TYNDP 2024

Guidance documents for system and project-level assessment

24 June 2024

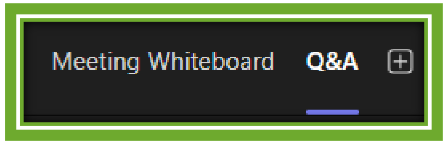
ENTSOG - System Development team
Simona Marcu, TYNDP project manager

Brussels

Webinar rules & Agenda

Webinar rules

For **questions**, please **ask by raising a virtual hand** or write it in the Ms. Teams **Q&A section**.



The **recording** of this session, as well as the **slides** will be made available.

Microphones are muted by default. Please unmute to intervene.

Thank you!

Agenda

Topic	Presenter	Time
Introduction & TYNDP context	Simona Marcu TYNDP PM	10:05 – 10:25
Annex D1 - Implementation Guidelines for project-specific cost-benefit analyses of hydrogen projects	Maria Castro Subject Manager Investment	10:25 – 12:00
Lunch break		12:00 – 13:00
Annex D2 - Hydrogen Infrastructure Gaps Identification methodology	Thilo von der Grün Director System Development	13:00 – 13:50
Annex D3 - Hydrogen and Natural Gas System Assessment methodology	Arturo de Onis Romero-Requejo Modelling Subject Manager	13:50 – 14:20
Gas quality monitoring	Lorella Palluotto Adviser Gas Quality & Hydrogen	14:20 – 14:30

Each session includes Q&A → please use the **Ms. Teams Q&A section**

TYNDP acronyms


Picture courtesy of Gaz System

AGSI – Aggregated Gas Storage Inventory
ATR – Autothermal Reforming
CD – Curtailed Demand
CDF –2 Week Cold Dunkelflaute
CODH – Cost of Disrupted Hydrogen
DC – Disruption Case
DGM – Dual Gas Model (H_2-NG)
DHEM – Dual Hydrogen Electricity Model
GLE – Gas LNG Europe
GSE – Gas Storage Europe
HDC – Hydrogen Disruption Case
IG – Implementation Guidelines
IGI – Infrastructure Gaps Identification
IL – Infrastructure Level
LSO – LNG System Operator
PCI – Project of Common Interest
PMI – Project of Mutual Interest
PA – Project Assessment
PS-CBA – Project-Specific Cost-Benefit Analysis
SA – System Assessment
SCN – Scenario(s)
SMR – Steam Methane Reformer
SLID – Single Largest Infrastructure Disruption
SSO – Storage System Operator
TSO – Transmission System Operator
WGV – Working Gas Volume
WTP – Willingness To Pay


Picture courtesy of Gaz System

Highlighted: particular relevance for TYNDP 2024

Introduction & TYNDP context

Context – general overview

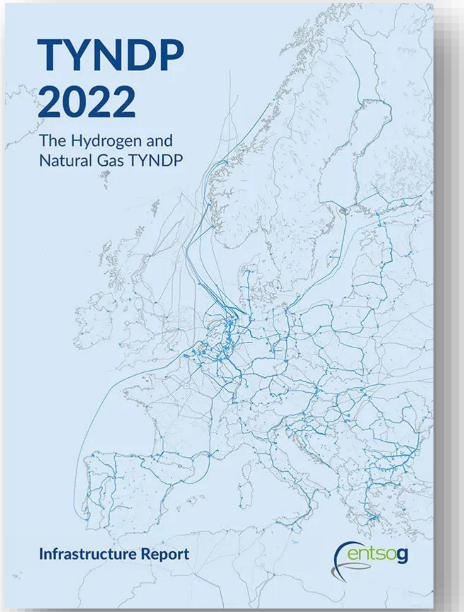
- TYNDP is developed **bi-annually** and is **non-binding**:
  - Task defined by new Regulation on the internal markets for renewable gas, natural gas and hydrogen and Reg. (EU) 2022/869 (“TEN-E”)
  - The European Commission (EC) approves the Scenarios and the Cost-Benefit Analysis Methodology applied to TYNDP and issues formal Opinion on the infrastructure gaps identification report
  - ACER monitors TYNDP and issues formal Opinions on the Scenarios, the CBA Methodology, the infrastructure gaps identification report, and the full TYNDP
- Process is public and involves ENTSO-E for joint network planning
  - It is open to all stakeholders through public consultations
- Projects which are **candidates to PCI or PMI status need to be submitted to the latest TYNDP** and assessed compared to the same reference

What is the TYNDP in practice?

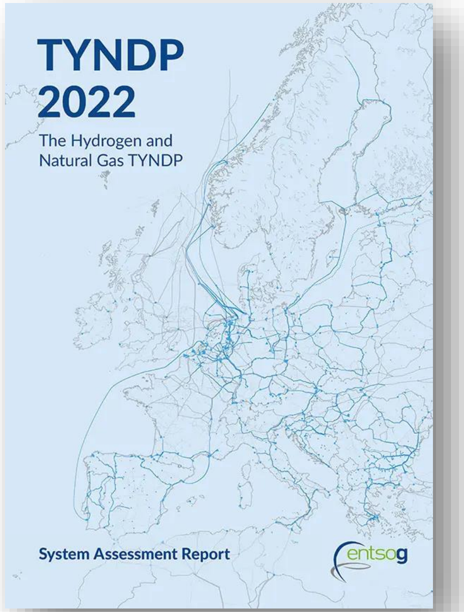
The TYNDP 2024 is composed of:

- 3 main reports:

(1). Scenarios



(2). Infrastructure

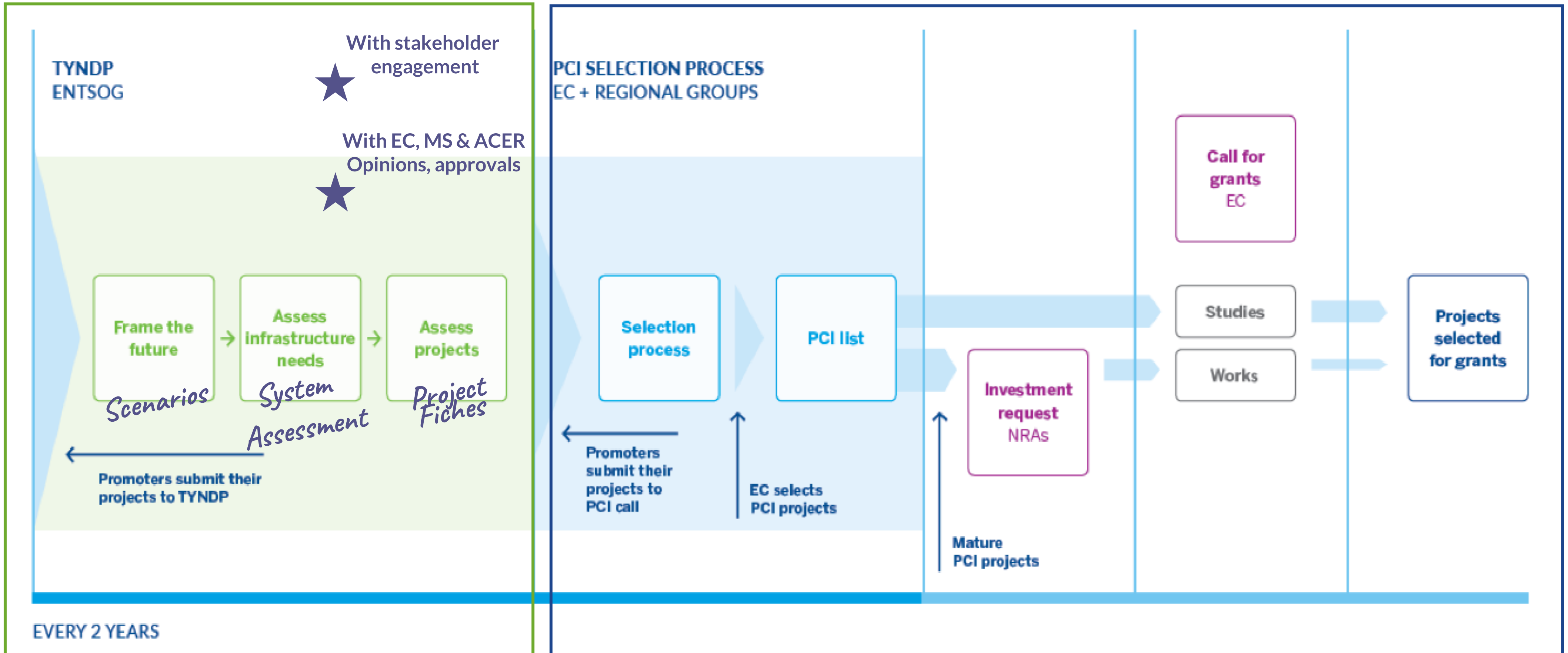


(3). System Assessment

- 5 annexes:
  - **Annex A** – Project details
  - **Annex B** – Infrastructure Maps
  - **Annex C** – Topology & Capacities
  - **Annex D** – Methodologies
  - **Annex E** – Analysis tables
- Project fiches (project assessment)
- A visualization platform

These can be accessed on www.entsog.eu/tyndp

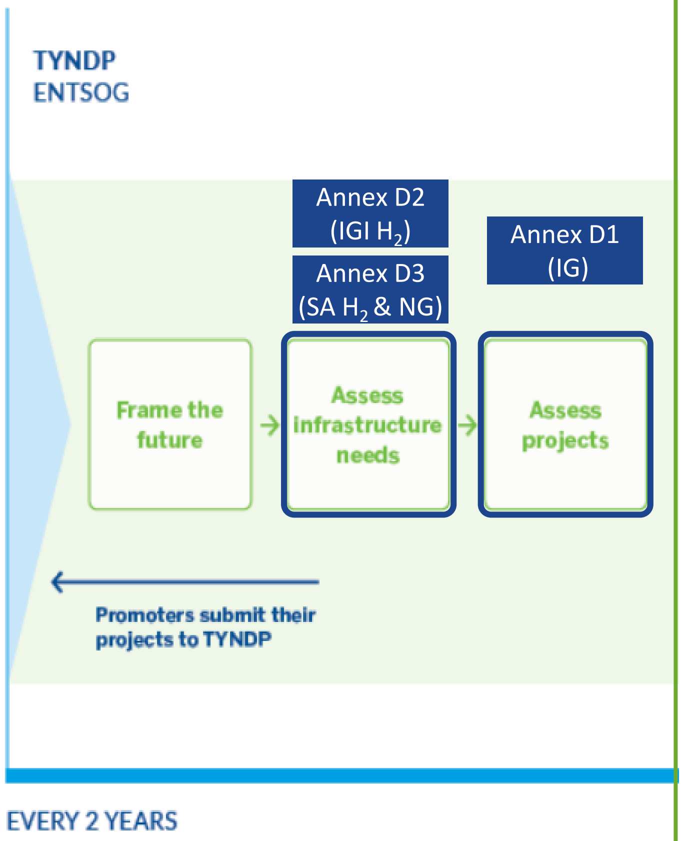
The TYNDP process in the wider TEN-E framework



Every two years ENTSOG & ENTSO-E **plan, assess and test** the infrastructure against **possible futures**

The **EC and regional groups attribute PCI or PMI status** to a list of candidate projects, considering their **contributions to covering the system needs** identified in the TYNDP.

