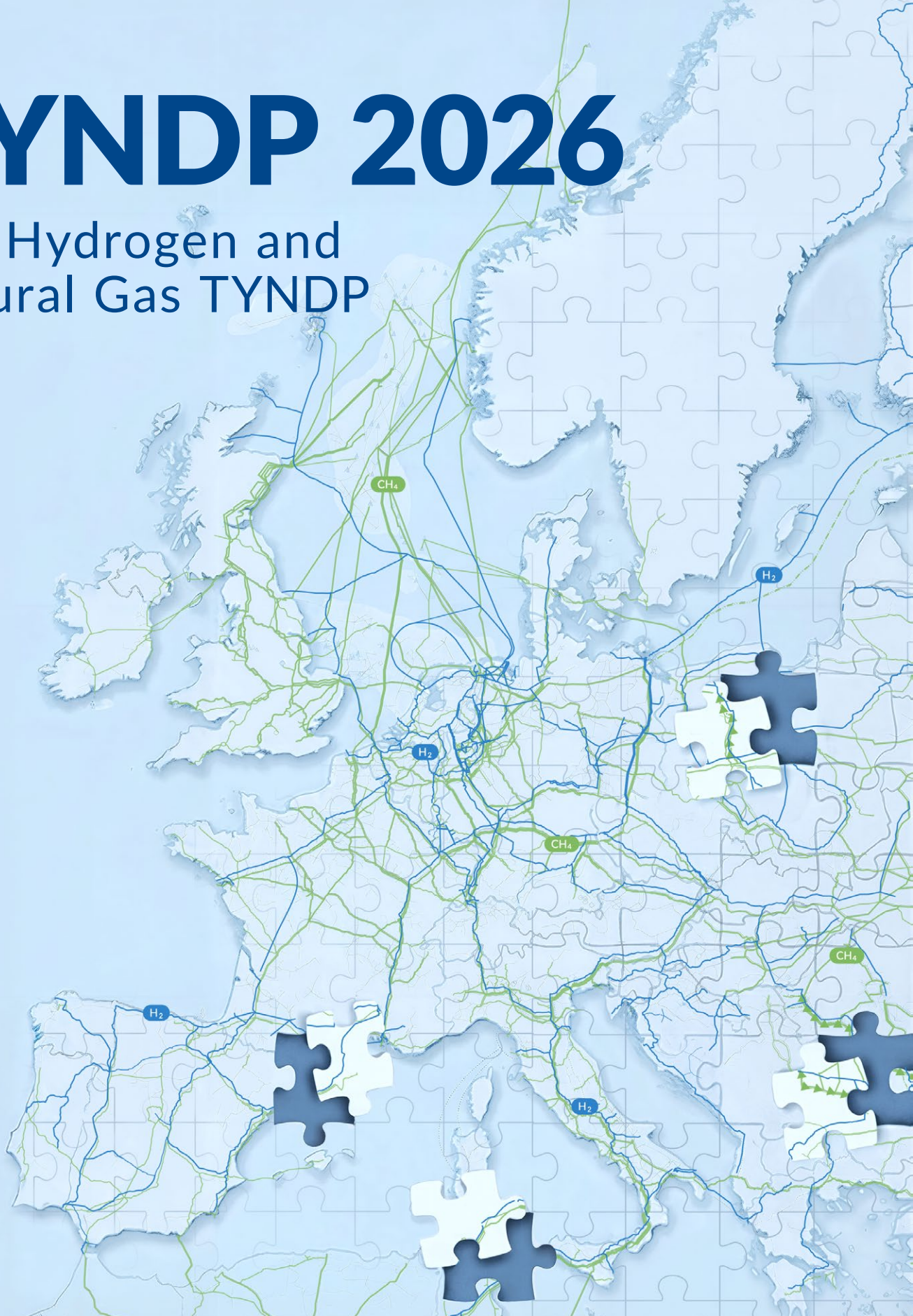


TYNDP 2026

The Hydrogen and Natural Gas TYNDP



ANNEX D2

Hydrogen Infrastructure Gaps Identification Methodology

Draft version, including stakeholder consultation feedback



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Picture courtesy of GASCADE



1 INTRODUCTION

The draft Annex D2 – Hydrogen Infrastructure Gaps Identification (IGI) methodology is part of the draft guidance documents package for the TYNDP 2026 cycle, together with Annexes D1 and D3¹. For wording simplicity, throughout the document, the materials will be referred to without explicitly mentioning the term **draft**.

The objective of this IGI methodology is to provide guidance on the different elements of relevance for the IGI report as part of the 2026 TYNDP cycle. The TYNDP 2026 IGI methodology thereby builds on the TYNDP 2026 Implementation Guidelines (TYNDP 2026 Annex D1) through cross-references. The TYNDP 2026 Implementation Guidelines specify the required elements of the project-specific cost-benefit analysis (PS-CBA) as part of the 2026 TYNDP cycle.

The TYNDP 2026 IGI methodology and the TYNDP 2026 Implementation Guidelines provide input to the PCI and PMI selection process. The TYNDP 2026 Natural Gas and Hydrogen System Assessment methodology (TYNDP 2026 Annex D3) covers the methodology of TYNDP 2026 sections that are not of relevance for the PS-CBA process and the IGI report.

¹ The TYNDP 2026 guidance documents are available in the [dedicated section](#) of the ENTSG website

2 LEGAL BACKGROUND

Article 60 of the Regulation (EU) 2024/1789 on the internal markets for renewable gas, natural gas, and hydrogen (GHR) stipulates that:

"The Union-wide network development plan for hydrogen shall include the modelling of the integrated hydrogen network, scenario development, a European supply adequacy outlook and an assessment of the resilience of the system. The Union-wide network development plan for hydrogen shall, in particular: [...] c) identify investment gaps, in particular with respect to the necessary cross-border capacities, to implement the priority corridors for hydrogen and electrolyzers as referred to in point 3 of Annex I to [the TEN-E Regulation]."

Point 3 of Annex I of the TEN-E Regulation defines the priority corridors for hydrogen and electrolyzers:

"[...] Hydrogen interconnections [...]: **hydrogen infrastructure and the repurposing of gas infrastructure, enabling the emergence of an integrated hydrogen backbone, directly or indirectly (via interconnection with a third country), connecting the countries of the region and addressing their specific infrastructure needs for hydrogen supporting the emergence of an Union-wide network for hydrogen transport**, and, in addition, **as regards islands and island systems, decreasing energy isolation, supporting innovative and other solutions involving at least two Member States with a significant positive impact on the Union's 2030 targets for energy and climate and its 2050 climate neutrality objective, and contributing significantly to the sustainability of the island energy system and that of the Union.**"

Electrolyzers: supporting the deployment of power-to-gas applications aiming to enable greenhouse gas reductions and contributing to secure, efficient and reliable system operation and smart energy system integration and, in addition, as regards islands and island systems, supporting innovative and other solutions involving at least two Member States with a significant positive impact on the Union's 2030 targets for energy and climate and its 2050 climate neutrality objective, and contributing significantly to the sustainability of the island energy system and that of the Union."

Three such priority corridors are defined Regulation (EU) 2022/869, hereafter the "TEN-E Regulation":

- ▲ HI West: Belgium, Czechia, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, Malta, Netherlands, Austria, Portugal.
- ▲ HI East: Bulgaria, Czechia, Germany, Greece, Croatia, Italy, Cyprus, Hungary, Austria, Poland, Romania, Slovenia, Slovakia.
- ▲ BEMIP Hydrogen: Denmark, Germany, Estonia, Latvia, Lithuania, Poland, Finland, Sweden.

In line with Article 60 of the GHR, the focus of ENTSOE's infrastructure gaps identification exercise is on the needed hydrogen interconnectors within the priority corridors for hydrogen and electrolyzers.

The infrastructure gaps identification is complementarily addressed by Article 13 of the TEN-E Regulation. An identified infrastructure gap thereby translates into an equivalent infrastructure need. The identified infrastructure gaps shall be reported as a part of the TYNDP and follow the procedural requirements of Article 13 of the TEN-E Regulation.

Article 13(1) of the TEN-E Regulation directs the focus of the analysis at system level to the effect of possible infrastructure gaps on the completion of the EU's 2030 climate and energy targets and 2050 climate-neutrality objective. The TYNDP scenarios, established in line with Article 12 of the Regulation, thereby comply with this requirement. In line with Article 13(1), these scenarios form the basis of the infrastructure gaps identification.

