TYNDP 2026 ANNEX D3 – HYDROGEN AND NATURAL GAS SYSTEM ASSESSMENT METHODOLOGY

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Content

1 Introduction

ENTSOG's TYNDP 2026 consists of different deliverables. Certain parts of the TYNDP 2026 contribute to the PCI/PMI selection process governed by the TEN-E Regulation. Those are described in the TYNDP 2026 Methodology for Cost-Benefit Analyses of Hydrogen Infrastructure Projects and TYNDP 2026 Implementation Guidelines (Annex D1) that contribute to the project-specific cost-benefit analyses (PS-CBA) process and in the TYNDP 2026 Infrastructure Gaps Identification (IGI) methodology (Annex D2) that contributes to the TYNDP 2026 IGI report. The methodologies for any other parts of the TYNDP 2026 are described in this TYNDP 2026 System Assessment methodology (Annex D3). Cross-references to the other documents are used whenever possible. All documents are based on the TYNDP 2026 scenarios[1].

This TYNDP 2026 System Assessment methodology specifies:

- the System Assessment approach of the hydrogen sector;
- the System Assessment approach of the natural gas sector, including natural gas infrastructure repurposing principles;
- the Supply Adequacy Outlook including a biomethane progress report.

The hydrogen-related System Assessment approach thereby is complementary to the findings of the TYNDP 2026 IGI report.

[1] Link to the TYNDP 2026 scenario documents: Link

2 System Assessment

The model description contained in section 2.2 of the TYNDP 2024 Methodology for Cost-Benefit Analyses of Hydrogen Infrastructure Projects is also valid for this TYNDP 2026 System Assessment methodology. Exceptions from this validity and required specifications are described in this section.

The TYNDP 2026 System Assessment methodology is focusing on the Dual Hydrogen/Natural Gas Model (Dual Gas Model, DGM). The Dual Hydrogen/Electricity Model (DHEM) is only relevant to provide certain input data as further detailed below.

In contrast to the TYNDP Implementation Guidelines and the TYNDP 2026 IGI methodology, this TYNDP 2026 System Assessment methodology considers

- both natural gas infrastructure levels (i.e., Low natural gas infrastructure level and Advanced natural gas infrastructure level), and
- both hydrogen infrastructure levels (i.e., PCI/PMI hydrogen infrastructure level and Advanced hydrogen infrastructure level).

As the TYNDP 2026 Implementation Guidelines and the TYNDP 2026 IGI methodology, this TYNDP 2026 System Assessment methodology considers the National Trends+ (NT+) scenario and 2030, 2035 and 2040 as simulation years.

This TYNDP 2026 System Assessment methodology assesses demand curtailments for various stress cases that go beyond those stress cases proposed in the TYNDP 2026 Implementation Guidelines or the TYNDP 2026 IGI methodology. These additional stress cases either apply for a whole year or for less than a year. Curtailment and any results derived from stress cases are the result of imbalances between supply and demand due to hard constraints like capacities. The stress cases are expressed in terms of demand curtailment (DC) for the assessed duration (e.g., 1 day for Peak Demand (PD), 2 weeks for Cold Dunkelflaute (CDF), and full year for stressful case in energetic terms (MWh), each for natural gas (NGDC) and hydrogen (HDC). It can be displayed on node level, country level, European Union level, or European level. It can also be displayed in relative terms (%) as curtailment rate (CR) for the mentioned levels, representing the share of total demand that is curtailed during the duration considered. The curtailment rates are labelled as hydrogen demand curtailment rate (HCR) or natural gas demand curtailment rate (NGCR). The natural gas system and the hydrogen system are thereby inter-depending, as i) hydrogen can be produced from natural gas, so hydrogen supply may depend on natural gas availability, and ii) repurposing of natural gas infrastructure may put additional stress on the natural gas system.

The TYNDP 2026 System Assessment methodology also evaluates increase in exposure to curtailed natural gas demand (ΔNGDC), the LNG and Interconnection Capacity Diversification (LICD) indicator and the Minimal Annual Supply Dependency (MASD) indicator, in line with the Criteria for Natural Gas Infrastructure Repurposing report, to assess the suitability of existing gas infrastructure for hydrogen transport. This assessment encompasses the impact of repurposing projects, as well as supply dependency and cross-border diversification, within the framework of EU regulations and market integration principles.