Documents under consultation



Every two years ENTSOG & ENTSO-E **plan, assess and test** the infrastructure against **possible futures**

Documents currently under consultation concern the second two blocks

The online form you can fill-in to reply to this consultation until **Tue, 9 July** is available here and consists of:

- Initial section: identification, TYNDP focus, document readability
- Annex D1 - **Implementation Guidelines** for project-specific cost-benefit analyses (PS-CBA) of hydrogen projects
  → 26 questions: infrastructure levels, stress cases & alternative fuel, assumptions for benefit indicators, sensitivities, etc.
- Annex D2 - **Hydrogen Infrastructure Gaps Identification** methodology
  → 5 questions: infrastructure levels, assumptions for IGI indicators, etc.
- Annex D3 - Hydrogen and natural gas **System Assessment** methodology
  → 3 questions: general assumptions, clarity and improvement
- In addition: 1 question on gas quality

ENTSOG Draft CBA Methodology H_2

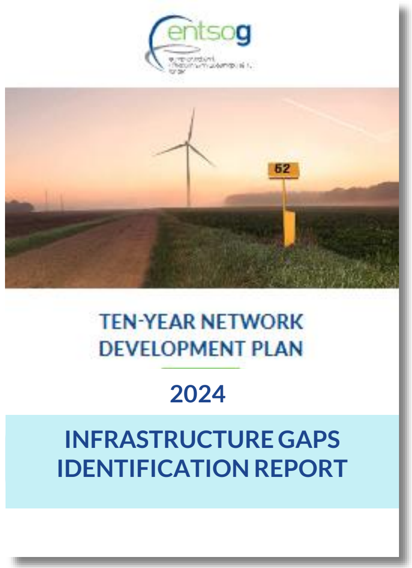
Approval process ongoing

Annex D - Methodology (public consultation 19 June – 9 July 2024)

Setting Guidelines and Indicators

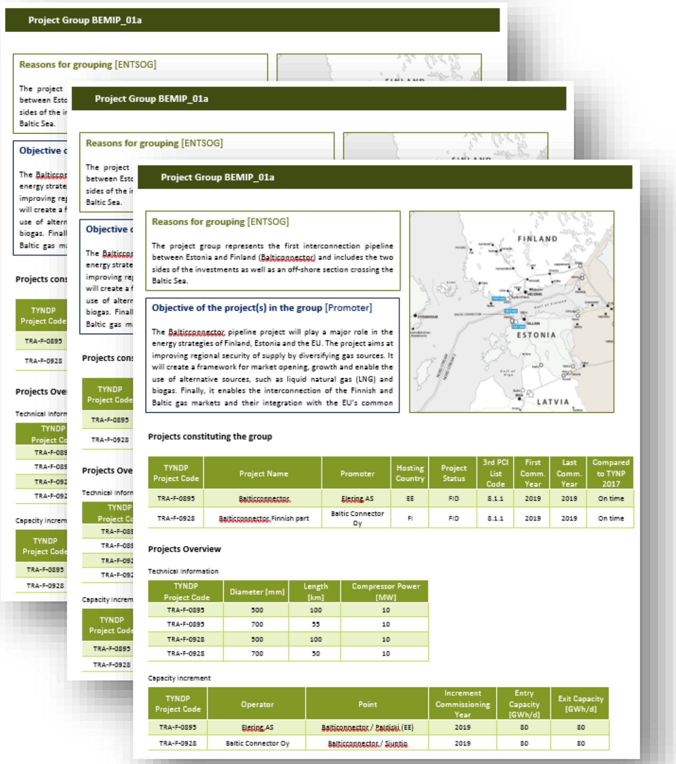
Infrastructure Gaps Identification (IGI)

(public consultations: of methodology Jun/Jul 2024 and of report: Q4 2024)



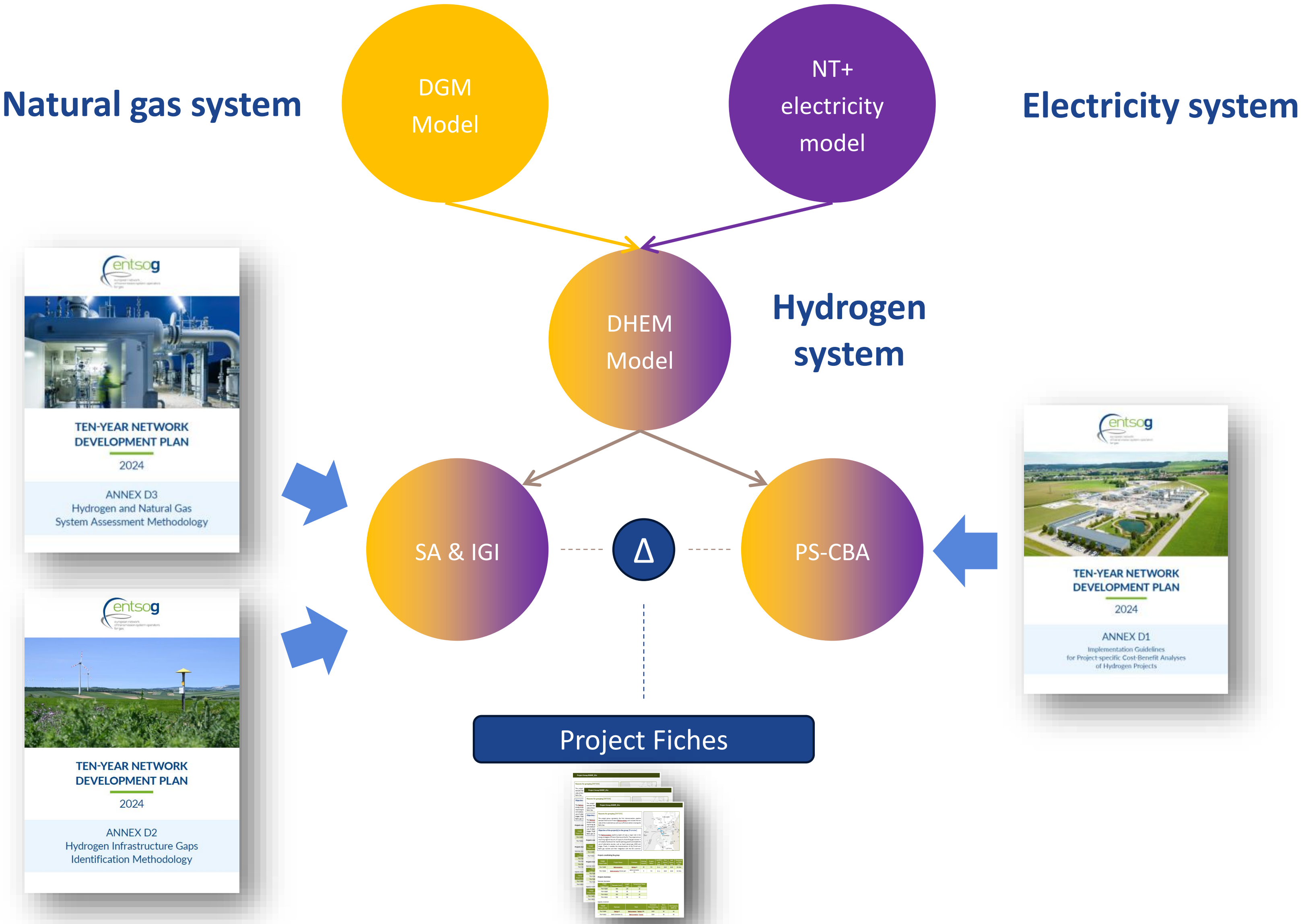
Assess Infrastructure needs

Project Assessment H_2



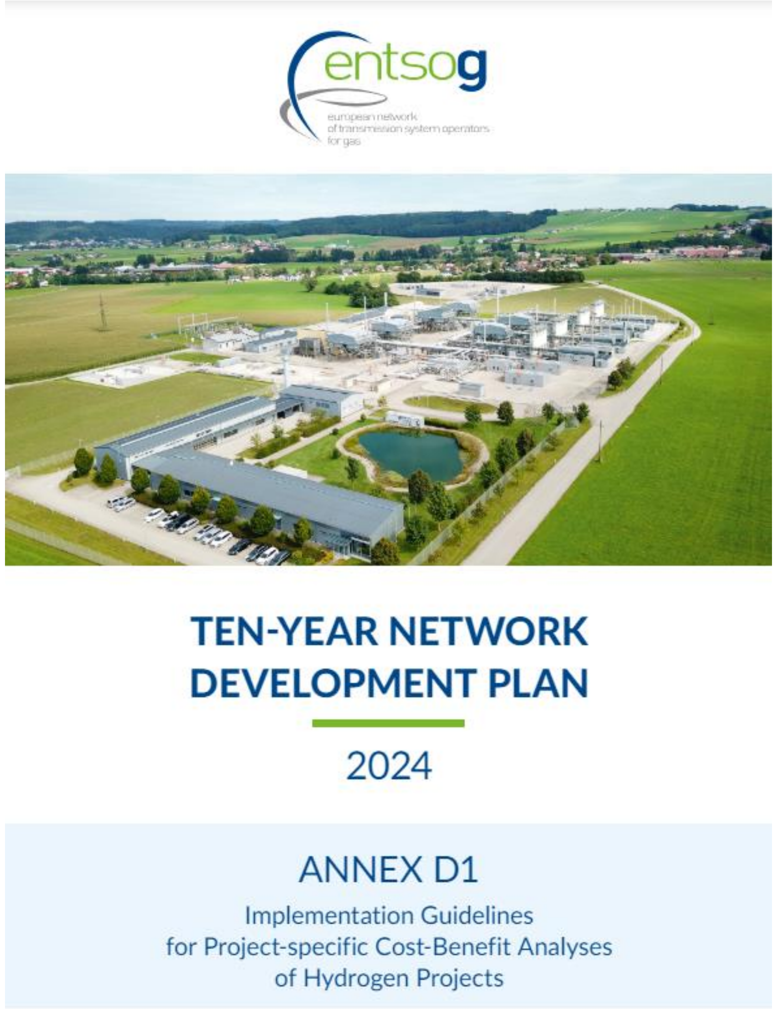
Assess Projects

TYNDP models vs. consulted documentation



Annex D1
Implementation Guidelines for project-specific cost-benefit analyses of hydrogen projects