3 MODEL DESCRIPTION

The model description contained in section 2 of the TYNDP 2026 Implementation Guidelines is also valid for this TYNDP 2026 IGI methodology. Exceptions and additional specifications are described in the current section.

- While for the TYNDP 2026 PS-CBA process, the Dual Hydrogen/Electricity Model (DHEM) is used, the same TYNDP 2026 scenario is considered (i.e., National Trends+), and the same years are modelled for both processes respectively, 2035 and 2040; the TYNDP 2026 IGI report additionally models the years 2030 and 2050. The benefit indicators described in the TYNDP 2026 Implementation Guidelines are not computed for the TYNDP 2026 IGI report. The TYNDP 2026 IGI report is based on own indicators.
- The PCI/PMI hydrogen infrastructure level is the only hydrogen infrastructure level that is assessed within the TYNDP 2026 IGI report.

The DHEM market assumptions listed in section 2.6 and Annex II, the GHG emissions factors of power plants listed in Annex III, the gross/net calorific value (GCV/NCV) ratios defined in Annex V as well as the infrastructure information provided by Annex I of the TYNDP 2026 Implementation Guidelines are also valid for this TYNDP 2026 IGI methodology. The remaining parts of section 3 as well as section 4, section 5 and Annex IV of the TYNDP 2026 Implementation Guidelines are not relevant for this TYNDP 2026 IGI methodology as they are related to project-specific assessments.

All hydrogen-related values specified in this TYNDP 2026 IGI methodology are considering the GCV².

² The TYNDP 2026 scenarios use the NCV. For hydrogen, the NCV can be converted into the GCV by multiplication with 1.176. Reference temperatures for NCV calculation are assumed at 25/0°.

4 GENERAL APPROACH

To identify the infrastructure gaps, the following elements must be defined:

**Already defined in the TYNDP 2026
Implementation Guidelines in combination
with the previous section:**

- ▲ General modelling concepts.
- ▲ The simulation tools and models to be used.
- ▲ The TYNDP scenario(s) and years to be used.
- ▲ The level of the network development (infrastructure level) to be considered as a reasonable counterfactual situation against which to assess the system and identify possible infrastructure gaps.

**Not defined in the TYNDP 2026
Implementation Guidelines:**

- ▲ The indicators based on which infrastructure gaps will be identified (see section 5).
- ▲ The threshold value for each infrastructure gaps identification indicator (IGI indicator). The comparison of the intermediate indicator result with its threshold value allows to judge whether i) an infrastructure gap does not exist or is less relevant, or ii) an infrastructure gap does exist (see section 5).
- ▲ The unlimited infrastructure methodology to derive project-related information about infrastructure gaps and the under-supply sensitivity (see section 6).

The results of the TYNDP 2026 IGI report are only related to infrastructure gaps that are based on the considered infrastructure level. Therefore, all the projects constituting the PCI/PMI hydrogen infrastructure level are to be treated as equally and jointly necessary in addressing the infrastructure gaps considered in the analysis.

Infrastructure gaps identified in ENTSOG's hydrogen-related TYNDP 2026 IGI report may in some cases also be addressed by energy infrastructure solutions in other sectors like the electricity sector³ or the natural gas sector. This is the case for any infrastructure gaps identification focusing on a specific energy vector.

No generic hydrogen infrastructure projects are used in this TYNDP 2026 IGI methodology. Instead, only real projects, submitted by project promoters are considered.

3 An example for which this is not the case are renewable energy imports by ship from distant production locations, which cannot be achieved by the electricity sector.

5 INFRASTRUCTURE GAPS IDENTIFICATION INDICATORS

The IGI indicators identify the existence of an infrastructure gap through the existence of effects of such infrastructure gap. The effect of this infrastructure gap is either expressed at a country for IGI indicator 1 (see section 5.1) or at a border for IGI indicator 2 (see section 5.2). For each simulation case (see section 6), the TYNDP 2026 IGI report presents each relevant IGI indicator on a map and/or in a table. Thereby, the following information is provided:

- ▲ the calculated value of relevance for the thresholds (i.e., hydrogen demand curtailment rate for IGI indicator 1 and hydrogen market clearing price spread for IGI indicator 2;
- ▲ evidence as to whether the threshold was reached or not;
- ▲ average and maximum yearly volumes;
- ▲ the amount of time that the maximum utilisation of IP capacity is reached;
- ▲ In addition, for comparison purposes, the estimated capacities derived from market consultations (when available).

The reason for an infrastructure gap is an infrastructure bottleneck. An infrastructure bottleneck represents physical congestion of the network, that can be observed based on full utilisation rates of all relevant transmission infrastructure during certain periods of time. If a limited cooperation mode

is used among countries in situations of hydrogen scarcity (see section 2.6 of the TYNDP 2026 Implementation Guidelines), the dominant infrastructure bottleneck is not necessarily located at a border of the country through which the IGI indicators demonstrated the existence of an infrastructure gap (see examples below). Also, besides the dominant bottleneck, non-dominant bottlenecks may exist at other locations that only decrease their effect once the dominant bottleneck is addressed. Additionally, an infrastructure bottleneck can in principle be addressed by different projects and via different routes. Therefore, the infrastructure gaps identified by the IGI indicators identify regional infrastructure gaps, as the potential solution to it is not limited to the country of IGI indicator 1 or the border of IGI indicator 2. The regional aspect of the infrastructure gap can be further investigated at project level (see section 6).

No.	Scenario	Infrastructure levels		Sensitivity	Weather Scenario	IGI indicator
1	NT+ 2030	NT+ 2030	PCI/PMI	–	Base	1 and 2
2	NT+ 2030	NT+ 2030	PCI/PMI	Yes	Base	1 and 2
3	NT+ 2035	NT+ 2035	PCI/PMI	–	Base	1 and 2
4	NT+ 2035	NT+ 2035	PCI/PMI	Yes	Base	1 and 2
5	NT+ 2040	NT+ 2040	PCI/PMI	–	Base	1 and 2
6	NT+ 2040	NT+ 2040	PCI/PMI	Yes	Base	1 and 2
7	NT+ 2050	NT+ 2050	PCI/PMI	–	Base	1 and 2
8	NT+ 2050	NT+ 2050	PCI/PMI	Yes	Base	1 and 2

Table 1: Combinations of scenarios, years, infrastructure levels, weather scenarios, and indicators for the infrastructure gaps identification of hydrogen infrastructure.

Two additional sensitivity analyses complement the base-case assessment. The Unlimited Infrastructure and Supply Sensitivities consider four hypothetical cases: Unlimited Pipelines, Unlimited Storage, Unlimited Imports, and a combination of all three. The Under-Supply Sensitivity assesses lower electrolytic hydrogen production by reducing P2X capacity and efficiency by 10%, together with a corresponding reduction in RES supply.

Compared with the TYNDP 2024 IGI, which assessed hydrogen demand curtailment under both reference and stressful weather conditions, the TYNDP 2026 IGI focuses on the base weather scenario. This methodological change reflects ACER's feedback ([ACER Opinion No 05/2025 of 27 May 2025 on ENTSOG's draft TYNDP 2024 Hydrogen Infrastructure Gaps Identification report](#)) that, at the current stage of development of the European hydrogen system, priority should be given to assessing infrastructure needs under the underlying scenario assumptions before considering additional extreme weather sensitivities.

5.1 IGI INDICATOR 1: CURTAILED HYDROGEN DEMAND IN DHEM

This IGI indicator identifies infrastructure gaps by measuring the hydrogen demand curtailment of individual nodes under the base weather scenario, and without infrastructure or source disruptions.

To expand the scope of the IGI indicator 1, ENTSOG might consider the possibility to simulate an additional sensitivity and measure the hydrogen demand curtailment of individual nodes under the stressful weather scenario.

To define which hydrogen demand curtailment represent a significant indication of a hydrogen infrastructure gap, the following threshold must be passed:

▲ Threshold: a yearly average hydrogen demand curtailment rate of more than 0 %.

If there is a hydrogen demand curtailment above the threshold, this indicates an infrastructure gap for the given assumptions.

As there is only a limited cooperation mode considered for hydrogen in the DHEM (see section 2.6 of the TYNDP 2026 Implementation Guidelines), the infrastructure bottleneck causing the hydrogen demand curtailment rate to be above the threshold (defined above) in a certain country is not necessarily located at the border between this country and its direct neighbours. This is explained by the following examples.



