3) Carbon intensity
(4) Russian pipeline gas supply to minimize Russian gas usage
(5) Residual incremental costs:
   - **Supply:** import and national production prices
   - **Infrastructure:** no tariffs but incremental residual costs
   - **SMR costs:** residual incremental cost to induce harmonized/cooperative behaviors between SMRs (production of hydrogen from methane), along the different periods and with blue hydrogen imports

Assumptions' consequences

- **Curtailment, and any results derived from it,** is the result of imbalances between supply and demand due to hard constraints (supply potential, capacities, …)
  - **The following results are not dependent on any price:** Curtailment rate, SLID, SLCD
- Once **curtailment is reduced** to the minimum, and **storage targets are met** as much as possible, to choose between several possible flow patterns, **the solver will minimize the carbon emissions**
- Pipelines are all treated the same way with residual incremental costs to induce an average utilization of equivalent routes (while flow rates are not an indicator of the TYNDP)

- As the TYNDP's system-wide assessment is the basis for project-specific CBA, project benefits refer to
  - **Curtailment reduction** (reference, disruption, SLID, SLCD)
  - **CO2 emissions reduction**

Simulation Indicators

Simulation indicators

- **Curtailment** (in GWh/d) is an output of the simulation. **Curtailment rate** is given by the formula:

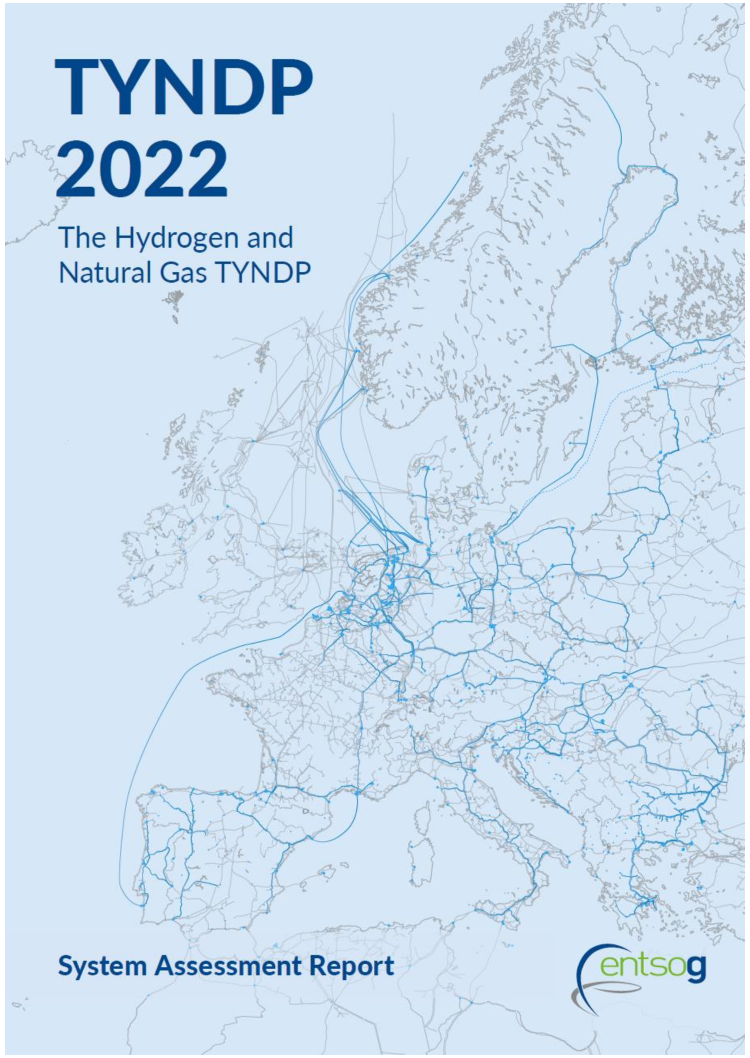
$$Curtailment\ rate = \frac{Curtailed\ demand}{Demand}$$

- The **SLID** is the "**Single Largest Infrastructure Disruption**" in a given country (excluding storage and national production). It applies only for the **CH4 infrastructure**. The SLID is computed on a **peak day** situation, with the associated supply and national production in this configuration.
- The **SLCD** is the "**Single Largest Capacity Disruption**" **including storages and electrolysis capacity** (National Production). It applies only for the **H2 infrastructure**. The SLCD is computed on a **peak day** situation, with the associated supply and national production in this configuration.
- **CO2 emissions** (in tons) is an output of the simulations to derive the CO2 savings.