Annex D1: Overview


TEN-YEAR NETWORK DEVELOPMENT PLAN

2024

ANNEX D1

Implementation Guidelines for Project-specific Cost-Benefit Analyses of Hydrogen Projects

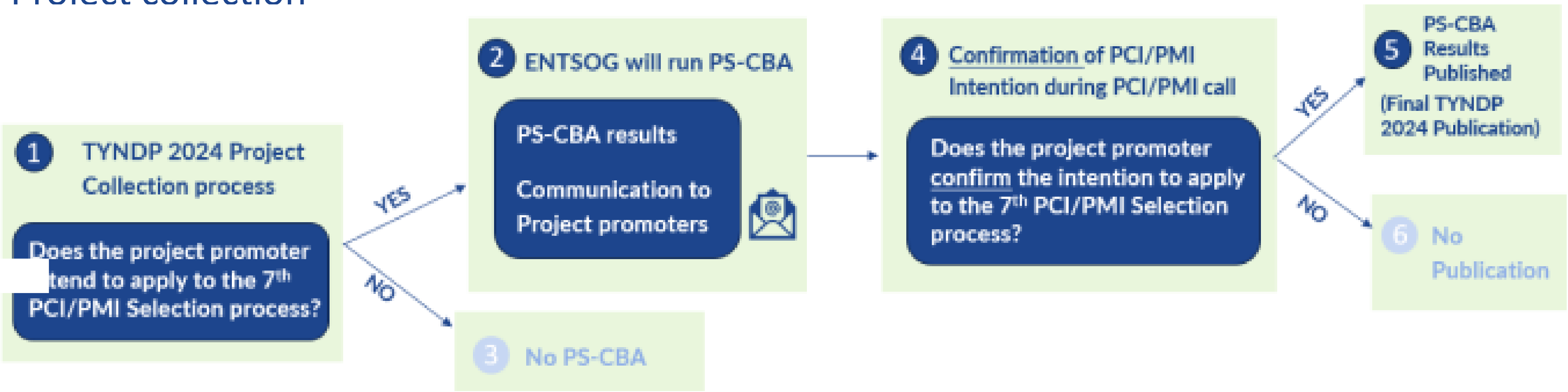
1. **Introduction**
2. **Modelling** (general principles, model(s) description, topology, objective functions, infrastructure levels)
3. **Project assessment**
   - ✓ Project grouping
   - ✓ PS-CBA general principles
   - ✓ Market assumptions
   - ✓ Benefit indicators
   - ✓ Other elements (environmental impact, climate adaptation measures)
   - ✓ Project costs
4. **Economic performance indicators**
5. **Sensitivity analysis**
6. **Annexes** (Detailed description of the hydrogen and NG infrastructure levels, detail of assumptions (e.g., emission factors, supply potentials, etc.)

Objective and introduction

OBJECTIVE

The objective of the ENTSOG TYNDP 2024 Implementation Guidelines is to provide detailed **guidance on the different elements of relevance for the project-specific cost-benefit analysis**, or PS-CBA, as part of the 2024 TYNDP cycle

ENTSOG runs PS-CBA for hydrogen projects that **declared PCI/PMI intention** during TYNDP 2024 Project collection

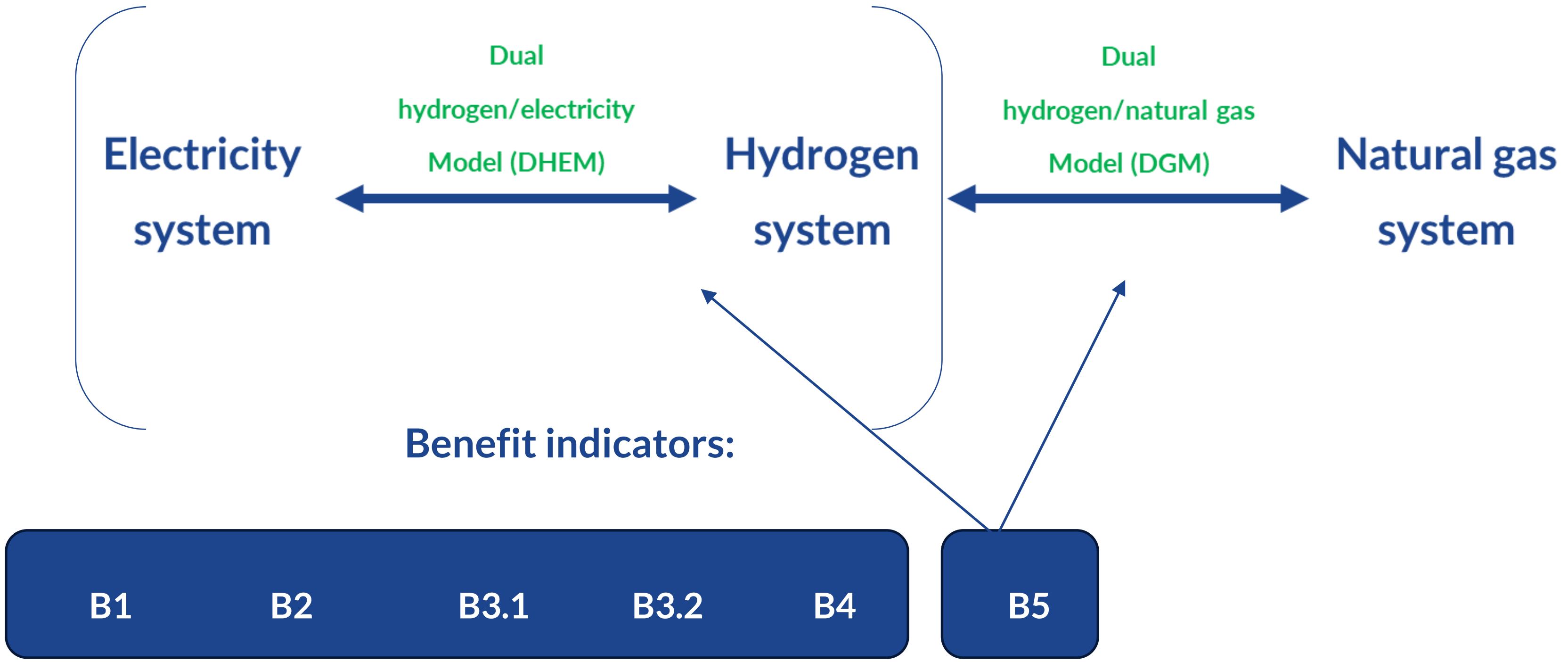


Hydrogen projects categories as defined by Annex II.3 of TEN-E regulation

Transport | Terminal | Storage | Transport sector

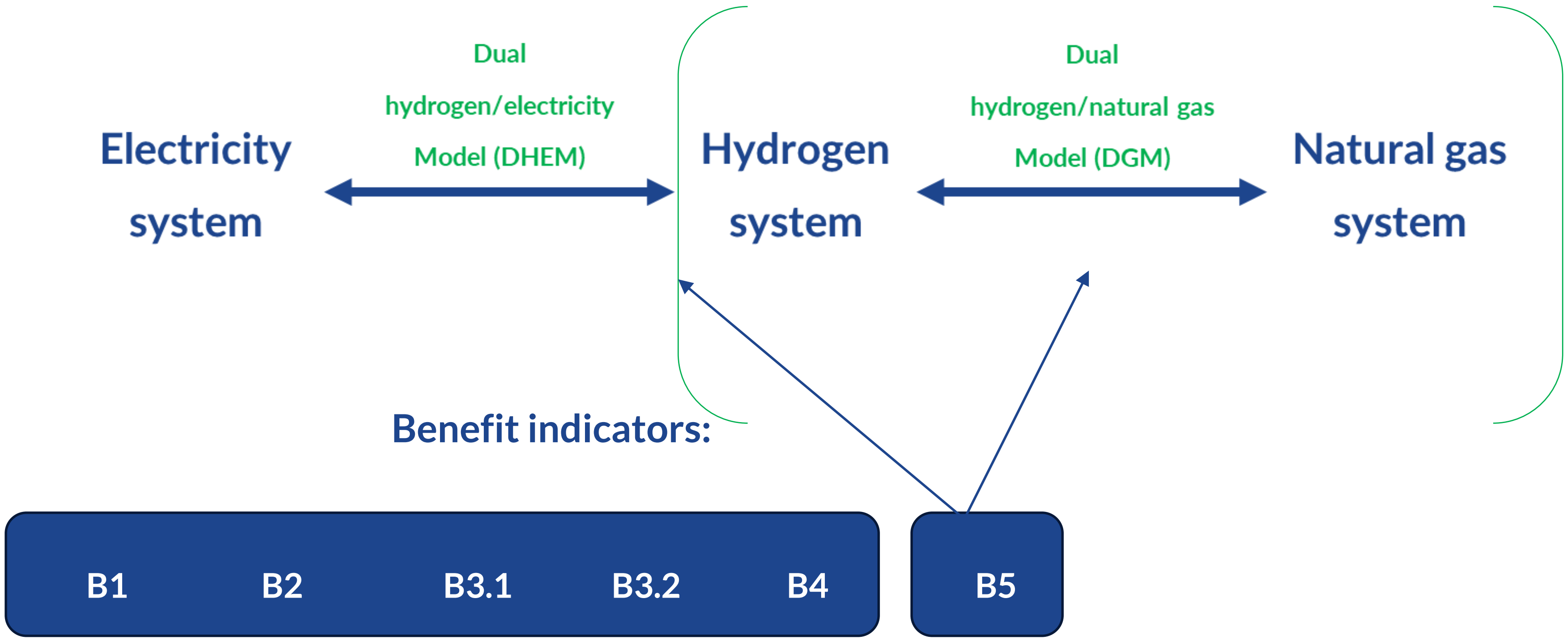
Two dual models in TYNDP 2024 PS-CBA

- DHEM: Dual hydrogen/electricity model:
  - Used for most PS-CBA indicators
  - Based on hourly modelling
  - Behaviour based on market model with prices that aspire to be realistic