Example of the identification of an infrastructure bottleneck under full cooperation mode:

Country J is neighbouring country K, country K is neighbouring country J and country L, and country L is neighbouring country K. Country J has a surplus of hydrogen supply options, while country K and country L are depending on supplies from country J. Under a full cooperation mode, the model will try to reach equal hydrogen demand curtailment rates in all three countries. Under this full cooperation mode, a difference between hydrogen demand curtailment rates between neighbouring countries can only be caused by fully utilised (or non-existing) infrastructure. The infrastructure that was fully utilised (or was non-existing) and thereby caused this difference is defined as the dominant infrastructure bottleneck.

- ▲ If as a result of this cooperation country K and country L have the same hydrogen demand curtailment rates, which are higher than the one of country J, the dominant infrastructure bottleneck is located between country J and country K.
- ▲ If country J and country K have the same hydrogen demand curtailment rates, which are higher than the one of country L, the dominant infrastructure bottleneck is located between country K and country L.
- ▲ If country J has a lower hydrogen demand curtailment rate than country K and the one of country K is lower than the one of country L, there are dominant infrastructure bottlenecks between country J and country K as well as between country K and country L.

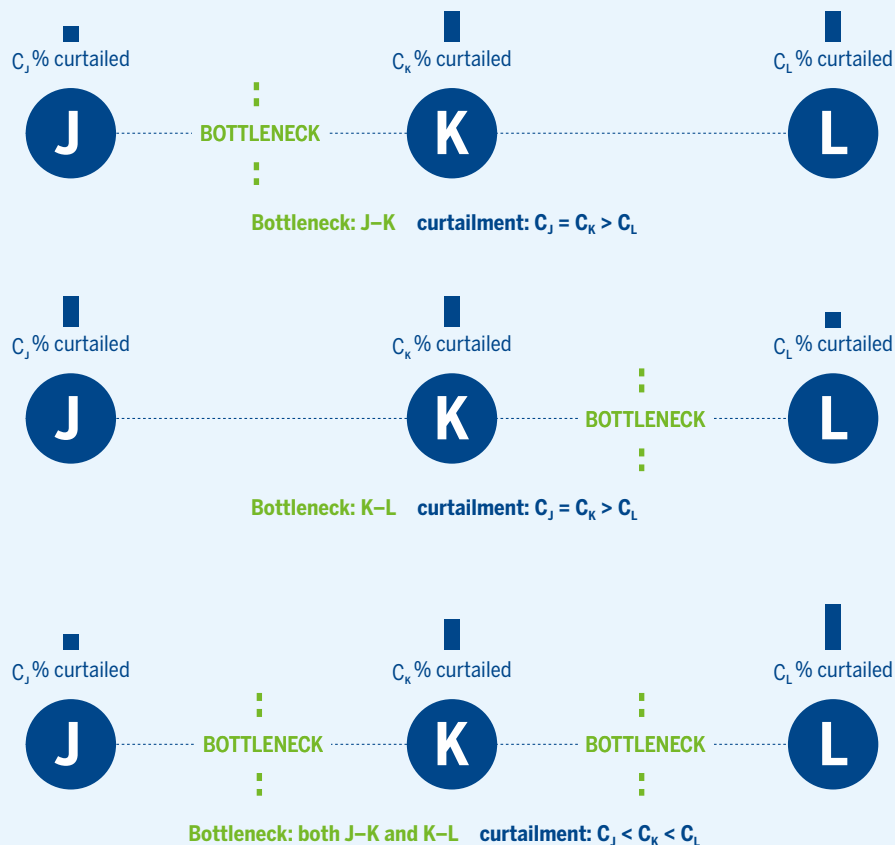


Figure 1: Illustrated example of the identification of an infrastructure bottleneck under full cooperation mode.

Example of the identification of an infrastructure bottleneck under limited cooperation mode applied for the hydrogen infrastructure gaps identification:

Country J is neighbouring country, country K is neighbouring country J and country L, and country L is neighbouring country K. Country J has a surplus of hydrogen supply options, while country K and country L are depending on supplies from country J and have no potential access to hydrogen import options. Under limited cooperation mode, the model will try to first satisfy the hydrogen demand of country J, then of country K, and only then of country L (as cross-border flows are penalised with a small hurdle cost). If only country L is curtailed, this does not mean that the infrastructure bottleneck, defined as the fully utilised

(or non-existing) infrastructure causing the curtailment, is located at the border between country K and country L. While this is a possible explanation, the infrastructure bottleneck could also be linked to the infrastructure from country J to country K. In the latter case, insufficient hydrogen can be sent out of country J to satisfy the hydrogen demand of both country K and country L. This would then be the dominant infrastructure bottleneck. If it were not, the total supply options of the three countries would be too limited, so the dominant infrastructure bottleneck would be the import infrastructure into country J.

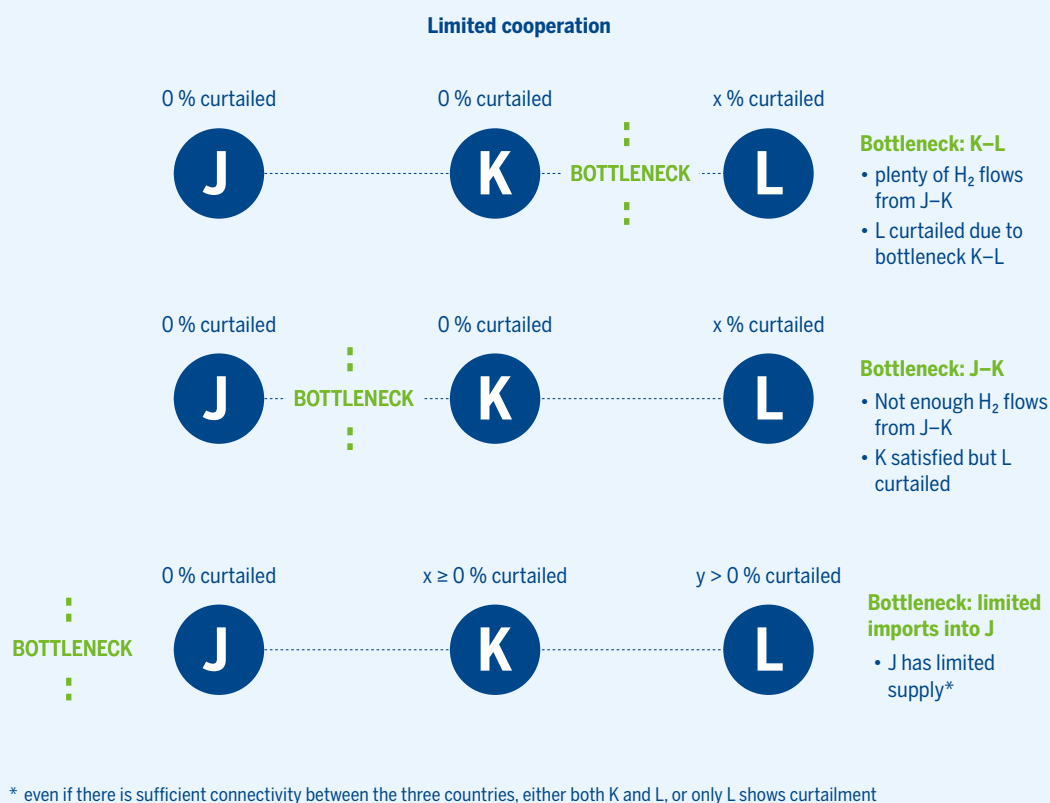


Figure 2: Illustrated example of the identification of an infrastructure bottleneck under limited cooperation mode.

The example above shows that the infrastructure bottleneck under a limited cooperation mode does not need to be at the node where the infrastructure

gap is identified. The approach to investigate the role of projects is described in section 6.

5.2 IGI INDICATOR 2: HYDROGEN MARKET CLEARING PRICE SPREADS IN DHEM

This IGI indicator aims at identifying hydrogen infrastructure gaps by assessing hydrogen market clearing price differences between Zone 2 nodes of different countries. When assessing hydrogen infrastructure gaps with this IGI indicator, it should be noted that they depend on scenario assumptions about supply prices, which present a degree of uncertainty due to the current early stages of the hydrogen market development.