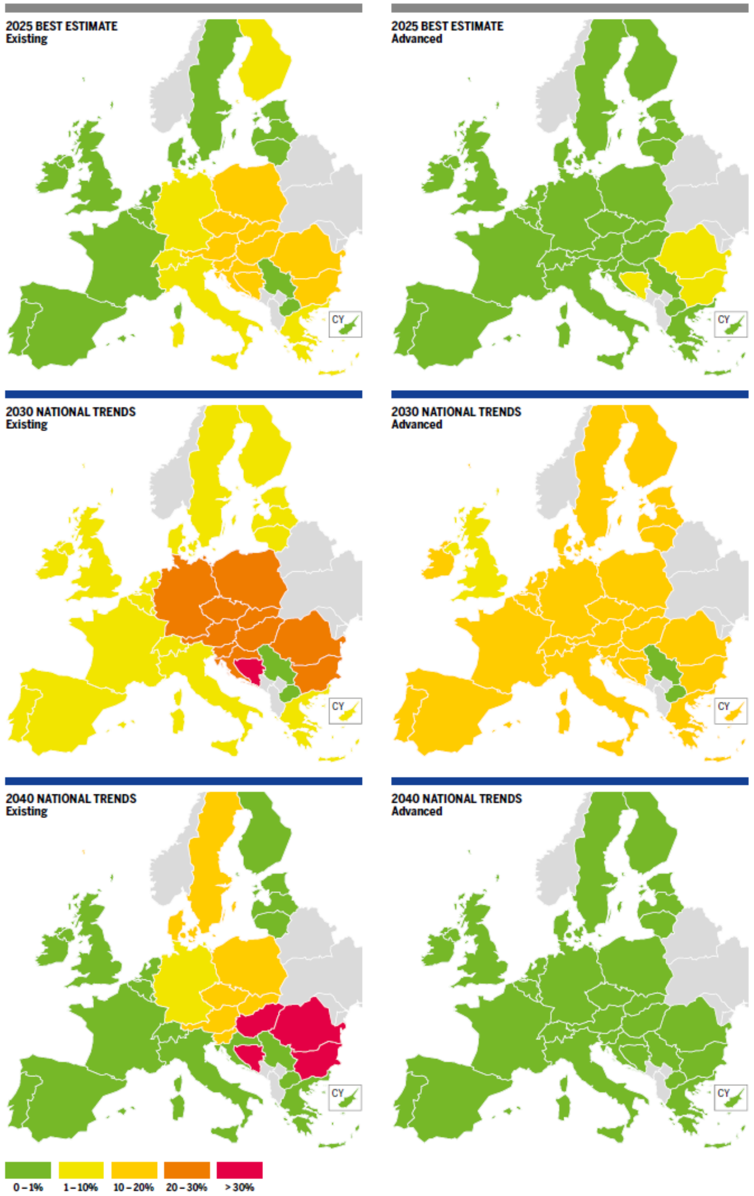
System Assessment Results

System Assessment Report

- Sustainability and independence
- Security of supply needs
- Sustainability: Yearly CO_2 emissions 2030, 2040 and 2050
- Supply mixes under peak demand and yearly demand
- Reference case (no disruption)
- Russia Methane Supply Disruption
- North Africa Hydrogen Supply Disruption
- Norway Hydrogen Supply Disruption
- Ukrainian Hydrogen Supply Disruption
- Liquified Hydrogen Supply Disruption
- Single Largest Infrastructure Disruption (SLID) - Methane
- Single Largest Capacity Disruption (SLCD) - Hydrogen



Methane independence from Russia



Distributed Energy and Global Ambition scenarios show no need for Russian gas in 2030 and 2040 to satisfy demand. However, in policy scenarios that are in line with national energy and climate policies (National Trends and Best Estimate), a supply disruption of Russian pipeline gas in many cases leads to methane demand curtailment.