Two dual models in TYNDP 2024 PS-CBA

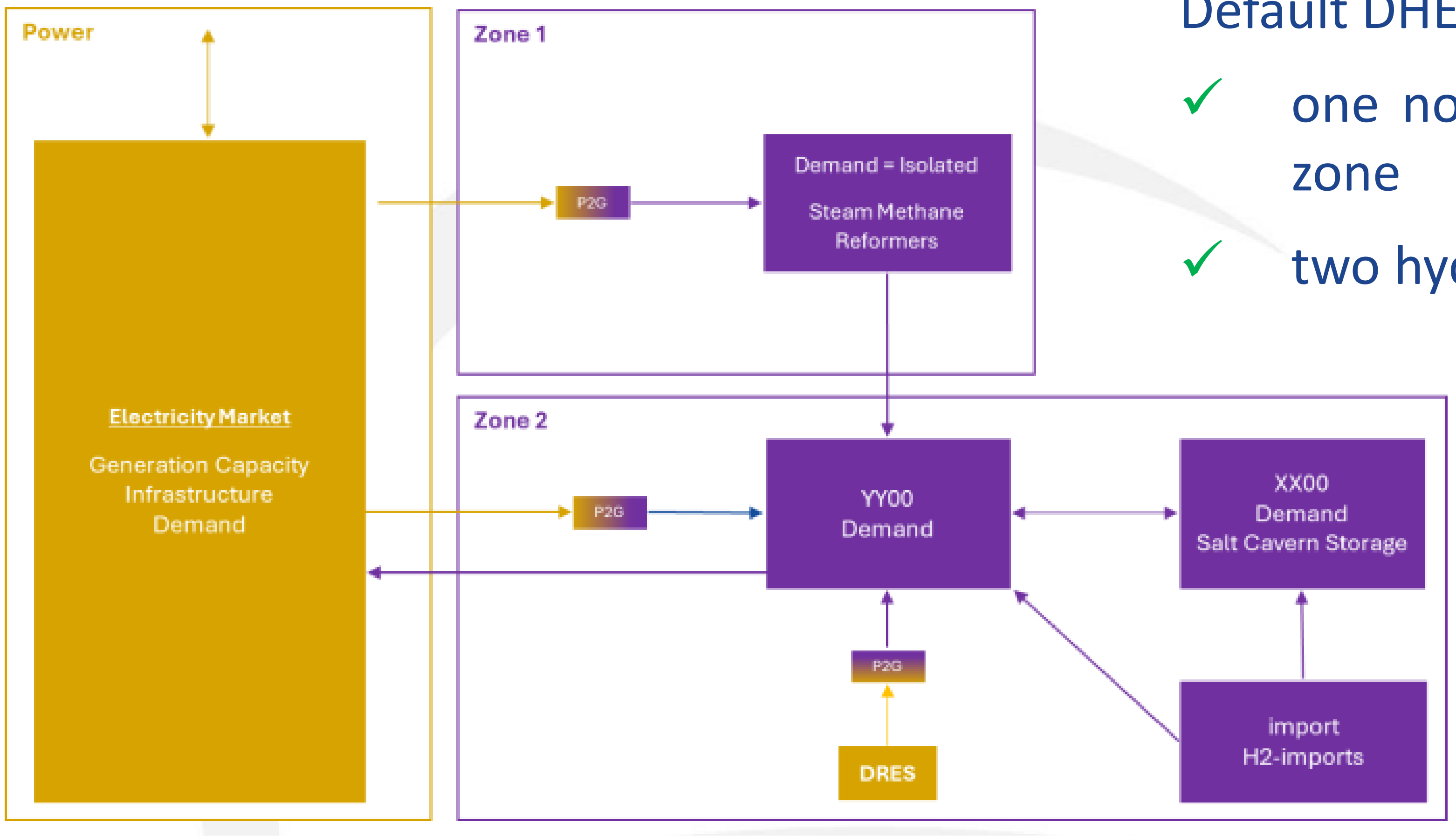
- DGM: Dual Gas Model
  - Used only for security of supply assessments
  - Based on monthly modelling
  - Supply and demand data sourced from scenarios and/or DHEM



Inputs to the analysis: Scenario

- Proposed scenario for PS-CBA assessment is National Trends+ 2030 and National Trends+ 2040 as described in ENTSOG‘s and ENTSO-E‘s joint draft TYNDP 2024 scenario documents
  - Contains data on capacities, costs, efficiencies, electricity generation assets, hydrogen production assets, energy storages, demand, extra-EU hydrogen supply potentials etc.

Dual-Hydrogen electricity model (DHEM) topology

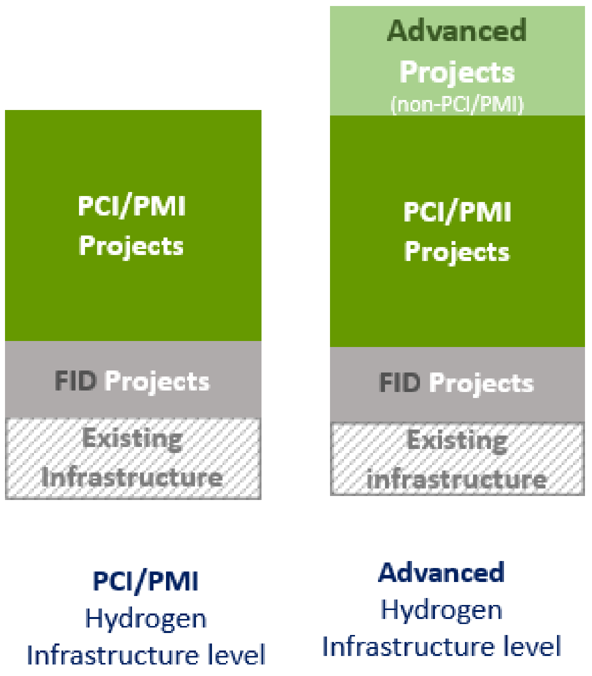


Default DHEM topology contains:

- ✓ one node per electricity bidding zone
- ✓ two hydrogen nodes per country

Inputs for PS-CBA: Infrastructure levels

- Hydrogen infrastructure for DHEM and DGM contains a subset of the projects submitted by project promoters during the TYNDP 2024 Project collection, published in the TYNDP 2024 Annex D implementations Guidelines (Annex I & II)
- Such a subset is called ***infrastructure level*** and is defined by the following criteria:
  - **PCI/PMI Hydrogen infrastructure level:** contains existing infrastructure, FID projects and projects that are part of the 6th PCI/PMI Union list as detailed in section B of the Annex VII to the TEN-E Regulation.
  - **Advanced Hydrogen infrastructure level:** contains PCI/ PMI Hydrogen infrastructure level plus advanced projects (Advanced maturity status for hydrogen projects is defined in the TYNDP 2024 Guidelines for project inclusion)
- The PS-CBA can be based on **one** out of two defined infrastructure levels
- Selected Infrastructure level will be defined based on the outcome of the public consultation and EC feedback

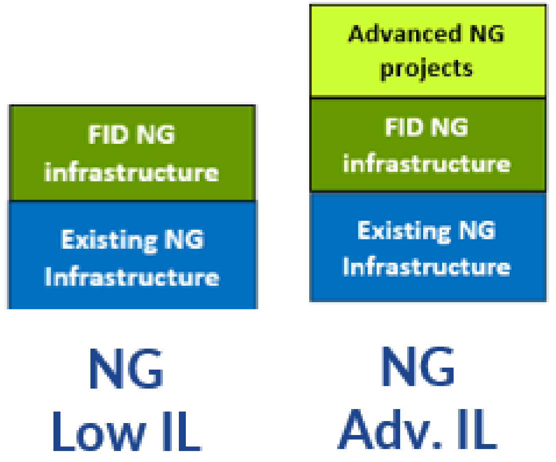


Consultation questions 12-13: Which hydrogen infrastructure level do you support to be used in the PS-CBA and why?

Inputs for PS-CBA: Infrastructure levels

- Electricity infrastructure for the DHEM is identical with the assumptions used in NT+ scenario model.
- Natural gas infrastructure for the DGM can be based on **one** of two defined infrastructure levels:

  - **Low NG infrastructure level:** contains existing infrastructure and FID projects
  - **Advanced NG infrastructure level:** contains low NG infrastructure level plus advanced projects (Advanced maturity status for NG projects is defined in the TYNDP 2024 Guidelines for project inclusion)



Consultation questions 14-15: Which natural gas infrastructure level do you support to be used in the PS-CBA and why?