The indicator is established:

- ▲ based on outputs of the objective function of the DHEM,
- ▲ for the considered scenario(s) (i.e., NT+)
- ▲ for each considered year of assessment (i.e., 2030, 2035, 2040 and 2050),
- ▲ for the least stressful weather year (base case) for each target year proposed to be used in TYNDP 2026 Scenario Methodology report.
- ▲ for each considered combination of hydrogen and electricity infrastructure levels, as well as “unlimited” sensitivities.



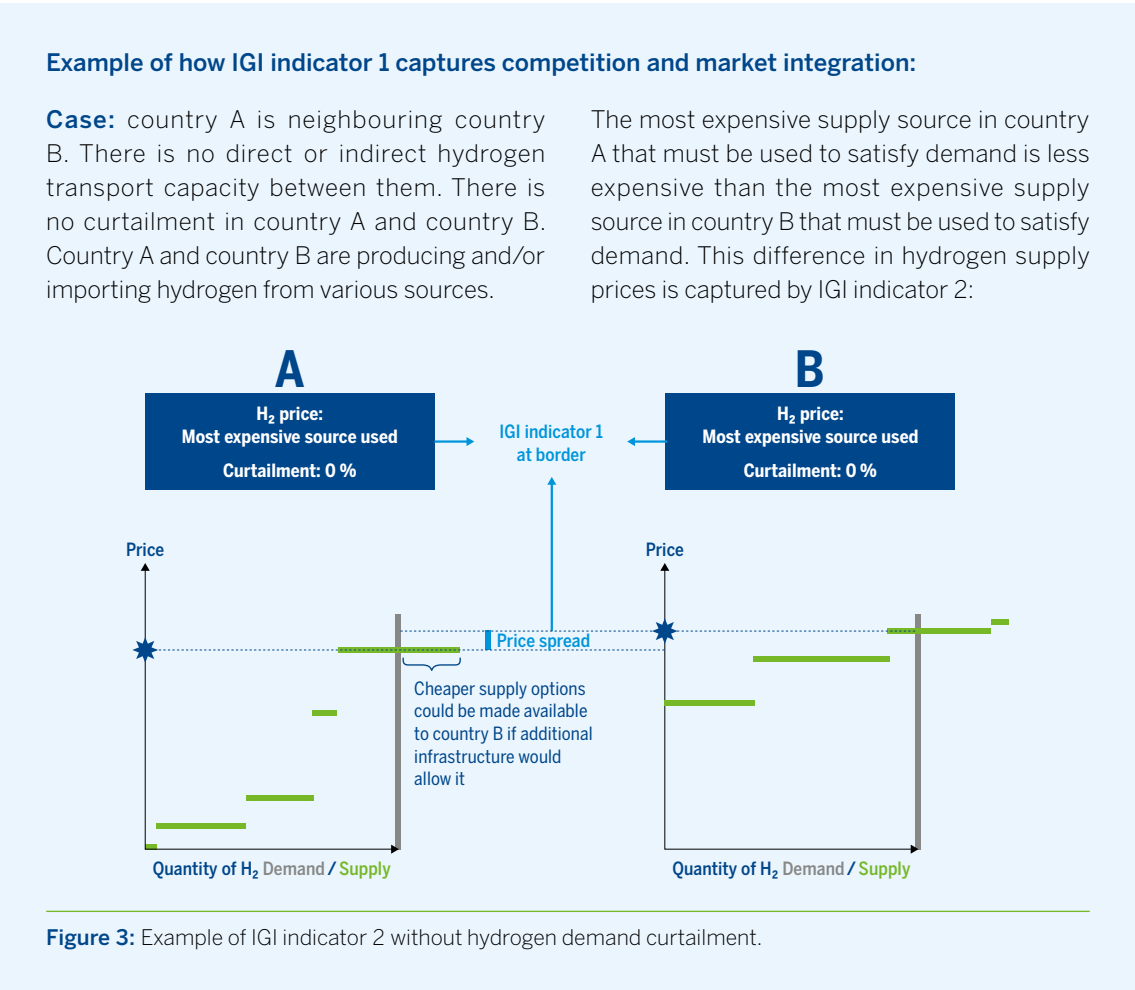
The DHEM provides hourly hydrogen market clearing prices per hydrogen node.

The hydrogen market clearing price spreads between different hydrogen nodes thereby allows to internalise information about several aspects that are listed below:

1. COMPETITION AND MARKET INTEGRATION

Undersized hydrogen cross-border capacities are cross-border trade barriers. These trade barriers limit the access of the hydrogen producers with the lowest marginal production cost to hydrogen consumers.

This results in hydrogen market clearing price spreads. On the other hand, perfect market integration would result in a full hydrogen market clearing price convergence between Member States.



2. HYDROGEN DEMAND CURTAILMENT⁴

Hydrogen demand curtailment in a certain node is a last resort. It is characterised by a hydrogen market clearing price at the level of the cost of hydrogen disruption that is assumed equal to the willingness to pay for hydrogen consumers (WTP_{H_2}).

The WTP_{H_2} is higher than the price of the most expensive hydrogen supply source. This creates hydrogen market clearing price spreads between nodes with and nodes without hydrogen demand curtailment.

Example of how IGI indicator 2 captures hydrogen demand curtailment:

Case: country C is neighbouring country D. There is no direct or indirect hydrogen transport capacity between them. There is hydrogen demand curtailment in country C but no hydrogen demand curtailment in country D. Country C and country D are producing and/or importing hydrogen from various sources.

The hydrogen market clearing price in country C is equivalent to the WTP_{H_2} . The hydrogen market clearing price in country D is equivalent to the most expensive supply source of hydrogen that must be used to satisfy the demand, which is lower than the WTP_{H_2} . This difference in hydrogen market clearing prices is captured by IGI indicator 2:

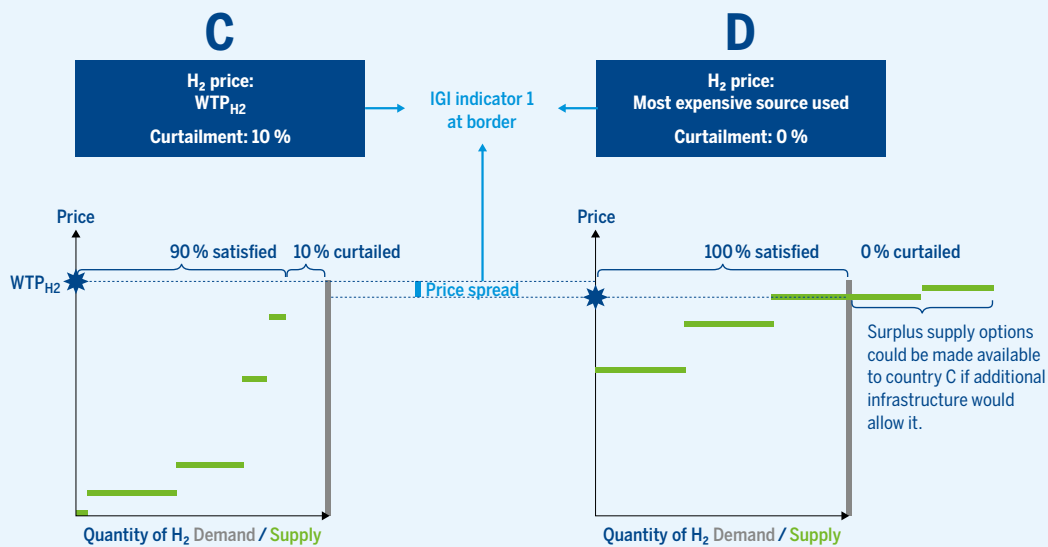


Figure 4: Example of IGI indicator 2 with hydrogen demand curtailment.

⁴ Selecting the curtailed hydrogen demand as single indicator would not allow to consider other listed aspects of relevance for the identification of hydrogen infrastructure gaps.

3. CURTAILED ELECTROLYTIC HYDROGEN PRODUCTION WITHIN THE EU

Curtailed renewable electricity production would as a symptom show an electricity market clearing price of 0. Thus, there would be a business case for producing electrolytic hydrogen from this curtailed renewable electricity at a very low marginal cost if in another country more expensive hydrogen sources were used (e.g., hydrogen production from electricity produced by nuclear power plants,

hydrogen production from natural gas, hydrogen imports from non-EU countries, etc.). If there were insufficient hydrogen transport capacity between the country with the curtailed renewable electricity production and a country that uses more expensive hydrogen sources, this would be displayed as a hydrogen market clearing price spread.