Yearly Supply Mixes: Methane

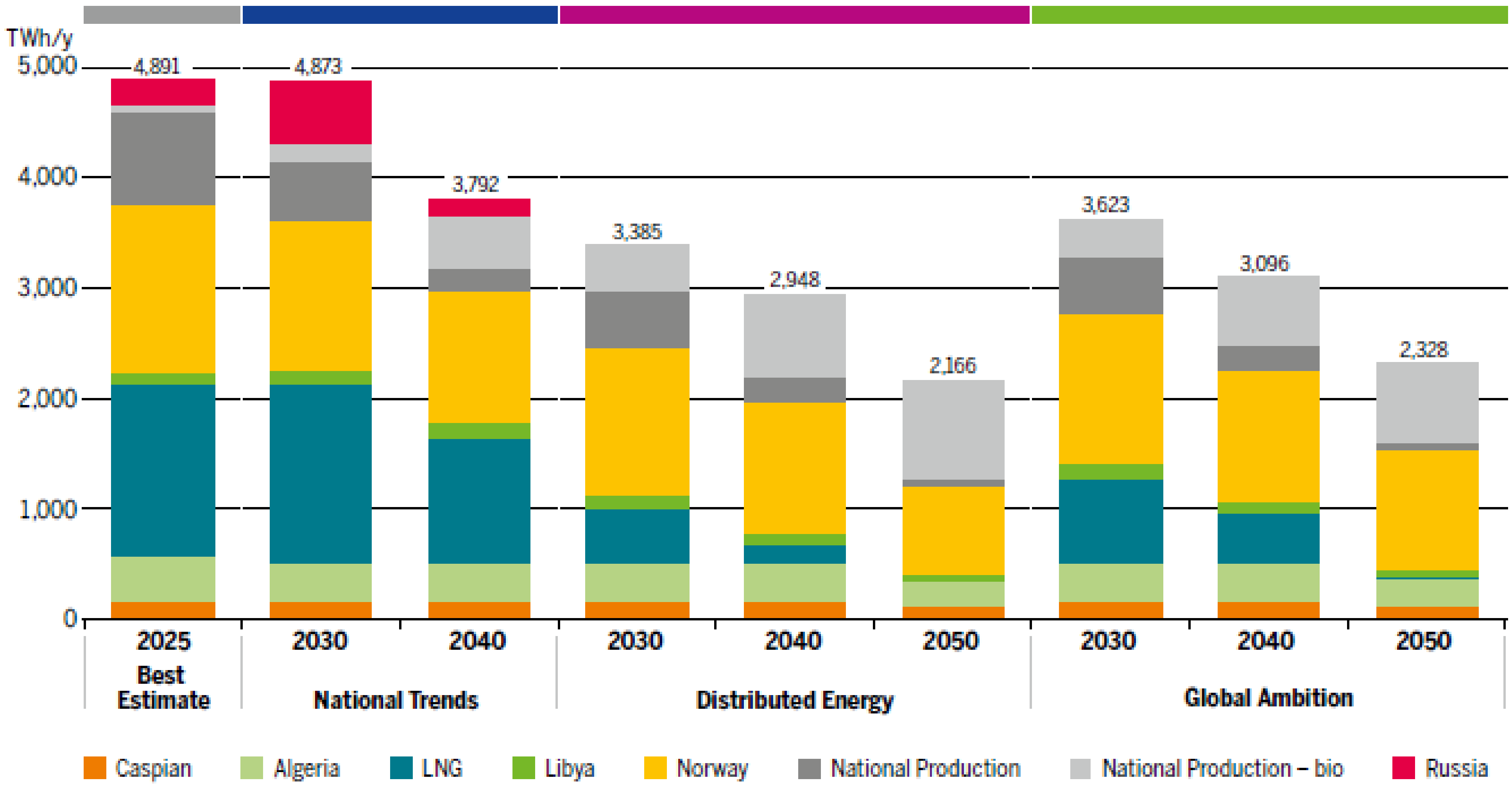


Figure 34: CH_4 Yearly Supply Results in Advanced CH_4 Infrastructure H_2 Level 1