The following cases and indicators for repurposing principles are assessed:

- Base case
- Stressful case
- Climatic stress conditions, i.e., 2-week Cold Dunkelflaute (CDF) and Peak Demand[2] (PD)
- Supply stress conditions as import source dependency (S-1) for natural gas sources
  - This case intends to identify dependence on a specific supply source and allows to identify cases where this dependence is related to an infrastructure bottleneck (physical dependence). The lower the value of the S-1 indicator, the lower the dependence. The supply dependence to source S is calculated as follows. First, the availability of source S is set down to zero. Second, the availabilities of the other sources remain in line with the defined supply assumptions. The supply source dependence $S\text{-}1_{Z,S}$ of the country Z to the source S is defined as the demand curtailment (in MWh) in Z when S is not available divided by the demand of Z (in MWh). In accordance with the Regulation of the European Parliament and of the Council on the phasing out Russian natural gas imports by November 2027 at the latest, the TYNDP 2026 System Assessment is conducted under the assumption that no Russian natural gas imports are included. Consequently, the S-1 stress condition for natural gas supply from Russia is applied across all assessed cases.
- Infrastructure stress conditions (N-1) as Single Largest Infrastructure Disruption for natural gas (SLID) during PD
  - This case intends to investigate the impact of the disruption of the single largest natural gas infrastructure entering a given country (excluding storages and national production) of the different countries to measure the impact of such disruptions at a European level during a day of PD. The SLID is computed in a peak demand situation, with the associated supply and national production in this configuration. This computation allows to identify potential bottlenecks for the considered country and the other European countries. SLID capacities will be reviewed and adjusted where necessary, with the next largest relevant infrastructure identified as the SLID when the single largest infrastructure serves as a transit route for Russian gas. The list of SLID capacities will be published as an Annex to the TYNDP 2026.
- Increase in exposure to curtailed natural gas demand during stressful case over full year
  - This case aims to measure the increase in curtailed natural gas demand resulting from the implementation of repurposing projects at the European level. Natural gas demand curtailment (NGDC) is calculated under stressful case over a full year, expressed in energy terms (MWh), both with and without the repurposing projects. Based on this

[2] Peak demand is the maximum level of demand used for the design of the network to capture the maximum transported energy and ensure consistency with national regulatory frameworks. The day of highest consumption in the year (also referred to as design case) is a key input that represents one of the most stressful situations to be covered by the infrastructure (transmission, distribution and storage).

comparison, the increase in natural gas demand curtailment (ΔNGDC) attributable to the implementation of the repurposing projects is determined. The results may also be presented in relative terms (%) as the natural gas curtailment rate (ΔNGCR).

$$\Delta NGDC = (NGDC_{with\ repurposing\ projects} - NGDC_{without\ repurposing\ projects})$$

> LNG and Interconnection Capacity Diversification (LICD) during stressful case over full year
  - This case intends to look at the diversification from the perspective of market integration. It measures the diversification of paths that gas can flow through to reach a market area. Import routes are not considered and capacities are capped by the country demand. The LICD is an HHI indicator[3] and ranges from 0 to 10,000. The lower the value, the better the diversification is. Where a market would have two borders the LICD cannot be lower than 5,000. For a market having three borders the LICD cannot be lower than 3,333.

$$LICD = \left(\frac{LNG_{border}}{Total\ Capa_{border}} \times 100\right)^2 + \sum_{i=1}^{N}\left(\frac{Capa_{border_i}}{Total\ Capa_{border}} \times 100\right)^2$$

with

$$Capa\_border_i = min\ [\textstyle\sum (from\ k\ to\ IP)\ IP_k\_border_i\ ,\ D\_yearly\ ]$$

where:

Capa_border$_i$ = min [∑ IP_k at border$_i$, D_yearly]
Dyearly = average yearly gas demand (GWh/d)
IP_k border$_i$ = capacity at interconnection point *k* at border *i*
LNG_border = min [∑ LNG_terminal$_m$, D_yearly$_m$]
Total Capa_border = LNG_border + ∑ Capa_border$_i$

> Minimum Annual Supply Dependence (MASD) during stressful case over full year
  - This case aims to investigate dependence on a specific supply source and to identify situations in which this dependence is related to an infrastructure bottleneck. It is calculated for each source over a full year. The lower the value of MASD, the lower the level of dependence. As for the NGDC and NGCR indicators, they are calculated assuming full cooperation among all European countries. Under this cooperative approach, all European countries share dependence levels unless constrained by infrastructure limitations.

$$MASD_{Z,S} = \frac{DC_{Z,S}}{Demand_Z}$$

[3] Herfindahl-Hirschman index, an indicator of concentration or, conversely, diversification.

where:

$\mathbf{DC_{Z,S}}$:Demand curtailment in area Z when source S is unavailable.