Example of how IGI indicator 2 captures competition and market integration in case of curtailment of renewable hydrogen production:

Case: country E is neighbouring country F. There is no direct or indirect hydrogen transport capacity between them. There is no curtailment in country E and country F. Country E experiences high electricity generation from RES that results in an electricity market clearing price of 0. Country E has sufficient electrolyser capacity to satisfy its own hydrogen demand with this inexpensive electricity, i.e., it defines the hydrogen market clearing price of country E.

Country F produces and/or imports hydrogen from various sources. At the same time, some renewable hydrogen production is curtailed in country E due to limited offtake and/or export options. The most expensive supply source that must be used to satisfy demand in country E is less expensive than the most expensive supply source used to satisfy demand in country F. This difference in hydrogen supply prices is captured by IGI indicator 2:

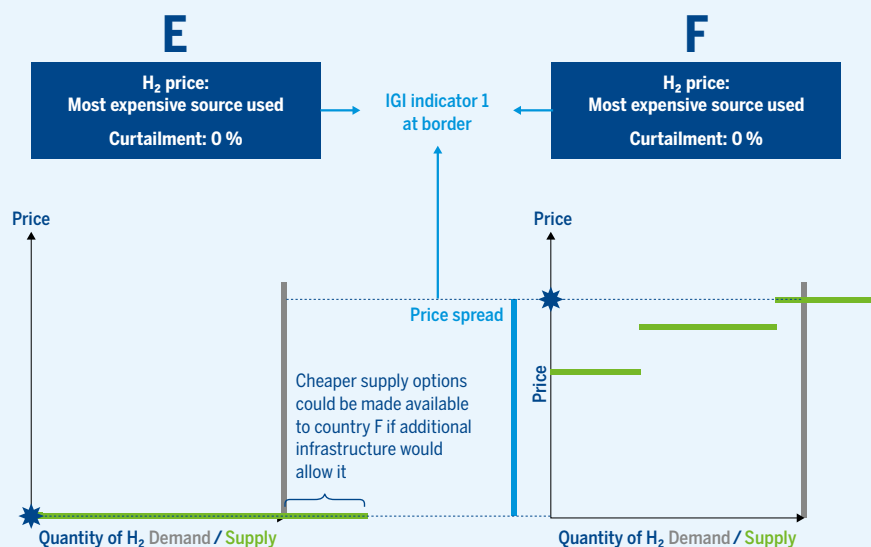


Figure 5: Example of IGI indicator 2 with renewable hydrogen production curtailment.

4. RENEWABLE HYDROGEN IMPORT OPTIONS

Hydrogen price spreads can also be calculated between the hydrogen market clearing prices in a Member State and relevant import prices of import options of renewable hydrogen (e.g., imports by

ship or hydrogen from North Africa or Ukraine) as established in the NT+ scenario. Such price spread shows which non-EU country or region could be an attractive prospective supply source.

Example of how IGI indicator 2 can be used to indicate attractive import options:

Case: country G is an island and cannot produce sufficient hydrogen in any hour along the year to satisfy its hydrogen demand. The hydrogen market clearing price is therefore equivalent to the WTP_{H_2} . Hydrogen import by ship is assumed to be available along the entire year in case its supply

potential as established in the TYNDP 2026 Scenario Methodology Report is not fully used. In this example, there is still remaining supply potential of shipped ammonia (NH_3). IGI indicator 2 then captures the difference between the WTP_{H_2} and the price of hydrogen imports by ship.

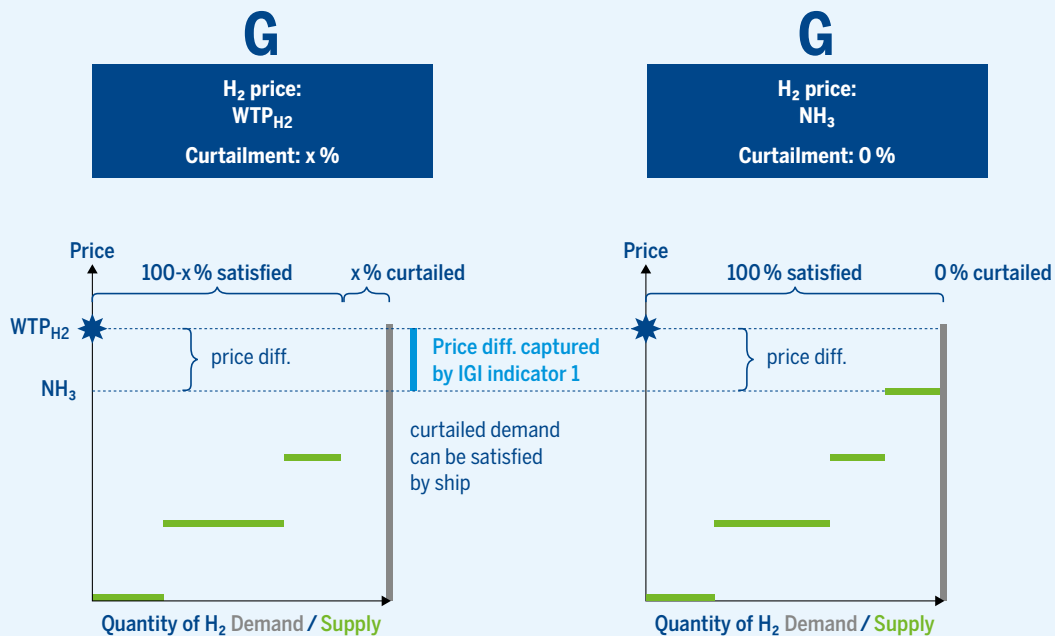


Figure 6: Example of IGI indicator 2 with ammonia imports.

To define which hydrogen market clearing price spreads are a significant indication of a hydrogen infrastructure gap, one of the following thresholds must be passed:

▲ **Threshold 1:** a hydrogen market clearing price spreads as the yearly average of the absolute hourly hydrogen market clearing price spread

between two Zone 2 nodes of different countries of more than 2 €/MWh_{H2}⁵; or

▲ **Threshold 2:** a hydrogen market clearing price spread as the absolute average daily⁶ hydrogen market clearing price spread between two Zone 2 nodes of different countries of more than 20 €/MWh_{H2} for more than 40 days per year.

5 In [ENTSO-E's implementation guidelines for TYNDP 2026](#) of 16 December 2025, several interconnection target recommendations to contribute to EU energy targets are listed. Amongst them is the price differential: "Market studies simulations will serve to account price differentials per border as the yearly average of absolute hourly price differentials. This indicator is computed per border in €/MWh. In those borders where this indicator is greater than 2 €/MWh will mean that further interconnectors should urgently be investigated." The hydrogen market clearing price spreads indicator allows for a similar approach.

6 By using daily average values, intra-day changes of the transport direction tend to equalise each other, a more conservative assumption compared to absolute average hourly hydrogen market clearing price spreads.

If there exists a hydrogen market clearing price spread above one of the thresholds, this indicates an infrastructure gap for the given assumptions.

Example 1 of the application of the thresholds:

Case: country H is neighbouring country I. There is no direct or indirect hydrogen transport capacity between them. Country H produces all its hydrogen with electrolyzers from renewable electricity at a marginal cost of 30 €/MWh_{H2} along the entire year. Country I produces hydrogen with electrolyzers from nuclear power at a marginal cost of 40 €/MWh_{H2} along the entire year.

▲ **Result for Threshold 1:** the yearly average of the absolute hourly hydrogen market clearing price spread between country H

and country I is 10 €/MWh_{H2}. As this is more than 2 €/MWh_{H2} Threshold 1 is passed.

▲ **Result for Threshold 2:** the absolute average daily hydrogen market clearing price spreads between country H and country I is above 20 €/MWh_{H2} for 0 days. Therefore, Threshold 2 is not passed.

▲ **Result:** as one of the thresholds is passed, an infrastructure gap is identified based on the IGI indicator 2 between country H and country I.