Peak Day Supply Mix: Methane

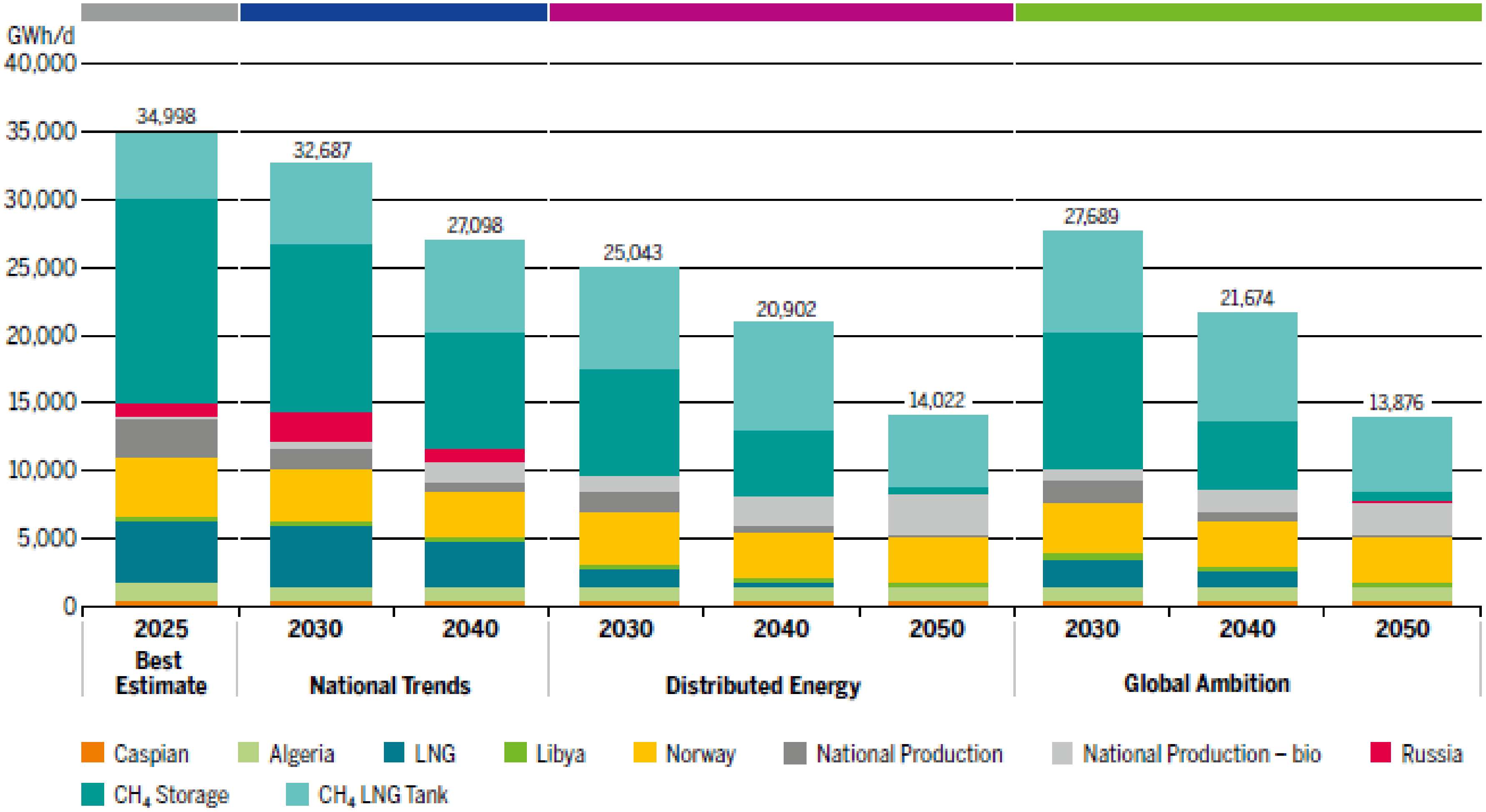
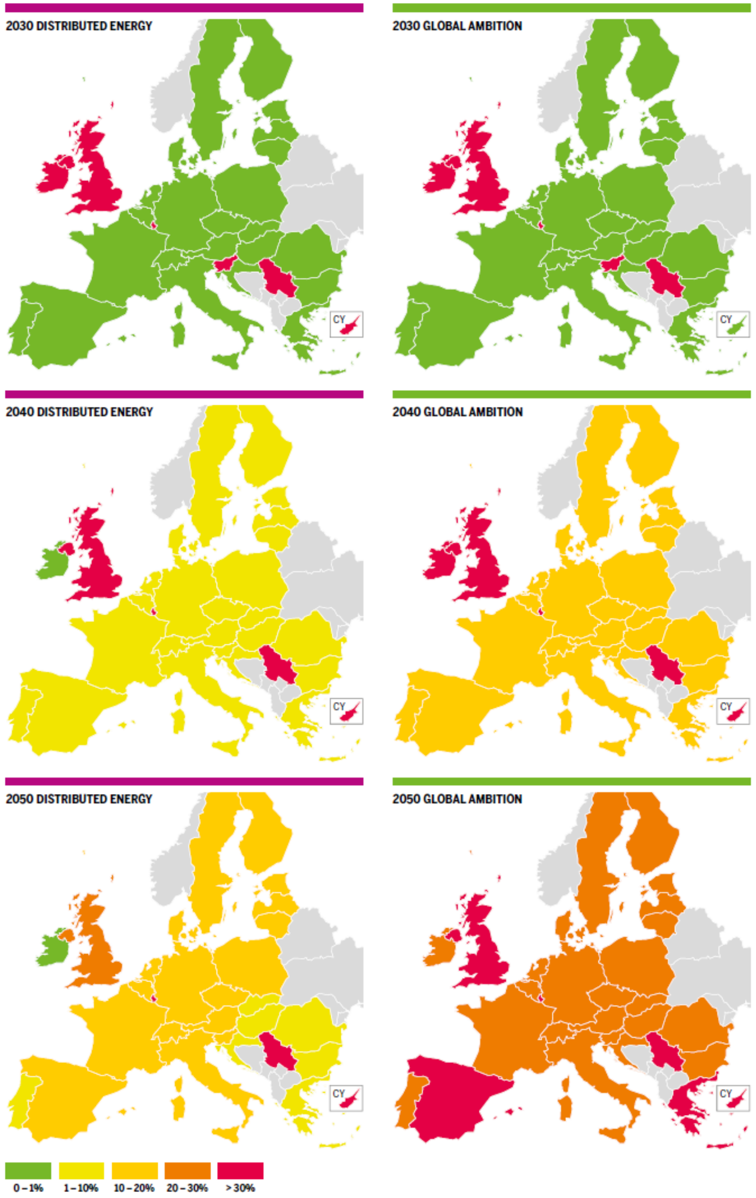


Figure 25: CH_4 Supply Results for Peak Demand in Advanced CH_4 Infrastructure H_2 Level 1

Hydrogen reference case (no disruption) – Example of H2 level 1

Seasonality of hydrogen production and demand in combination with **limited infrastructure** leads to **hydrogen demand curtailment**.