$\mathbf{Demand_{Z}}$:Total annual demand of area Z.

For the yearly DGM simulations, the inputs for supply and demand are sourced from the DHEM simulations as described in sections 2.2.3.5 and 2.2.3.6 of the TYNDP 2024 Methodology for Cost-Benefit Analyses of Hydrogen Infrastructure Projects.

> The DHEM market assumptions listed in section 3.2.4 and Annex III as well as the infrastructure information provided by Annex I and II of the TYNDP 2026 Implementation Guidelines as well as TYNDP 2026 Annex C are also valid in this context for this TYNDP 2026 System Assessment methodology. The remaining parts of section 3, section 4, section 5, and section 6.2 of the TYNDP 2026 Implementation Guidelines are not relevant for this TYNDP 2026 System Assessment methodology as they are related to project-specific assessments.

For the non-yearly DGM simulations, the country-specific values of the final natural gas demand and of the national natural gas production are sourced from the respective values for PD and CDF as stated in the TYNDP 2026 Scenario report. Node-specific values for the natural gas demand for power generation, hydrogen demand, and electrolytic hydrogen production are sourced from the DHEM simulation of the stressful case as follows:

> For each relevant period (i.e., one day for PD and 2 weeks for CDF), the hourly natural gas usage for power generation derived from the DHEM simulation under stressful case conditions is aggregated into daily demand for the PD case or into a two-week rolling average for the CDF case. The statistical percentile function (indicating the value below which a given percentage of observations in a dataset falls) is applied at each node. For each node, the resulting natural gas demand for power generation is used as input to the DGM for the relevant period.

> For each relevant period (i.e., one day for PD and two weeks for CDF), the hourly hydrogen demands and electrolytic hydrogen productions, derived from the DHEM simulation under stressful case conditions, are aggregated at the European level into daily demand for the PD case or into a two-week rolling average for the CDF case. The relevant period when the EU had the highest net hydrogen demand (i.e., hydrogen demand minus electrolytic hydrogen production) is identified. For each node, the corresponding hydrogen demand and electrolytic hydrogen production values are extracted for the relevant period to be used as input to the DGM.

For the non-yearly DGM simulations, the following additional assumptions are needed on top of the specifications provided in the points above:

> LNG tanks' flexibility in the PD and the CDF cases: Flexibility from the LNG tanks is used as additional supply for the PD and during both weeks of the CDF. In the first week, the global LNG flows are limited to the level observed in February from the previous modelling of the entire year. In the second week, additional cargos can arrive allowing supply to reach the daily

maximum supply potential of CDF. No tanks of hydrogen import terminals have been considered for additional hydrogen supply.

> Storage filling levels in the PD and the CDF cases: All storages' filling levels are assumed to be at a level of 35% of the working gas volume. Through the storage-specific curves that define the maximum withdrawal capacity from a storage as a function of its filling level (i.e., withdraw deliverability curves), this filling level of 35% determines how much energy the storages can deliver. The working gas level, the withdrawal capacities and the withdrawal curves therefore define the constraints for the storage usage during high demand situations. The actual usage of storages is a result of the model taking into account these constraints.

The results of all DGM simulations are interpreted by identifying infrastructure bottlenecks by assessing which demand curtailments are caused by all relevant transmission infrastructure being used at their maximum capacity. By comparing the results of different combinations of infrastructure levels for simulations that are identical concerning all other parameters, the effect of including additional infrastructure can be identified. For example, the Advanced hydrogen infrastructure level contains the exact PCI/PMI hydrogen infrastructure level as well as additional projects. If a bottleneck is observed in the PCI/PMI hydrogen infrastructure level but is not observed in the Advanced hydrogen infrastructure level, the additional projects contained in latter infrastructure level removed the bottleneck.