Public consultatin questions about Infrastructure levels

12. Which hydrogen infrastructure level do you support to be used in the Dual Hydrogen/Electricity Model (DHEM) for the TYNDP 2024 PS-CBA and why? *

- ◯ "PCI/PMI" hydrogen infrastructure level,
- ◯ "Advanced" hydrogen infrastructure level
- ◯ No preference

13. Please add any comments here regarding your answer to the previous question (infrastructure levels in the DHEM). *

Enter your answer

14. Do you support the application of a seasonality of natural gas prices in the TYNDP 2024 PS-CBA that influences the production cost of hydrogen from natural gas as described in the TYNDP 2024 Implementation Guidelines? *

- ◯ Yes
- ◯ Yes, but with different parameters (please specify in next question)
- ◯ No (please specify in next question)
- ◯ No preference

15. Please add any comments here regarding your answer to the previous question (seasonality of natural gas prices). *

Enter your answer

Grouping: General principles

PS-CBA groups will be drafted by ENTSOG with following grouping principles:

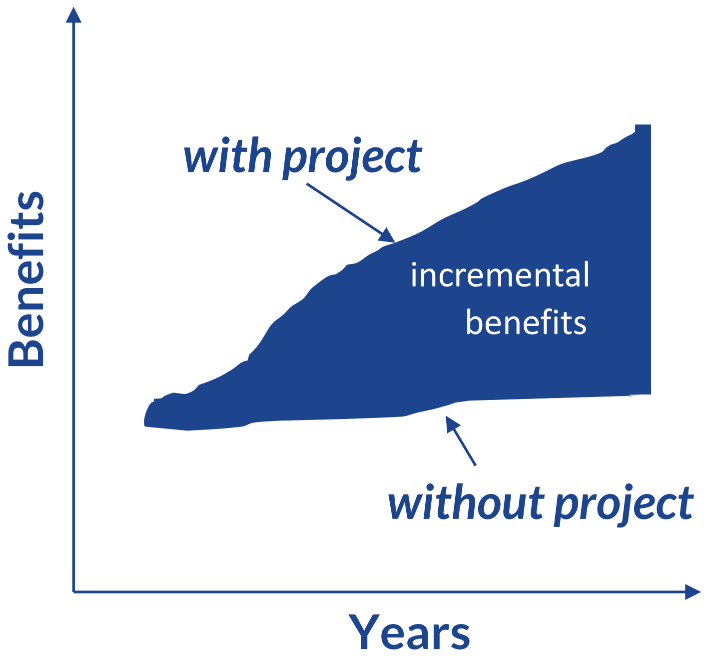
- At minimum, the transmission projects on both sides of a boarder that jointly form an interconnector must be grouped together
- At minimum, a hydrogen reception terminal and its connecting pipeline to the hydrogen grid must be grouped together
- At minimum, a hydrogen storage and its connecting pipeline to the hydrogen grid must be grouped together.
- Enabled projects to be grouped together with its enabling project
- Enhancer projects to be grouped with the enhanced project (separate groups to capture incremental benefit)
- Competing project to be grouped separately and as many groups as competing projects identified
- Maximum 5 years difference between commissioning years
- Maximum one stage of advancement apart(*)

Final project groups will be shared with project promoters after validation by EC and ACER

(*) Except for enabling and enabled projects under consideration (only grouped within same advancement level)

Incremental approach

– PS-CBA estimates benefits associated with the project by **comparing** two situations: **“WITH the project”** vs. **“WITHOUT the project”** based on the infrastructure level



Legal background

- *TEN-E Regulation*: PCIs‘ and PMIs‘ potential overall benefits must outweigh costs in accordance with specific criteria
  - Specific criteria to meet: Sustainability at least one other criterion out of:

    Competition | Market integration | Security of supply
  - This requirement is tested with **PS-CBA**
  - PS-CBA results in the form of project fiches will feed into the PCI/PMI selection process

PS-CBA assessment: benefit indicators

Benefit indicators:

- **B1: GHG emissions variation** — CO_2 eq. emissions (Unit: t CO_2 eq/ y)
- **B2: non-GHG emissions variation** — Non-GHG emissions (Unit: t non-GHG emission/ y)
- **B3.1: Integration of renewable electricity generation** — Renewable energy curtailment (Unit: GWh/ y)
- **B3.2: Integration of renewable and low-carbon H_2** — Hydrogen supply (Unit: GWh/y)
- **B4: Increase of market rents** — Market rents (Unit: €/y)
- **B5: Reduction in exposure to curtailed hydrogen demand** — Curtailed H_2 demand (Unit: GWh/y)

TEN-E Criterion

- Sustainability
- Competition
- Market integration
- Security of supply

DHEM: Objective function

$$Maximise(Market\ rents)$$

$$= Maximise\left(R_{el} + R_{H2} + R_{alternative\ fuel,relevant}\right)$$

$$= Maximise(R^{el,H2}_{Producer} + R^{el,H2,AF}_{Consumer} + R^{el,H2}_{Grid\ congestion} + R^{el,H2}_{Cross-sector})$$

Producer rent (for electricity or hydrogen)

= Sum of hourly differences between cost of generating or withdrawing energy and the market clearing price multiplied by the quantity of energy produced by a certain production type.

*Ex.: nuclear electricity producer rent in 2040 for 1 MWhel production at a market clearing price of 80 €/MWhel = (market clearing price – production cost)*quantity = (80 €/MWhel – 27.5 €/MWhel) *1MWhel = 52.5 €*

Consumer rent (for electricity or hydrogen or alternative fuel)

= Sum of hourly differences between price consumers are willing to pay and the market clearing price multiplied by the quantity of energy consumed by a certain consumer type.

*Ex.: Hydrogen consumer rent for 1MWhH_2 at a market clearing price of 100 €/MWhH_2 and at a WTPH2 of 150 €/MWhH_2 = (WTPH2 – market clearing price)*quantity = (150 €/MWhH_2 - 100 €/MWhH_2)*1MWhH_2 = 50 €*

Congestion rent (for electricity or hydrogen)

= Sum of hourly differences between market clearing prices at both sides of an interconnection point multiplied by the quantity of energy transported across this IP.

*Ex.: Hydrogen congestion rent for 1 MWhH_2 being transferred at an IP from a node with a market clearing price of 80 €/MWhH_2 to a node with a market clearing price of 100 €/MWhH_2 = (100 €/MWhH_2 - 80 €/MWhH_2)*1MWhH_2 = 20 €*

Cross-sector rent (between electricity and hydrogen)

= Sum of hourly differences between (1) market clearing price in one energy system multiplied by the quantity of transferred energy and (2) market clearing price in another energy system multiplied by the quantity of transferred energy after conversion efficiency.

*Ex.: Cross-sector rent of an electrolyser for 1 MWhel at a market clearing price of 0 €/MWhel and resulting 0.7 MWhH_2 at a market clearing price of 80 €/MWhH_2 = 0.7*80 € - 1*0 € = 56 €*

Alternative fuel is used for a certain share of disrupted hydrogen demand as a more polluting, eventually cheaper, last resort supply

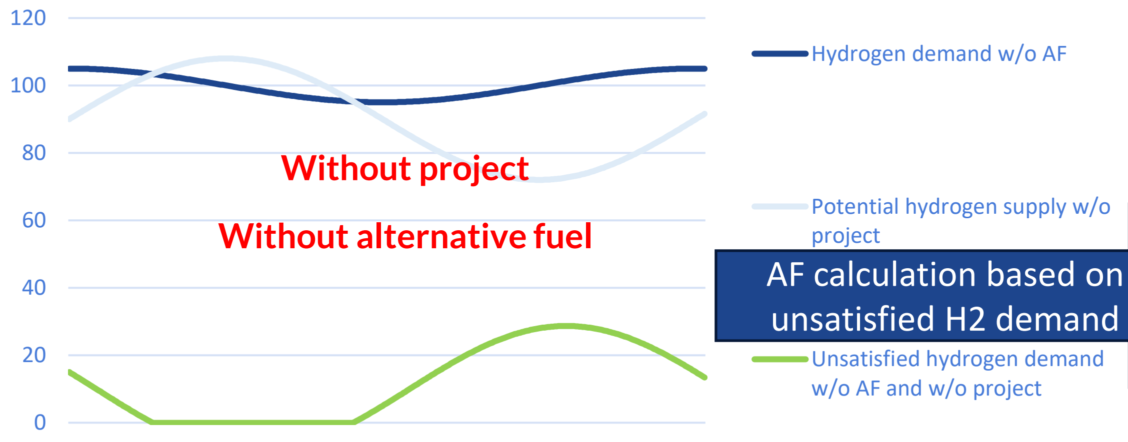
DHEM: alternative fuel approach

- Idea:
  - End users that do not receive hydrogen without interruptions may stay with their incumbent fuel to prevent deindustrialisation
    - Disruption frequency threshold to be defined
  - Solves modelling issue that interrupted demand has no emissions, while certain low-carbon hydrogen sources do
  - Alternative fuel may be less expensive than hydrogen but more expensive, influencing several benefit indicators
    - Example for B4: The consumer rent is calculated by multiplying the quantity used with the delta between the willingness to pay for the energy carrier and its market clearing price. As demand shifts from hydrogen (disruption) to other fuels, this delta changes. It is assumed that the willingness to pay for alternative fuels is lower than for hydrogen.
- Proposed alternative fuel(s): Light oil for transport sector and natural gas for other sectors

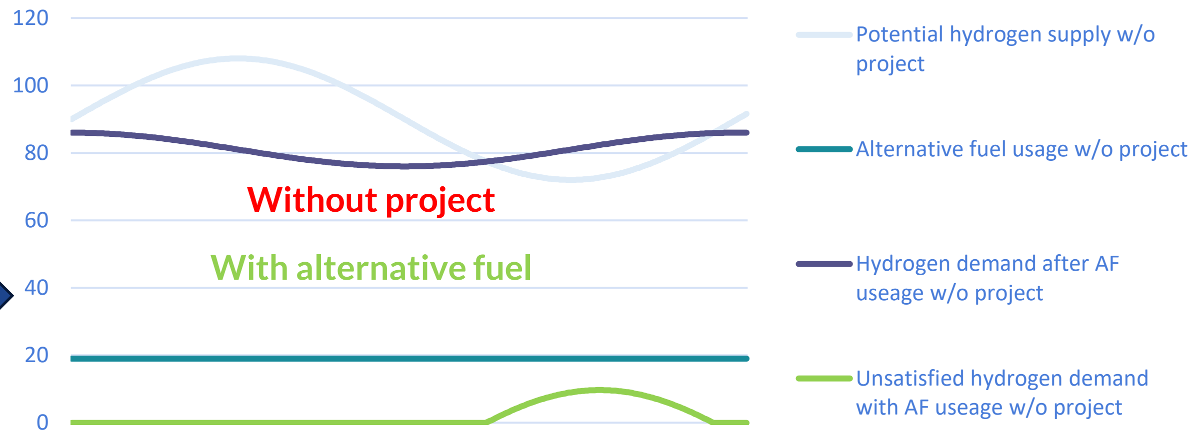
Consultation questions about approach, curtailment frequency threshold, WTP for alternative fuels