Yearly Supply Mixes: Hydrogen

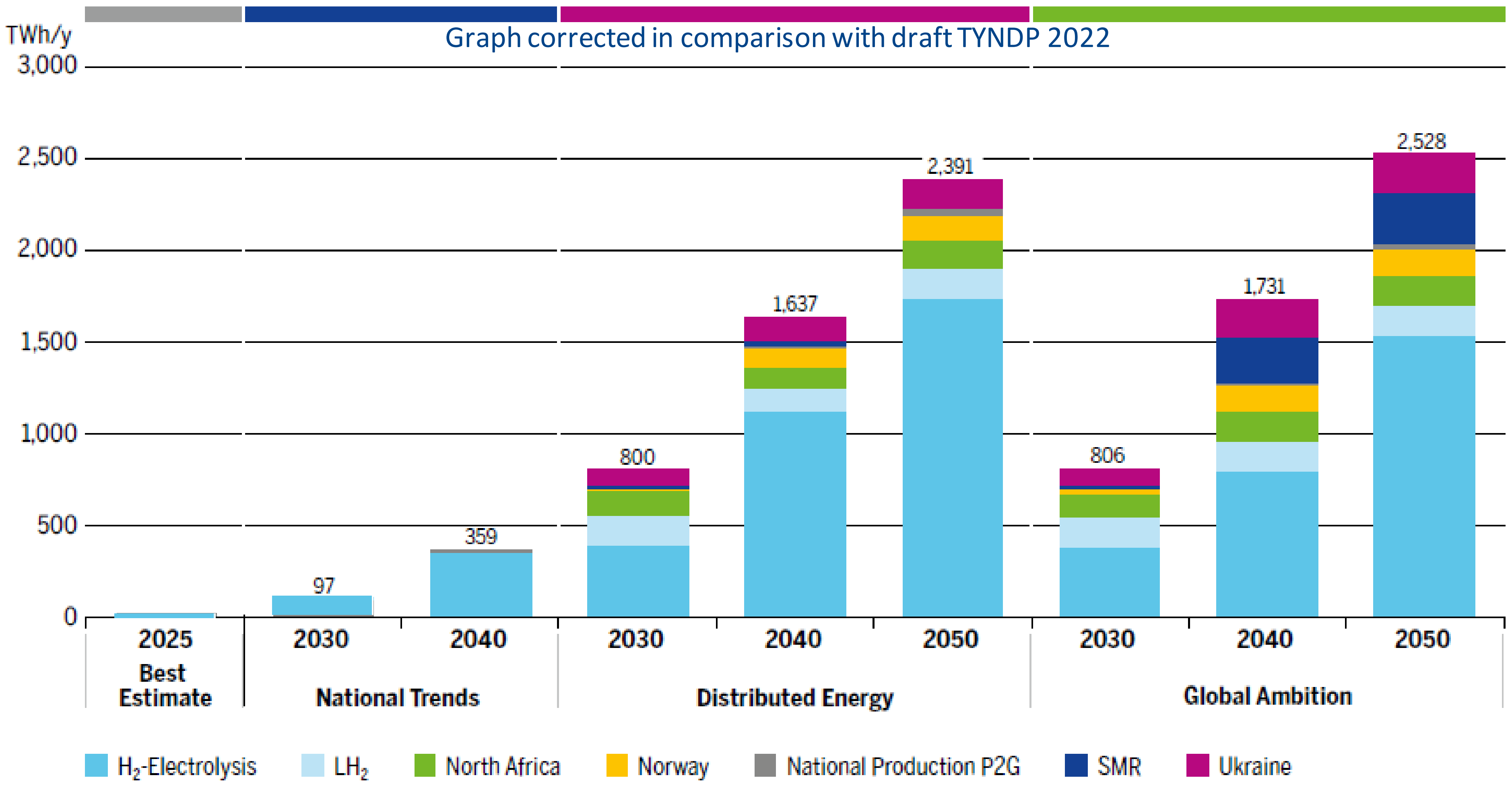


Figure 37: H_2 Yearly Supply Results in Advanced CH_4 Infrastructure with H_2 Level 1