A summary of the base case and stress cases proposed be considered in the TYNDP 2026 System Assessment is provided by Table 1:

<table>
<tr><th>Cases per combination of scenario, modelling year, and combination of natural gas and hydrogen infrastructure levels[4]</th><th>Duration</th><th>Results</th><th>Granularity options</th></tr>
<tr><td>Base case</td><td rowspan="2">Full year</td><td rowspan="5">HDC
HCR
NGDC
NGCR</td><td rowspan="7">Node,
Country,
European Union,
or Europe</td></tr>
<tr><td>Stressful case</td></tr>
<tr><td>PD</td><td rowspan="2">1 day</td></tr>
<tr><td>PD with SLID for natural gas for each Member State individually</td></tr>
<tr><td>CDF</td><td>2 weeks</td></tr>
<tr><td>Increase in exposure to curtailed natural gas demand</td><td>Full year</td><td>ΔNGDC
ΔNGCR</td></tr>
<tr><td>MASD</td><td>Full year</td><td>NGDC
NGCR</td></tr>
<tr><td>LICD</td><td>Full year</td><td>HHI</td><td>Per border between the countries</td></tr>
</table>

Table 1: Overview of stress case options for the TYNDP 2026 System Assessment

[4] S-1 stress condition for natural gas supply from Russia is applied across all assessed cases

3 Supply Adequacy Outlook

The GHR mandates ENTSOG to include in its TYNDP a European supply adequacy outlook which shall cover the overall adequacy of the natural gas system to supply current and projected demands for natural gas for up to 10 years from the date of that outlook.

Consequently, the Supply Adequacy Outlook is a comparison of the annual European natural gas demand versus the annual natural gas supply options. The data for the European natural gas demand as well as the natural gas supply options (i.e., extra-EU natural gas supply potential and different forms of national production like biomethane and synthetic methane) are sourced as described in the previous chapter and based on the respective TYNDP 2026 scenario storyline. Thereby, the TYNDP 2026 scenarios established together with all gas TSOs represent the national supply outlooks that shall feed into the assessment. The comparison allows to identify whether the natural gas supply options are higher than the European natural gas demand. This is a prerequisite for adequate supply of natural gas. Furthermore, the comparison allows to calculate the minimum natural gas imports needed by subtracting the national production from the natural gas demand.

Complementarily, final Supply Mix overviews are produced that are not limited to an annual comparison and that consider infrastructure constraints like transit and underground storage capacities. Therefore, the Supply Mix results are based on the DGM simulations described in the previous sections where, especially under high demand situations, the supply and demand balance is highly dependent on the underground storage utilisation.

The underground storage utilisation is only visible in Supply Mix overviews for non-yearly DGM simulations. In yearly simulations, storage filling levels start and end at the same value. Therefore, for the annual Supply Adequacy Outlook as well as for the Supply Mix overviews that are based on yearly DGM simulations, storages are not displayed.

The GHR furthermore states that the European supply adequacy outlook shall specifically include a monitoring of the progress on the annual production of sustainable biomethane. For this purpose, i) the European biomethane production forecast for 2030 and 2035 from the TYNDP 2026 draft Scenarios Report, ii) the biomethane-related target of the REPowerEU communications[5] for 2030 and 2035, and iii) other benchmarks for 2030 and 2035 are evaluated against the expected new biomethane production capacities to be commissioned before 2030 and 2035. Information about such capacities will be collected by Gas Infrastructure Europe (GIE) and/or the European Biogas Association (EBA) and provided to ENTSOG. The information may be complemented by insights provided by ENTSOG's annual report on the quantity of renewable gas and low-carbon gas injected into the natural gas network on the basis of Article 26.3(i) GHR. The progress report will allow to estimate whether the European Union

[5] Link to the REPowerEU plan of 18 May 2022: https://eur-lex.europa.eu/resource.html?uri=cellar:fc930f14-d7ae-11ec-a95f-01aa75ed71a1.0001.02/DOC_1&format=PDF