DHEM: alternative fuel approach

– Example: Hydrogen users stay with alternative fuel (all year) if their hydrogen demand was curtailed with a frequency above 1/3. No storages are available. Incremental case **WITHOUT project**:



AF calculation based on unsatisfied H2 demand



DHEM: alternative fuel approach

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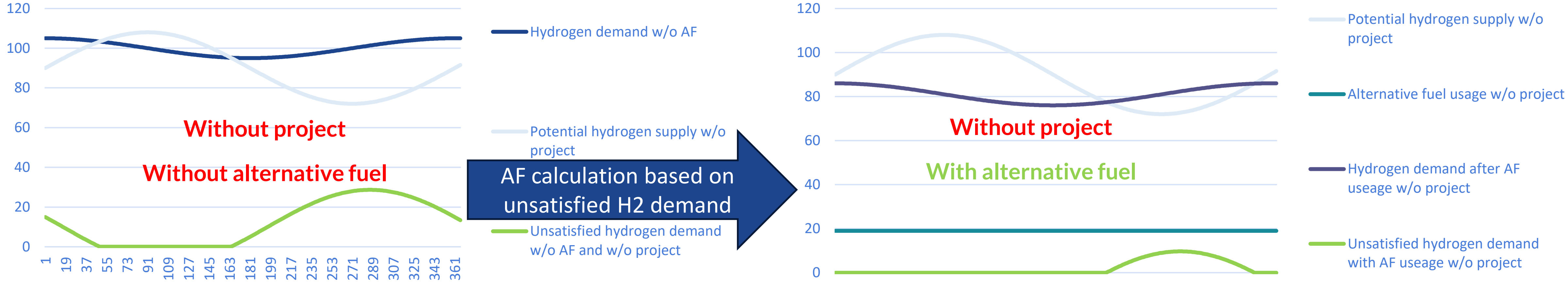
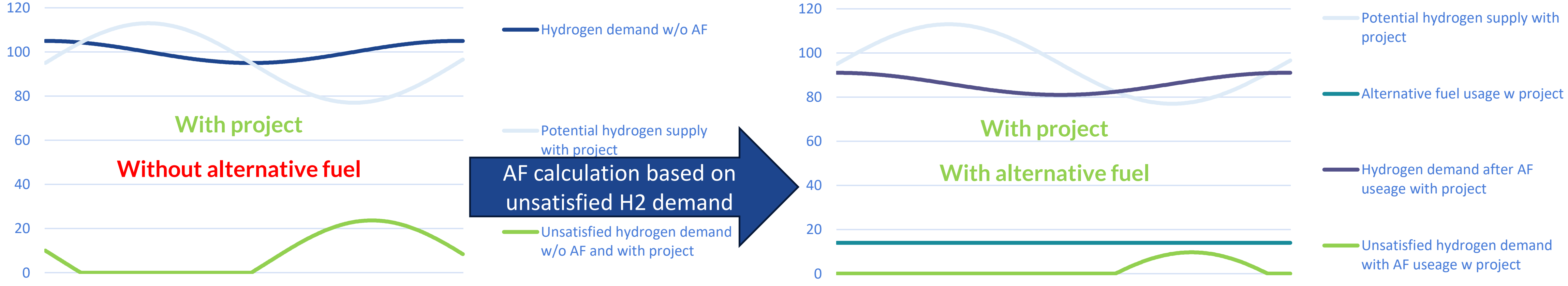


- Example: A project is assessed that provides hydrogen supply of 5 GWh/d. For the incremental case **WITH project**, less alternative fuel is needed as less hydrogen demand is curtailed in the initial calculation.



B1: GHG emissions variations

- Measures the variation of GHG emissions as a result of the implementating a group of projects.
- Considers the change of GHG emissions as a result of:
  - Changing the generation mix in the **electricity sector**
  - Supply sources to meet hydrogen demand in the **hydrogen sector**
- Calculates the GHG emissions by multiplying the usage of electricity generation type, hydrogen production type, hydrogen import options , and alternative fuel with respective GHG-emission factors
- Calculated for the reference weather year (i.e., 2009)
- Proposed emissions factors consider direct GHG emissions (at least CO_2, CH_4, N_2O) from stationary combustion
- Emissions factors are included in the Annex IV of the document

B1: GHG emissions variations

Primary output: savings of **tCO_2eq/year**

Monetised with Social Cost of Carbon under removal of GHG emission costs monetised in the B4 indicator (i.e., considered ETS price): **delta €/year**

Example for monetisation

- Case: a hydrogen project allows increased usage of renewable hydrogen which replaces unabated (grey) hydrogen
- Assumed ETS price in the assessed year: 113.4 €/tCO_2
- Assumed social cost of carbon in the assessed year: 250 €/tCO_2
- Results:
  - Reduction of CO_2 equivalent emissions covered by the ETS and this benefit indicator (B1): 0.1 $MtCO_2$/year
  - Reduction of CO_2 equivalent emissions covered by the ETS and the increase of market rents indicator (B4): 0.05 $MtCO_2$/year
  - Reduction of total CO_2 equivalent emissions covered by this benefit indicator (B1): 0.1 $MtCO_2$/year
  - CO_2 equivalent emissions variations monetised in the increase of market rents indicator (B4): 0.05*113.4 M€/year = 5.7 M€/year
- CO_2 equivalent emissions variations monetised in this benefit indicator (B1): 0.1*250 M€/year – 5.7 M€/year = 19.33 M€/year

B2: Non-GHG emissions variations

- Captures how the implementation of projects changes the non-GHG emissions
- Only based on main simulation run of reference weather year in DHEM
- Measures non-GHG emissions (NOx, SO_2, NH_3, PM2.5, PM10 , NMVOC) from electricity generation, hydrogen production, imports and alternative fuel usage, with specific emission factors per pollutant.
- Proposed non-GHG emissions factors are included in the Annex IV of the document.
  - Primary output: savings of **tPollutantX/year**
  - Can be monetised with pollutant-specific damage costs: **delta €/year**

Example for monetisation

- Case: a hydrogen project allows increased usage of renewable hydrogen which replaces unabated (grey) hydrogen. Pollutant A and pollutant B are assessed.
- Assumed damage cost of pollutant A in the assessed year: 150 €/tCO_2
- Assumed damage cost of pollutant B in the assessed year: 200 €/tCO_2
- Non-monetised results of this benefit indicator (B2):
  - Reduction of emissions of pollutant A: 0.1 Mt/year (monetised at 0.1 Mt/year x 150 €/tCO_2 = 15 M€/year)
  - Reduction of emissions of pollutant B: 0.05 Mt/year (monetised at 0.05 Mt/year x 200 €/tCO_2 = 10 M€/year)
- Non-GHG emissions variations monetised in this benefit indicator (B2): 15 M€/year + 10 M€/year = 25 M€/year

B3.1: Integration of renewable electricity generation

- Captures how the implementation of projects changes the uncurtailed renewable electricity generation
- Only based on main simulation run of reference weather year (i.e., 2009)
- Output: **Energy/year**
  - Not monetised in this indicator

Example

- Case: The hydrogen storage project allows increased usage of renewable electricity production by providing a storage option for renewable energy in the form of hydrogen.
- Non-monetised results of this benefit indicator (B3.1):
  - Variation of renewable electricity generation: +1 TWh/year

B3.2: Integration of renewable and low-carbon hydrogen

- Captures how the implementation of projects changes the integration of renewable and low-carbon hydrogen
- Only based on main simulation run of reference weather year in DHEM
- Considers the sum of electrolytic hydrogen production (considered renewable or low-carbon), blue hydrogen production (considered low-carbon), renewable hydrogen imports (e.g., ammonia, North Africa, etc.), low-carbon hydrogen imports (i.e., Norway)
  - Output: **Energy/year**
  - Not monetised in this indicator

Example

- Case: Country A's domestic hydrogen market is already is fully satisfied. As it is not connected to other countries, this is limiting further usage of electrolytic hydrogen production. Country B's hydrogen demand is satisfied with unabated hydrogen production from natural gas. The hydrogen transmission project allows for exports from country A to country B. Thereby, it allows for increased usage of electrolytic hydrogen production in country A. In the importing country B, this reduces the usage of unabated (grey) hydrogen production from natural gas.
- Non-monetised results of this benefit indicator (B3.2):
  - Variation of relevant hydrogen production: +10 TWh/year

B5: Reduction in exposure to curtailed hydrogen demand

- Captures how the implementation of projects changes curtailed energy when considering a climatically stressful year
- This climate year reduces the availability of renewable energy, and pushes both the electricity and hydrogen system to rely on other sources of energy
- Considers the changes in curtailed hydrogen demand with and without the project under these climatic conditions
- Proposed climatic stressful conditions:
  - Year: 2012
  - Probability of occurrence: 10%

B5: Reduction in exposure to curtailed hydrogen demand

- Assessed through a multi-step approach:
  - First step, HDC is calculated by DHEM for stressful weather year
  - Second steps, HDC is calculated by DGM for stressful weather year
  - Third step, HDC is calculated by DHEM for reference weather year
  - Fourth step, HDC under reference conditions (3rd step) is removed from maximum HDC identified in step 1 and 2
- Monetization of B5 indicator through the cost of hydrogen disruption
  - CODH should reflect the potential economic impacts of disruptions in hydrogen supply across Europe
  - CODH is the price that hydrogen users would pay to prevent damage to their appliances and/or the price that a user would pay in exceptional situations
  - CODH will be defined as the maximum value of daily average wholesale electricity prices from 2022

Public consultatin questions about benefit indicators

20. Do you consider the European Investment Bank values for the societal cost of carbon appropriate for the calculation of the GHG emissions variations indicator (B1) in the TYNDP 2024 PS-CBA as proposed in the draft TYNDP 2024 Implementation Guidelines? *