Peak Day Supply Mix: Hydrogen

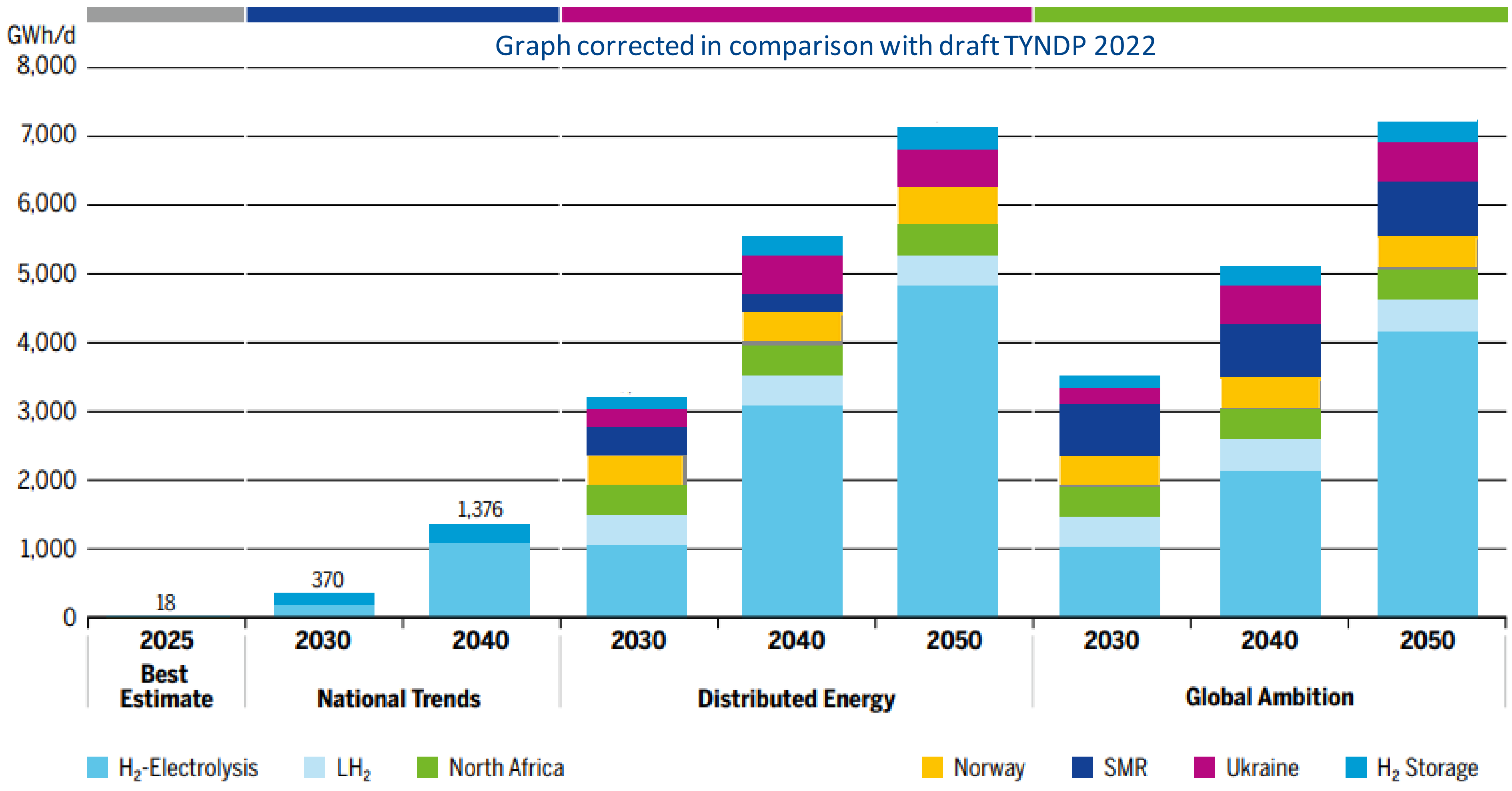