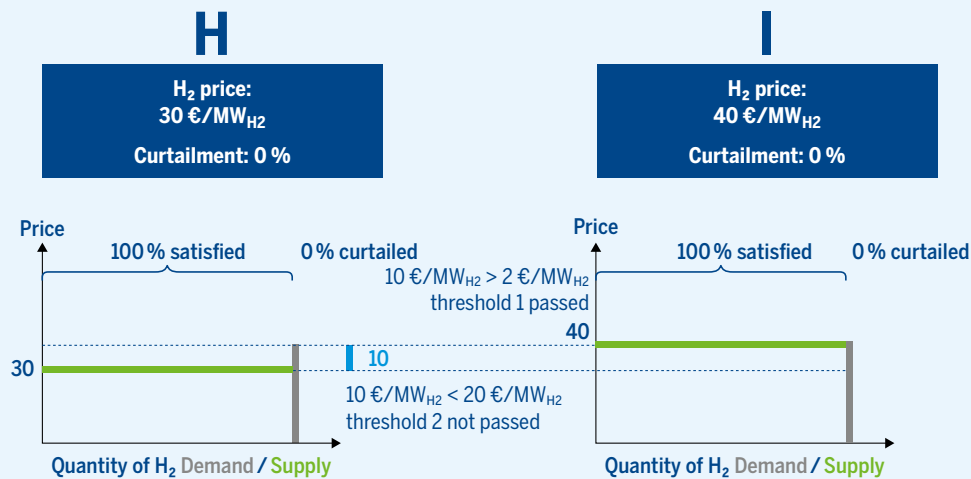


Figure 7: Example of IGI indicator 2 and application of thresholds in neighbouring countries.

Addressing an identified infrastructure gap by addressing the underlying dominant infrastructure bottleneck does not exclude the existence of non-dominant infrastructure gaps based on

non-dominant infrastructure bottlenecks that would affect other nodes once the identified dominant infrastructure gap was addressed. This is explained on the next page.

Example 2 of the application of thresholds:

Case: country G is an island and cannot produce sufficient hydrogen in any hour throughout the year to satisfy its hydrogen demand. The hydrogen market clearing price is therefore equivalent to the WTP_{H_2} , e.g. 154 €/MWh_{H₂}. Hydrogen import by ship in form of ammonia (NH₃) is assumed to cost 116.5 €/MWh_{H₂} and to be available throughout the entire year.

Result: both thresholds are passed. As at least one threshold is passed, an infrastructure gap is identified based on the IGI

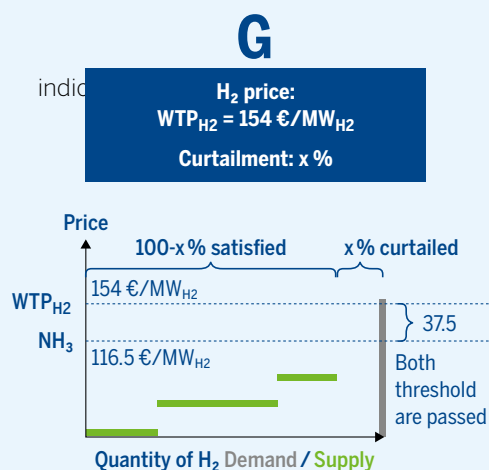


Figure 8: Example of infrastructure gaps identification based on the application of the thresholds when H₂ is imported by ship.

Example of a non-dominant infrastructure gap:

Initial case: country A is neighbouring country B, country B is neighbouring country A and country C, and country C is neighbouring country B. There is no hydrogen transport capacity between these three countries. Country A has surplus hydrogen supply options while country B and country C has no surplus hydrogen supply option for its hydrogen demand.

Result of the hydrogen market clearing price spread indicator: the hydrogen market price spread indicator will indicate an infrastructure gap based on the IGI indicator 2 between country A and country B.

There is no such indication between country B and country C as both show the high hydrogen market clearing price associated with hydrogen shortage.

Case after identified infrastructure gap was addressed: The non-dominant infrastructure gap between country B and country C would continue to exist, as there is still no connection between the countries, so the non-dominant infrastructure bottleneck remains, and country C continues to have the high hydrogen market clearing price associated with hydrogen shortage.

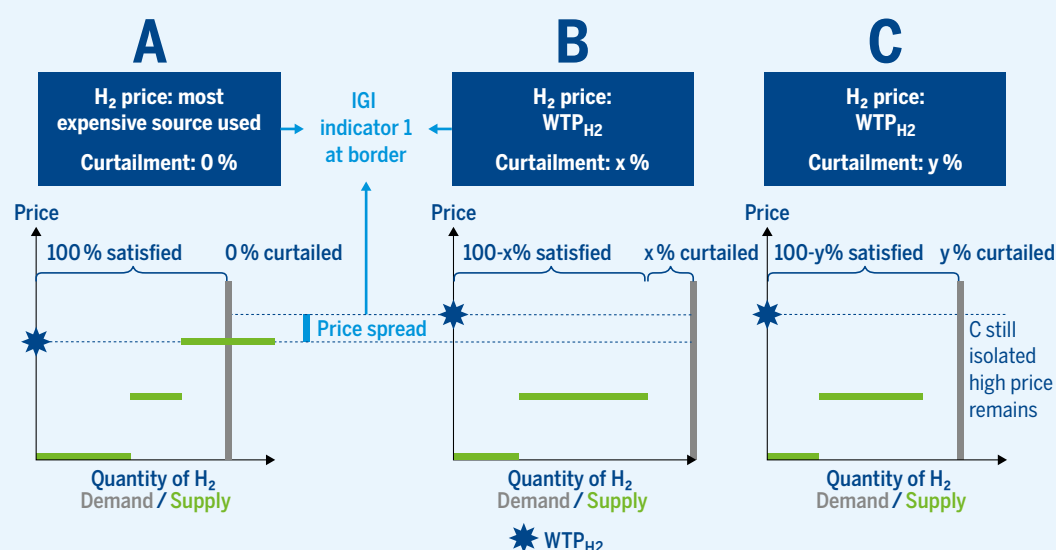


Figure 9: Example IGI indicator 2 and non-dominant infrastructure gap identification.

The added value of combining both indicators is explained below, following the example above, in Figure 9.

Example of application of indicator 1 and indicator 2:

Additional case: Following the example of a non-dominant infrastructure gap, described in Figure 9, country A is neighbouring country B, country B is neighbouring country A and country C, and country C is neighbouring country B. There is no hydrogen transport capacity between these three countries. Country A has surplus hydrogen supply options while country B and country C have insufficient hydrogen supply options to satisfy their hydrogen demand. The hydrogen market clearing price of countries B and C is therefore equivalent to the WTP_{H_2} .

- While the hydrogen market price spread (indicator 2) will show an infrastructure gap between country A and country B, there is no such indication between country B and country C, both of which show the same high hydrogen market clearing price, associated with hydrogen shortage.
- In this case, an infrastructure gap between B and C may be detected solely from the application of Indicator 1, as both countries are being curtailed.
- Complementarily, indicator 1 does not detect whether cheaper sources could be used to satisfy the curtailed demand, while indicator 2 does.

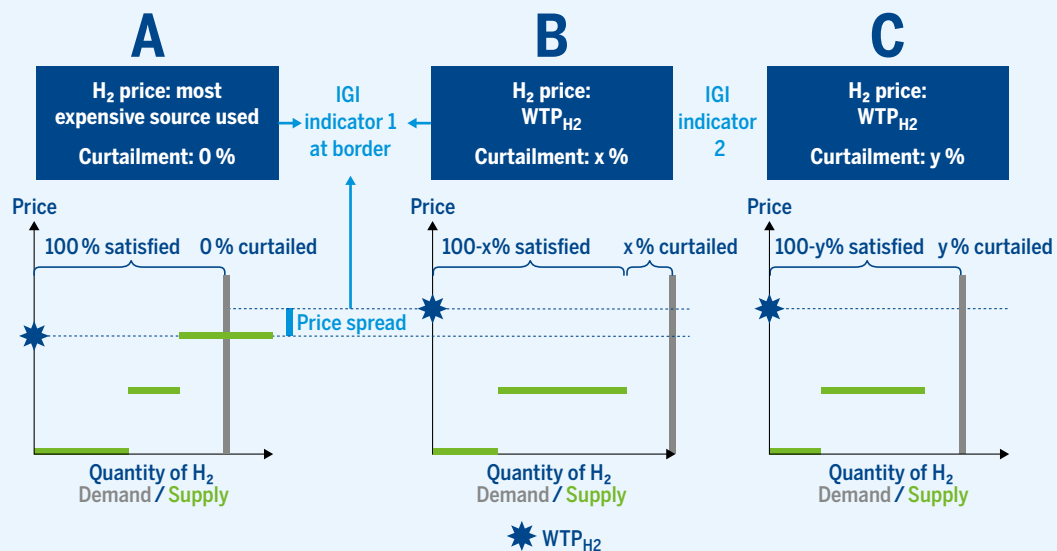


Figure 10: Example of IGI indicator 1 and 2 for an isolated country with ammonia imports.