is on track to reach the listed targets (see

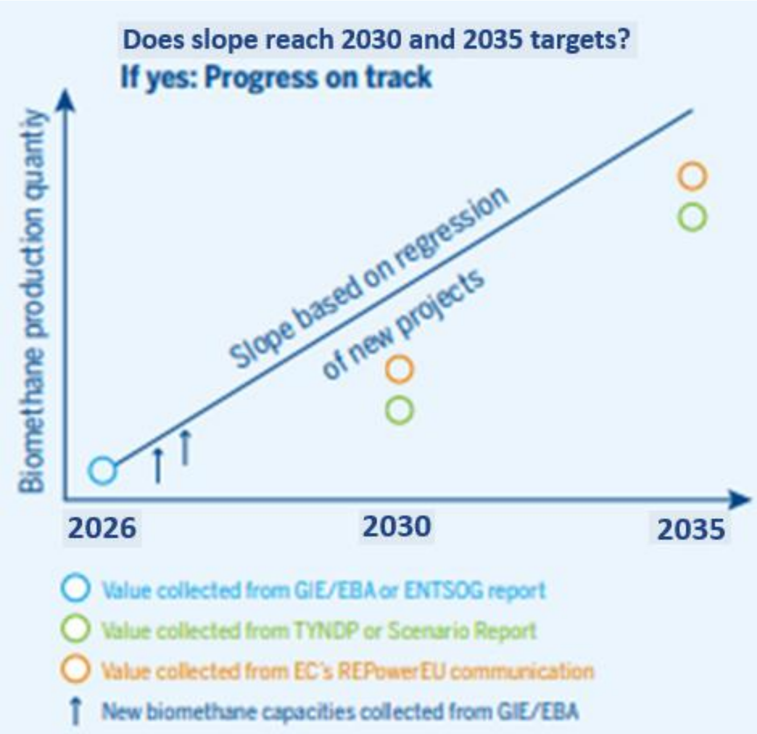

Figure 1).

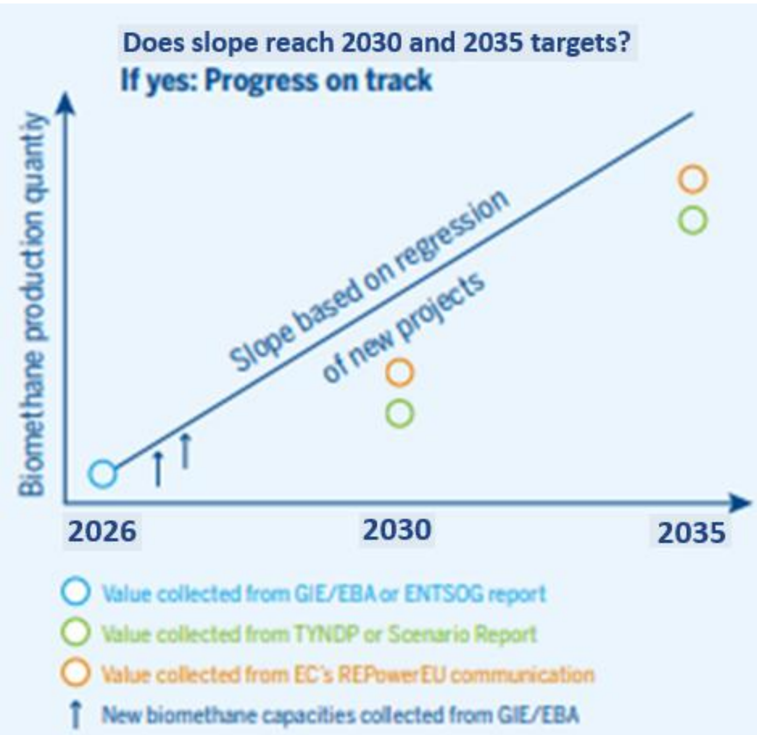

Figure 1: Methodology for the analysis of progress of the European Biomethane production.

Abbreviations

The lists of abbreviations of the TYNDP 2026 Implementation Guidelines[6] and the TYNDP 2026 Infrastructure Gaps Identification (IGI) methodology[7] are also valid for this document. Additionally, the following abbreviations apply:

[6] Link to draft TYNDP 2026 Implementation Guidelines: link
[7] Link to the draft TYNDP 2026 IGI methodology: link

CDF	2-week Cold Dunkelflaute
CR	Curtailment Rate
DC	Demand Curtailment
DGM	Dual Hydrogen/Natural Gas Model or Dual Gas Model
DHEM	Dual Hydrogen/Electricity Model
EBA	European Biogas Association
ENTSOG	European Network of Transmission System Operators for Gas
EU	European Union
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)
GIE	Gas Infrastructure Europe
HCR	Hydrogen Demand Curtailment Rate
HDC	Hydrogen Demand Curtailment
IGI	Hydrogen Infrastructure Gaps Identification
LICD	LNG and Interconnection Capacity Diversification
LNG	Liquefied Natural Gas
MASD	Minimum Annual Supply Dependence
MWh	Megawatt Hour
N-1	Unavailability of a certain infrastructure element
NGCR	Natural Gas Demand Curtailment Rate
NGDC	Natural Gas Demand Curtailment
PD	Peak Demand (Design Case)
PCI	Project of Common Interest
PMI	Project of Mutual Interest
PS-CBA	Project-Specific Cost-Benefit Analysis
S-1	Unavailability of a certain supply source
SLID	Single Largest Infrastructure Disruption for Natural Gas
TYNDP	Ten-Year Network Development Plan

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
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