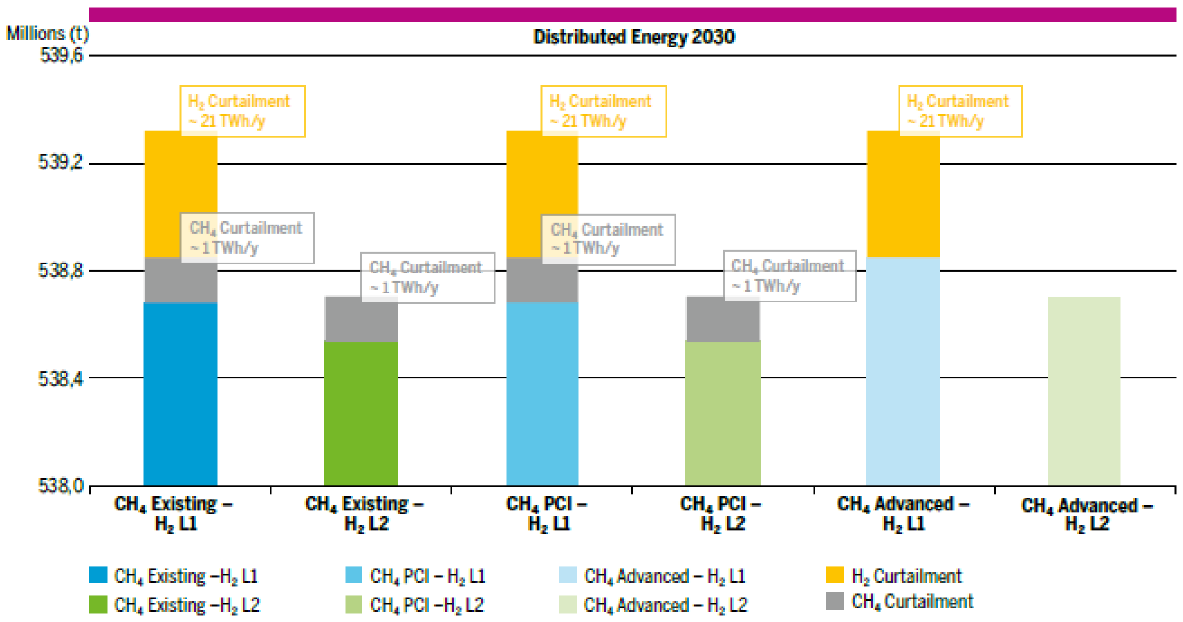
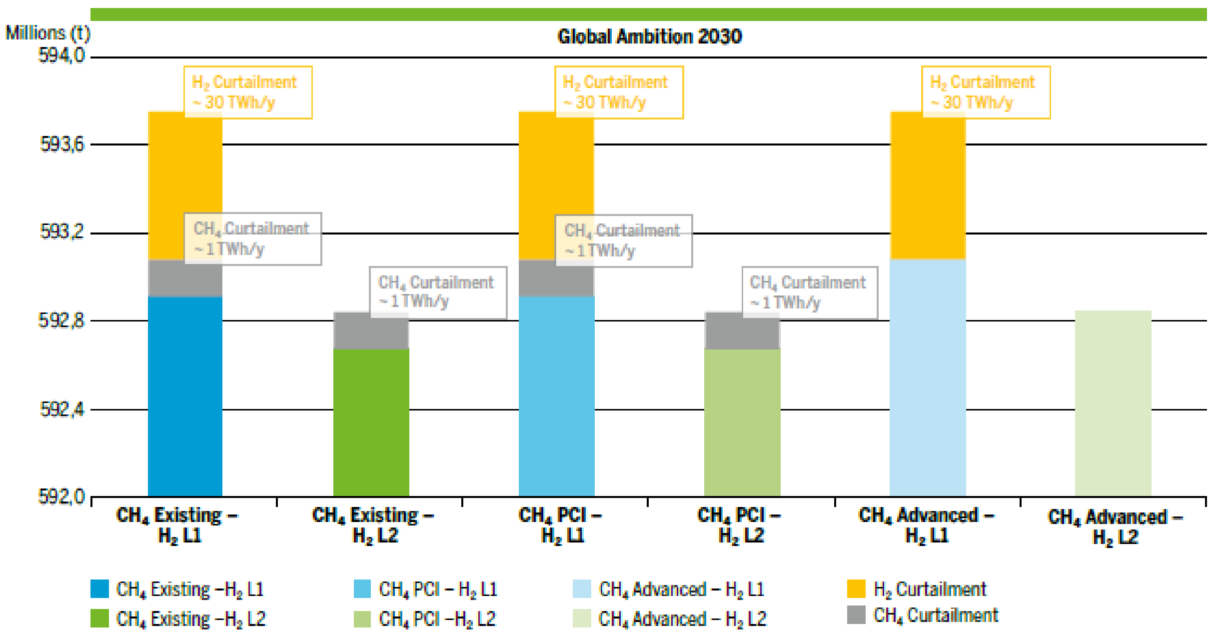