The benefit of applying both indicators is evident also in cases where there are several countries in a row that are curtailed. An infrastructure gap may not be detected solely from the application of indicator 2, as the price spread between countries may be zero.

However, indicator 1 does it by nature. Complementarily, indicator 1 does not detect whether cheaper sources could be used to satisfy the curtailed demand, while indicator 2 does.

6 COMPARISON OF THE INDICATOR RESULTS FOR THE PROPOSED SENSITIVITIES

6.1 SENSITIVITY ANALYSIS WITH HYPOTHETICAL INFRASTRUCTURE APPROACH (“UNLIMITED” SIMULATIONS)

The proposed exercise aims at identifying (any) infrastructure gaps caused by restrictions on the supply side (i.e., structural undersupply) and/or import capacities directly connected to the import potential. As a result, it can provide additional and in-depth information on the bottlenecks linked to transport and storage capacities.

For this purpose, a set of infrastructure and/or supply assumptions will be considered and their impact analysed through the variation of IGI indicators.

The infrastructure and/or supply assumptions that are considered in the current section are the following:

- ▲ Infrastructure assumptions:
 - unlimited intra-EU transport capacities
 - unlimited storage withdrawal/injection capacities
 - unlimited intra-EU transport and withdrawal/injection capacities
- ▲ Supply assumptions:
 - unlimited import potential and import capacities

In the TYNDP 2026 IGI report, the unlimited infrastructure/supply sensitivity will be performed following a multi-step approach detailed below and it will cover all target years (i.e., 2030, 2035, 2040 and 2050) and PCI/PMI infrastructure level:

1. Display the maximum and average interconnection usage (as percentage of technical capacity) per interconnection and listing unconnected (groups of) countries (or nodes) for the hydrogen infrastructure levels and the two weather scenarios (i.e., base case and stressful case).⁷

⁷ Some hydrogen transmission projects aim at connecting offshore electrolyzers. If those projects are represented in the topology as an individual arc, their usage is available. If the project is not represented in the topology as an individual arc, the maximum interconnection usage is estimated by first calculating which share of the relevant country's Zone 2 electrolyser capacity (e.g., 10 GW_{el}) is enabled by the project (this information was collected during the project collection phase) (e.g., 20 %) and then calculating the ratio between i) the maximum hourly electrolyser utilisation rate of the country (e.g., 98 %) times the share of enabled electrolyser production (e.g., 20 %) times the relevant country's Zone 2 electrolyser capacity (e.g., 10 GW_{el}) times the electrolyser efficiency (e.g., 69 %) and ii) the project's technical capacity (e.g., 5 GW_{H2}), resulting in a maximum utilisation of 27 %).

2. Display the which hydrogen demand curtailment is caused by limited intra-EU hydrogen transport capacity, limited hydrogen storage or import capacities, calculated as follows at EU level based on the DHEM results:

- a. For each hour, the absolute EU-wide hydrogen demand curtailment is calculated.
- b. For each hour, the hypothetical absolute minimum EU-wide hydrogen demand curtailment is calculated, that could be achieved if there existed **unlimited intra-EU transport capacity** but no variation in storage capacity.
- c. For each hour, the hypothetical absolute minimum EU-wide hydrogen demand curtailment is calculated that could be achieved if there existed **unlimited storage** capacity but no variation in the intra-EU transport capacities.

The needed additional storage capacity can be estimated by using the fact that each consecutive hour, the unused import or electrolyser capacity can be injected into a hypothetical additional hydrogen storage and hydrogen stored therein can be withdrawn to reduce hydrogen demand curtailment. The hypothetical additional hydrogen storage level can never be negative or higher than the assumed working gas volume. Furthermore, the filling level must be identical in the first and in the last hour of the year (steady-state requirement). The delivery of this step is the hypothetically needed additional hydrogen storage capacity. It can be displayed as a factor of additional hydrogen storage need compared to the actual hydrogen storages in the hydrogen infrastructure level (e.g., factor 5.2).

- d. For each hour, the hypothetical absolute minimum EU-wide hydrogen demand curtailment is calculated that could be achieved if there existed **unlimited import capacity**, but no variation in the intra-EU transport or storage capacities.

→ The consideration of hypothetical infrastructure, either intra-EU pipeline connections or storage or import capacities considered in the steps 2.b/2.c/2.d will naturally lead to lower hydrogen demand curtailment (without allowing more unabated hydrogen production from natural gas to reach other nodes).

If hydrogen curtailment in step 2.b/2.c/2.d is lower than the hydrogen demand curtailment of step 2.a, the additional hydrogen infrastructure that is not part of the assessed hydrogen infrastructure level could mitigate hydrogen demand curtailment. This assessment can be further broken down into (groups of) countries.

3. Calculate the hourly unused hydrogen import and electrolytic potential for the three previous steps (i.e., step 2.b, 2.c and 2.d). With the consideration of unlimited intra-EU transport/storage/import infrastructure, we search to optimise the hydrogen supply available. Removing transport, storage or import capacity constraints will allow additional supply to reach demand nodes and subsequently reduce the identified infrastructure gaps for the PCI/PMI infrastructure level (by reducing IGI indicator 1 and/or indicator 2 thresholds for one or more countries/nodes). When comparing the supply that was used in the infrastructure level (i.e., 2.a), with the hypothetical unlimited infrastructure (steps 2.b, 2.c and 2.d), the additional hydrogen import and hydrogen electrolytic supply unused due to the limited intra-EU transport or storage or import capacities of the PCI/PMI infrastructure level would become used.

4. If after step 3, there still exists unused import potential and/or unused electrolysis potential, **a combination of unlimited intra-EU transport and unlimited storage** infrastructure might be needed. If this is still insufficient, a further combination including unlimited intra-EU transport, unlimited storage, and unlimited import capacities may be assessed.

5. There can still exist remaining hydrogen demand curtailment after step 4. Such remaining hydrogen demand curtailment is equivalent to a structural undersupply of hydrogen that cannot be mitigated by making full use of all hydrogen import potentials as described in the previous steps. This supply gap can only be satisfied by additional supplies. As the electrolyser capacities of each country are limited by the TYNDP 2026 Scenario Report, the remaining option is additional extra-EU hydrogen supply potentials according to the TYNDP 2026 Scenario Report. The supply gap is therefore quantifying the minimum need of additional hydrogen import potential (as the hydrogen supply potential of the hydrogen infrastructure level is already used to its maximum).

6.2 SENSITIVITY ANALYSIS ON LOW ELECTROLYTIC HYDROGEN PRODUCTION (P2X) AND RES SENSITIVITY

The purpose of this sensitivity is to assess the robustness of the hydrogen system under less favorable conditions for electrolytic hydrogen production and renewable electricity availability. Given the strong reliance of the European hydrogen market on renewable-based hydrogen production, variations in the deployment and performance of electrolyzers, as well as in the associated RES, may significantly affect hydrogen supply adequacy, infrastructure utilisation and the identification of infrastructure gaps.

Under this sensitivity, the capacity of electrolytic hydrogen production (P2X) is reduced by 10 %, while the applied efficiency of the available P2X facilities is simultaneously reduced by 10 %. In addition, the renewable electricity supply associated with P2X production is reduced proportionally to the decrease in P2X capacity, as follows:

- ▲ **Dedicated RES and shared RES:** 10 % reduction in the hourly rating (that is, the hourly potential RES generation, which is actually available, depending on weather conditions).
- ▲ **E-market RES:** for volatile RES (i.e., solar PV rooftop, solar PV Utility, solar CSP, wind Onshore, wind offshore radial, wind Offshore hub ready) connected to the electricity market, per-country hourly rating reduction was applied. Installed capacities considered per country, node, RES type and generation technology are available in the following link: [Microsoft Power BI IGI 2026 Results](#).



7 IMPLEMENTATION OF THE ENERGY EFFICIENCY FIRST PRINCIPLE IN THE INFRASTRUCTURE GAPS IDENTIFICATION

The introduction part of section 6 of this document as well as section 6.1 of the TYNDP 2026 Implementation Guidelines are also valid for this TYNDP 2026 IGI methodology.