- Yes
- No (please specify in next question)
- No preference

21. Please add any comments here regarding your answer to the previous question (societal cost of carbon). *

Enter your answer

22. Do you propose another approach for the non-GHG emissions variations indicator (B2) than the one proposed in the draft TYNDP 2024 Implementation Guidelines? *

- No
- Other

23. Do you support the usage of the European Environment Agency values for the VOLY cost or the VSL cost to be used in the TYNDP 2024 PS-CBA for the non- GHG emissions variations indicator (B2)? *

- VOLY
- VSL
- No preference
- Other

Notes:
VOLY - Value of a Life Year
VSL – Value of Statistical Life

27. Do you support that the reduction in exposure to curtailed hydrogen demand indicator (B5) considers 2012 as the stressful weather year, as well as the probability of occurrence and CODH value proposed in the draft TYNDP 2024 Implementation Guidelines? *

- Yes
- Other

PS-CBA assessment

Benefit indicators:

Modelling tool:

DHEM

- **B1: GHG emissions variation** — CO_2 eq. emissions (Unit: t CO_2 eq/ y)
- **B2: non-GHG emissions variation** — Non-GHG emissions (Unit: t non-GHG emission/ y)
- **B3.1: Integration of renewable electricity generation** — Renewable energy curtailment (Unit: GWh/y)
- **B3.2: Integration of renewable and low-carbon H_2** — Hydrogen supply (Unit: GWh/y)
- **B4: Increase of market rents** — Unit: Increased rents (Unit: M €/y)
- **B5: Reduction in exposure to CD under stress-case Climatic year** — Curtailed H_2 demand (Unit: GWh/y)

DGM

- **B5: Reduction in exposure to CD under stress-case Climatic year** — Curtailed H_2 demand (Unit: GWh/y)

Costs:

- **CAPEX** — Unit: M €
- **OPEX** — Unit: M €/ y
- **Replacement costs** — Unit: M €

Residual impact:

- **Environmental impact** — Qualitative (Unit: M €)

Criterion

- Sustainability
- Competition
- Market integration
- Security of supply

PS-CBA assessment: monetisation of benefits

Benefit indicators:

B1: GHG emissions variation
CO_2 eq. emissions (Unit: t CO_2 eq/ y)

B2: non-GHG emissions variation
Non-GHG emissions (Unit: t non-GHG emission/ y)

B3.1: Integration of renewable electricity generation
Renewable energy curtailment (Unit: GWh or % CD)

B3.2: Integration of renewable and low-carbon H_2
Hydrogen supply (Unit: GWh/)

B4: Increase of market rents
Unit: Directly expressed in monetized terms (M€/y)

B5: Reduction in exposure to CD under stress-case Climatic year
Curtailed H_2 demand (Unit: GWh or % CD)

Monetized elements to be considered in the EPI of each PS-CBA group

Monetisation factor:

B1: Shadow cost of carbon(*)
Source: EIB — Granularity: Assessed years

B2: Non-GHG emission cost
Source: EEA — Granularity: Assessed years

Already monetised as part of B4 indicator

Already monetised as part of B4 indicator

B4: Increase of market rents
Unit: M€/y — Source: ENTSOG (IG)

B5: CODH
Source: ENTSOG Granularity: assessed years

(*) Monetization of GHG (B1) **should not consider** the GHG emissions costs already monetized as part of B4 (avoid double counting)

PS-CBA assessment: monetisation of benefits

Monetisation factor:

B1: Shadow cost of carbon(*)

Source: EIB Granularity: Assessed years

Monetization factor (B1)[39]	2030	2040	2050
Proposed societal cost of carbon (unit: € /t CO_2-eq)	250	525	800

B2: Non-GHG emission cost

Source: EEA/ENTSO-E Granularity: Assessed years

Pollutant	Average EU damage cost (unit: € (2021)/t pollutant)	
	VOLY	VSL
NO_x	15.353	42.953
SO_2	16.212	38.345
PM 10	51.482	141.145
PM 2.5	86.490	237.123
NH_3	18.991	52.268
NMVOC	1.844	4.480

Already monetised as part of B4 indicator

Already monetised as part of B4 indicator

B4: Increase of market rents

Unit: M€/y Source: ENTSOG (IG)

B5: CODH

Source: ENTSOG Granularity: assessed years

CODH (monetization of B5 indicator)	
Proposed CODH (€)	598.1

EPI - Economic Performance Indicators

Monetisation factor:

B1: Shadow cost of carbon
Source: EIB Granularity: Yearly value

B2: Non-GHG emission cost
Source: EEA/ENTSO-E Granularity: Yearly value

B4: Increase of market rents
Source: ENTSOG (IG) Granularity: 10-years

B5 CODH
Source: tbd (IG) Granularity: tbd (IG)

Monetised indicators

Costs:

(source: Project promoters)

CAPEX Unit: M €

OPEX Unit: M €/ y

Replacement costs Unit: M €

Costs

Inputs to the EPI

Economic Performance Indicators (EPI)

ENPV – Economic Net Present Value Unit: M €

EB/C ratio – Economic Benefit/Cost ratio Unit: n.a.

Assumptions:

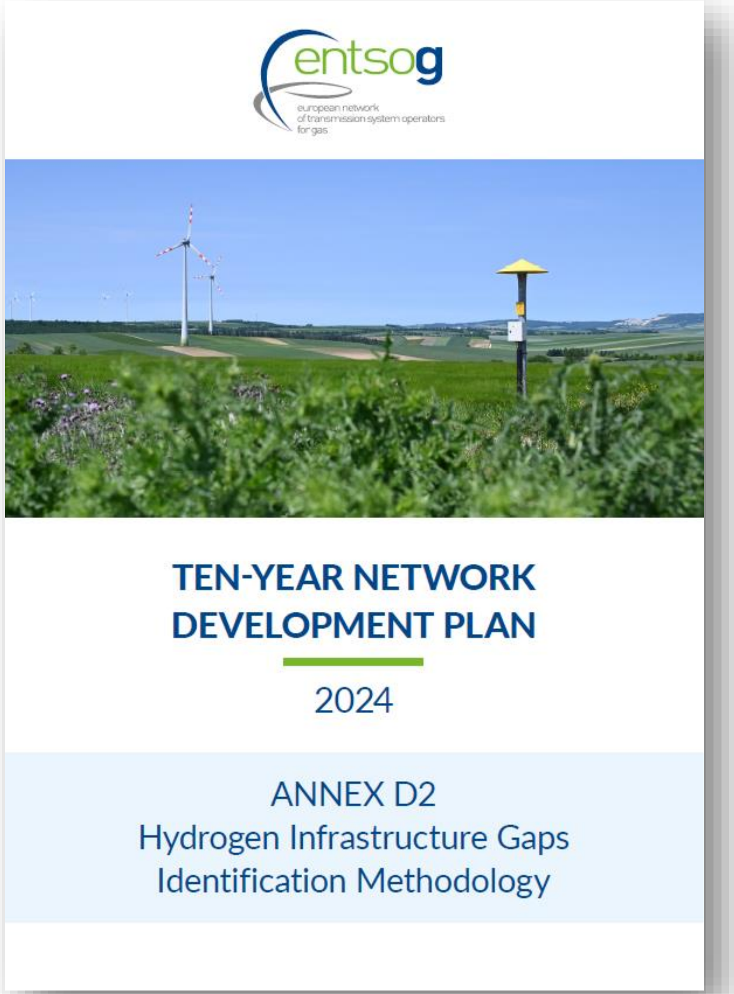
- ✓ EPI are calculated considering constant (real) prices
- ✓ Before/After first/last simulated year: benefits equal to 1st / last simulated year
- ✓ Between simulated years: linear interpolation

Economic parameters:

- ✓ Basis year for Social Discount Rate: 2024
- ✓ Social Discount Rate: 4%
- ✓ Assessment period: 25 years
- ✓ Residual value: Not considered
- ✓ Simulated years: 2030 and 2040

Annex D2
Hydrogen Infrastructure Gaps Identification methodology

Annex D2: Overview



1. Introduction
2. Legal background
3. Model description
4. General approach
5. Infrastructure Gaps Identification Indicators
   - 5.1. IGI indicator 1: Hydrogen market clearing price spreads in DHEM
   - 5.2. IGI indicator 2: Curtailed hydrogen demand in DHEM and DGM
6. Comparison of the indicator results for different hydrogen infrastructure levels
7. Overview of simulation cases
8. Implementation of the energy efficiency first principle in the infrastructure gaps identification

Legal background

- New *Regulation on the internal markets for renewable gas, natural gas and hydrogen* and *TEN-E Regulation*: Hydrogen TYNDP shall identify cross-border hydrogen infrastructure gaps to implement the TEN-E priority corridors for hydrogen and electrolysers on the basis of the TYNDP scenarios
- Priority corridors:

HI WEST

HI EAST

BEMIP HI

Inputs to the analysis

- As for PS-CBA: Scenarios, years, models, electricity infrastructure level, natural gas infrastructure level
- Different from PS-CBA:
  - 2 hydrogen infrastructure levels
  - No alternative fuel approach as only useful for incremental approach
  - Other indicators:
    - IGI indicator 1: Hydrogen Market Clearing Price Spread
    - IGI indicator 2: Curtailed Hydrogen Demand
  - **IGI indicators identify the existence of a regional hydrogen infrastructure gap by observing the effects of such infrastructure gap**