Figure 28: H_2 Supply Results for Peak Demand in Advanced CH_4 Infrastructure with H_2 Level 1

Sustainability: Yearly CO2 Emissions – Example of 2030



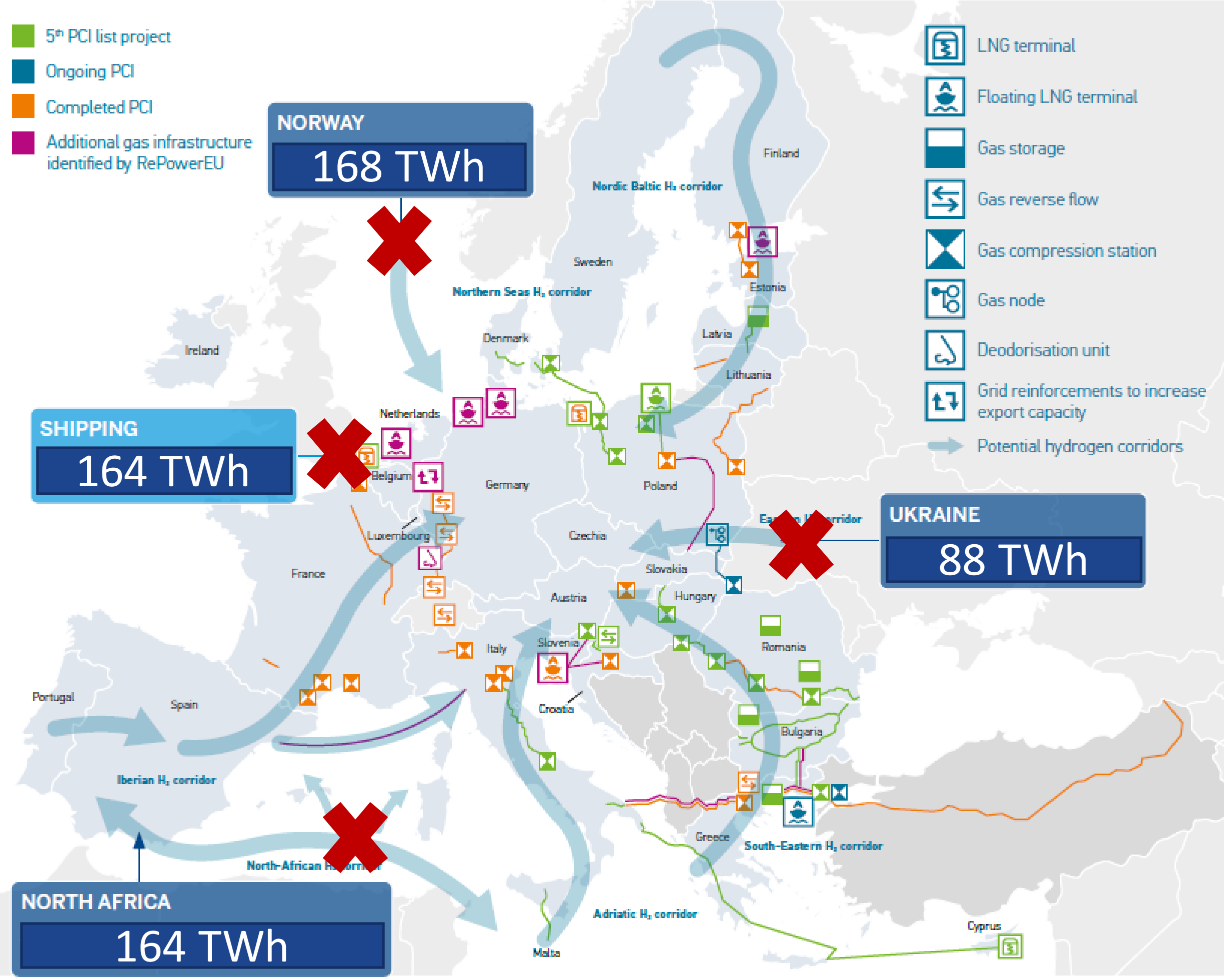


All graphs displayed in this chapter show combined CO2 emissions from methane and hydrogen for the Reference case.

Hydrogen Supply Disruptions

The Hydrogen supply disruptions do not impact simulation 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 is not impacted.

The system assessment is therefore limited to Distributed Energy and Global Ambition demand scenarios in 2030, 2040 and 2050.



2022 scenarios: H_2 potential before adjustment to RePowerEU
Project collection: H_2 projects collected for TYNDP 2022

REPowerEU 2030 Target	
Pipeline	200 TWh
Shipping	133 TWh

SLID and SLCD

For each country, the Single Largest Infrastructure or Capacity depend on the year and the infrastructure level.

- The SLID measures the curtailed demand following the disruption of this Methane infrastructure in a country (excluding storage and national production).
- The SLCD measures the curtailed demand following the disruption of this Hydrogen capacity in a country (including storage and national production).

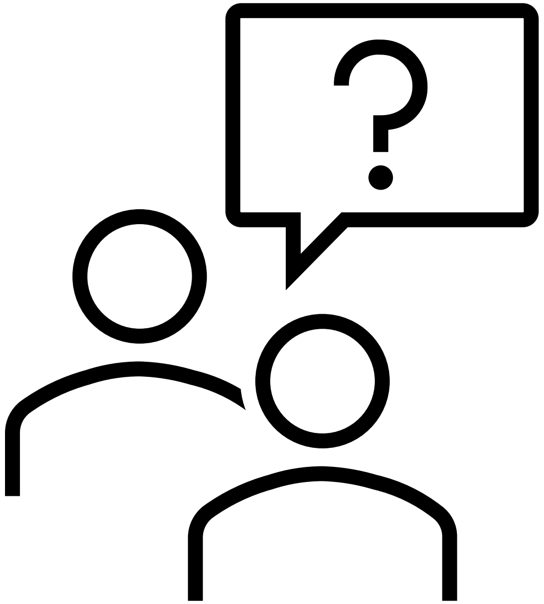
N–1 situations

Conclusions

Establishment of hydrogen projects is beneficial to prevent the usage of more carbon intensive alternatives, which would risk the climate goals included in the scenarios.

At the same time, if demand is not satisfied on a yearly basis, any additional stress case (climatic stress, infrastructure disruption or supply disruptions) may result in higher demand curtailment. **This situation could be mitigated by additional hydrogen projects.**

Q&A



Next Steps

Next steps

– Public consultation open until 19 May 2023
  – Available via this event site or
  – [Public Consultation (office.com)]
– Draft TYNDP 2022 and received feedback will be shared jointly with ACER
– After receiving feedback from ACER final TYNDP 2022 will be published with a dedicated feedback chapter

Thank you for your attention

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