INCLUSION OF OPTIONS FOR BETTER UTILISATION OF EXISTING INFRASTRUCTURE

The infrastructure considered in the TYNDP 2026 topology is updated with information provided by infrastructure operators. This provides the option to update the underlying energy infrastructure capacity assumptions, which are the main parameter behind better asset utilisation through operational improvements, including digital solutions.

Also, the consideration of infrastructure of multiple energy sectors like hydrogen, electricity, and natural gas allows for optimisation of the utilisation of the existing infrastructure's capacities in the model through flexibility provisions across energy sectors.

INCLUSION OF OPTIONS TO INCLUDE MORE ENERGY-EFFICIENT TECHNOLOGIES

The TYNDP 2026 IGI report is prepared based on the NT+ scenario that includes energy efficiency measures as described in section 6.1 of the TYNDP 2026 Implementation Guidelines. Thereby, a decisive share of the measures (e.g., renovations of buildings) have been set at the highest level that can be considered as feasible and realistic under current targets, policies, and expected technological advancements.

Thereby, in line with the Energy Efficiency First principle, the most energy efficient solution does not have to prevail but should be considered within the decision-making process and be preferred if being similarly cost-efficient, and beneficial for security of supply. By already being part of the NT+ scenario, the selected energy efficiency measures are not associated with additional investments in the simulations for the TYNDP 2026 IGI report and their usage is always an option alongside the identification of infrastructure gaps.

INCLUSION OF OPTIONS TO MAKE BETTER USE OF THE MARKET MECHANISMS

By considering perfect competition, only limited by infrastructure constraints between nodes, as well as by allowing demand side response to be acting without infrastructure or market restrictions (e.g., if the demand side response is located at DSO level) within a zone, the market behaviour is optimistic regarding the effects of demand side management. Several demand side responses are therefore considered. The pattern of the total demand is not simply transferred from the NT+ scenario to the TYNDP, but the underlying assets are used within their specifications to allow their optimised utilisation.

Concerning the DHEM-based assessments, this relates to:

- ▲ assets coupling the sectors through conversion (i.e., electrolyzers and hydrogen-fired power plants);
- ▲ demand shedding (e.g., reduction of industrial demand for a limited time that is triggered by a certain market clearing price).

AIMING AT BALANCING SECURITY OF SUPPLY, QUALITY OF ENERGY SUPPLIED, AND COST-EFFICIENCY

The wider benefits of investments are addressed from a system efficiency and societal perspective.

Concerning the DHEM-based assessments, this relates to:

- ▲ The monetisation of unserved energy demand (i.e., VoLL and WTP_{H₂});
- ▲ The Inclusion of adequacy loops;
- ▲ Considering penalties for energy losses, negatively contribute to life cycle efficiencies (e.g., reflection in marginal costs of fuels, conversion losses of electrolyzers, conversion losses of power plants, efficiencies of energy storages);

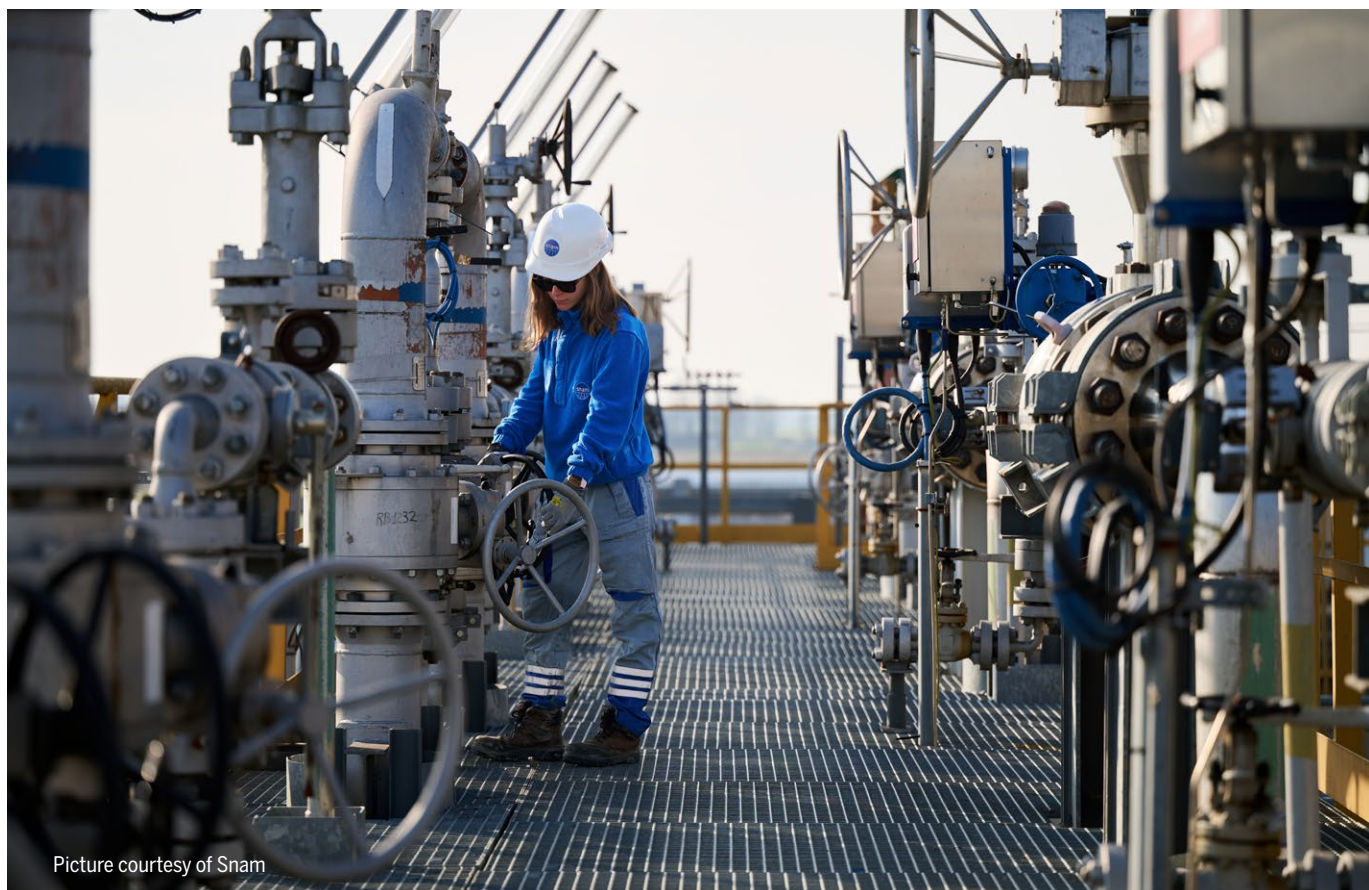
- ▲ Considering penalties for emissions (e.g., reflection in marginal costs of fuels and thereby in the merit order);
- ▲ Simulating with an integrated model, covering both the hydrogen and the electricity sector.

In line with the Energy Efficiency First principle, the most energy efficient solution does not have to prevail but should be considered within the decision-making process and be preferred if being similarly cost-efficient, and beneficial for security of supply.

LIST OF ABBREVIATIONS

The list of abbreviations of the TYNDP 2026 Implementation Guidelines is also valid for this document. Additionally, the following abbreviations apply:

ENNOH	European Network of Network Operators for Hydrogen
BEMIP Hydrogen	Hydrogen and electrolyser priority corridor containing Denmark, Germany, Estonia, Latvia, Lithuania, Poland, Finland, Sweden
GHR	Regulation of the European Parliament and of the Council on the internal markets for renewable gas, natural gas and hydrogen, amending Regulations (EU) No 1227/2011, (EU) 2017/1938, (EU) 2019/942 and (EU) 2022/869 and Decision (EU) 2017/684 and repealing Regulation (EC) No 715/2009 (recast)
HI East	Hydrogen and electrolyser priority corridor containing Bulgaria, Czechia, Germany, Greece, Croatia, Italy, Cyprus, Hungary, Austria, Poland, Romania, Slovenia, Slovakia
HI West	Hydrogen and electrolyser priority corridor containing Belgium, Czechia, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, Malta, Netherlands, Austria, Portugal
IGI indicator	Infrastructure Gaps Identification Indicator



COUNTRY CODES (ISO)

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

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Publisher

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