Definition of infrastructure gaps

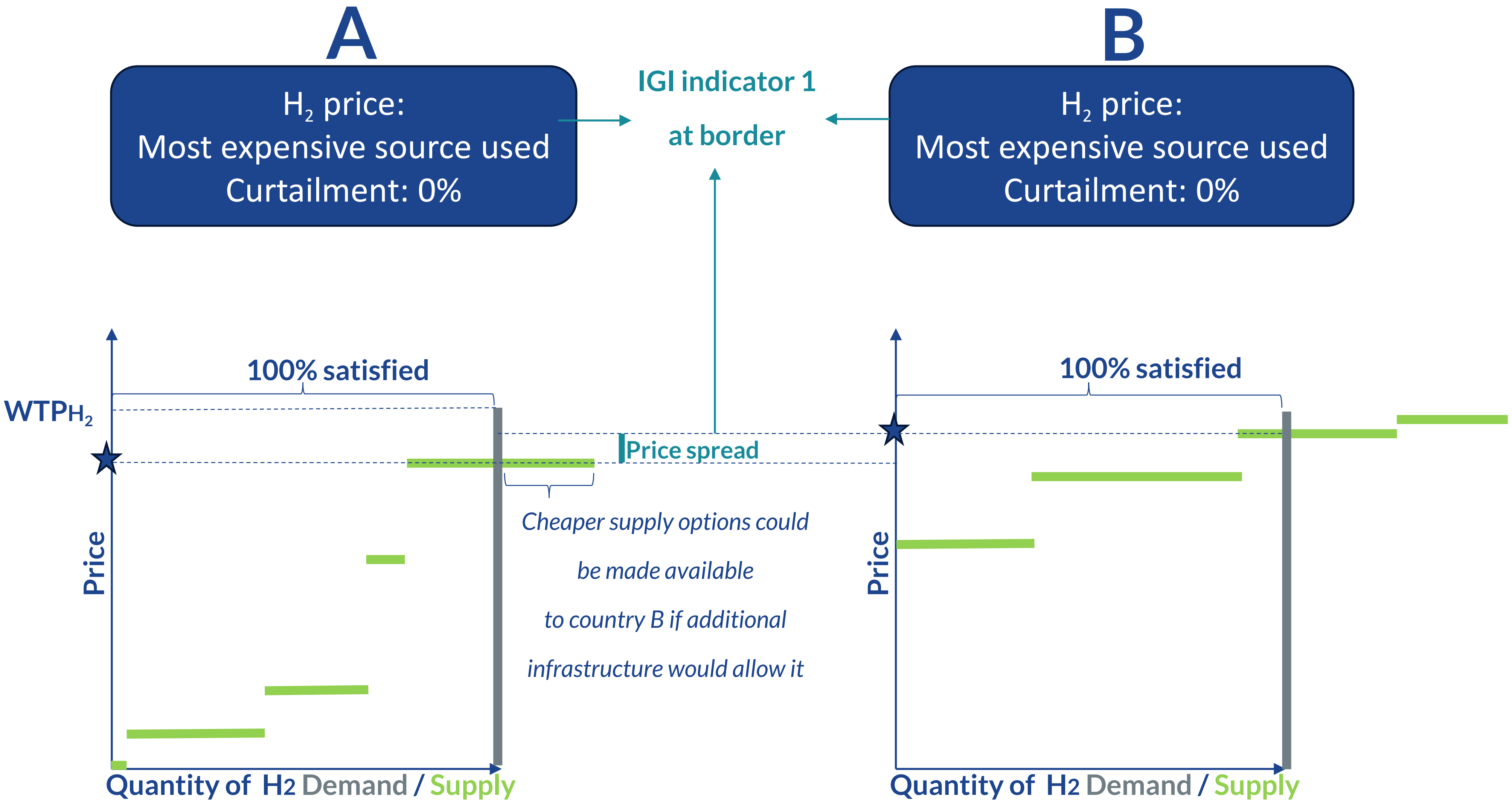
- For both IGI indicators, **thresholds are defined to classify if the observation is significant enough to present an infrastructure gap**
- The reason for an infrastructure gap is an infrastructure bottleneck
  - **An infrastructure bottleneck is a physical congestion of the network** that can be observed based on full utilization rates of all relevant transmission infrastructure during certain periods of time
  - An infrastructure bottleneck can in principle be solved by different projects and via different routes. Therefore, **infrastructure gaps have a regional nature**.

IGI indicator 1: Hydrogen market clearing price spread in DHEM

- Based on 2009 as reference weather year
- The DHEM produces **hourly hydrogen market clearing prices per hydrogen node**
- The spread is the difference between hourly hydrogen market clearing prices of different hydrogen nodes. It internalises information about
  - Competition and market integration
  - Hydrogen demand curtailment
  - Curtailed electrolytic hydrogen production
  - Hydrogen import options

IGI indicator 1: Example

- *Case: No curtailments, but different prices in country A and country B*



IGI indicator 1: Thresholds

- Proposed thresholds for public consultation:
  1. A hydrogen market clearing price spread as the yearly average of the absolute hourly hydrogen market clearing price spread between different countries of more than 4 €/MWhH2.
  2. A hydrogen market clearing price spread as the absolute average daily hydrogen market clearing price spread between different countries of more than 20 €/MWhH2 for more than 40 days per year.
- If one of the two thresholds is passed, an infrastructure gap is identified

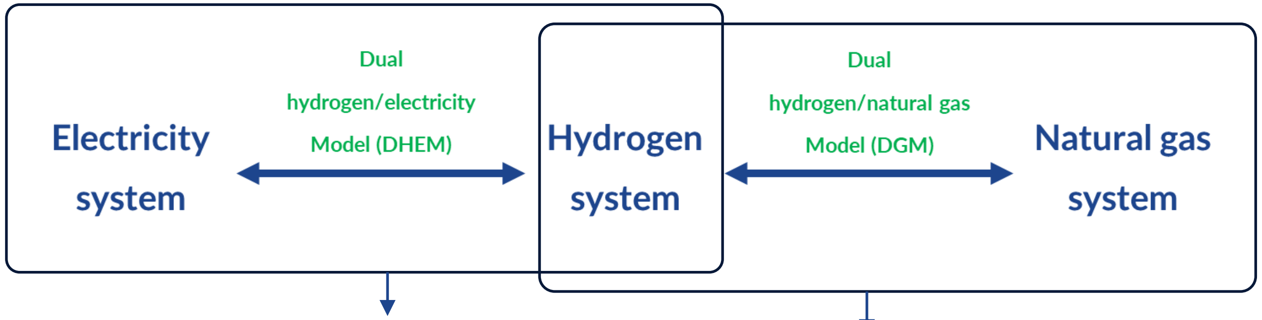
Consultation question 33: Do you support the proposed thresholds?

IGI indicator 2: Curtailed hydrogen demand in DHEM and DGM

– Based on 2 different types of stress cases:
1. **Stressful weather year:** Less renewable electricity production and more electricity demand for heating reduces renewable hydrogen production in the EU
2. **S-1 cases:** Removal of a non-EU source of hydrogen supply (e.g., North Africa, Norway, shipped ammonia, Ukraine) that is available in the infrastructure level for a whole year

How much electrolytic hydrogen can be produced?

How much gas is needed for power plants?



Is there sufficient natural gas available for SMR/ATR at the needed locations?

Combined curtailed hydrogen demand

Consultation question 34: Do you support the proposed stress cases?

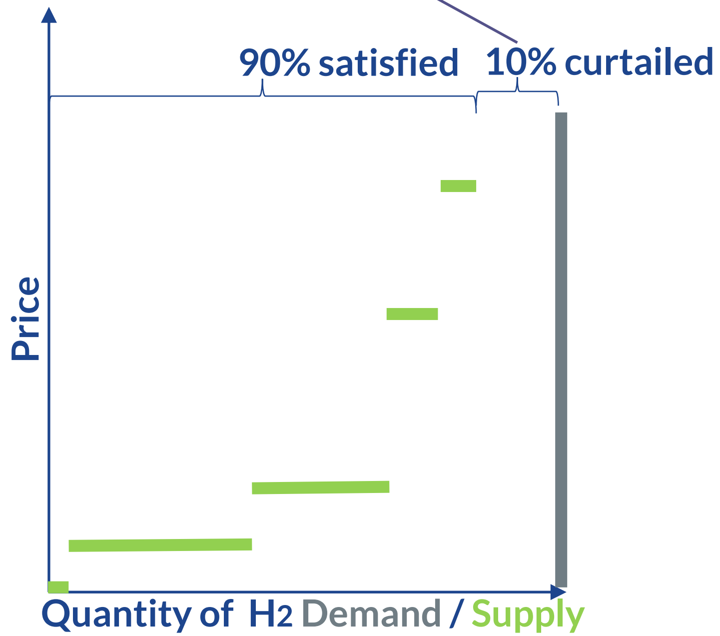
IGI indicator 2: example

- *Case: Curtailment in country C but not in country D*

C

H2 price:
WTPH2
Curtailment: 10%

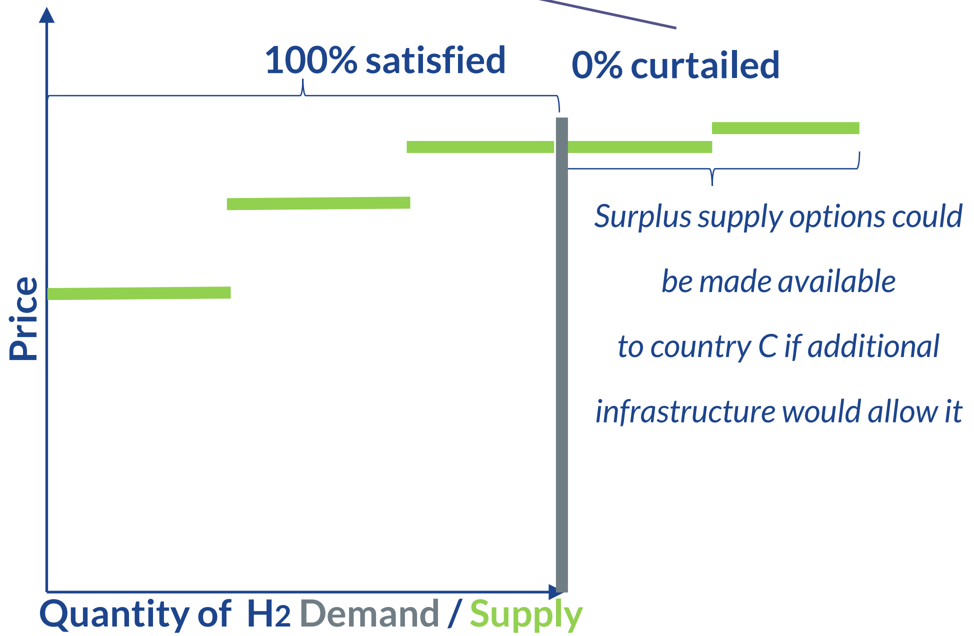
IGI indicator 2 at country-level



D

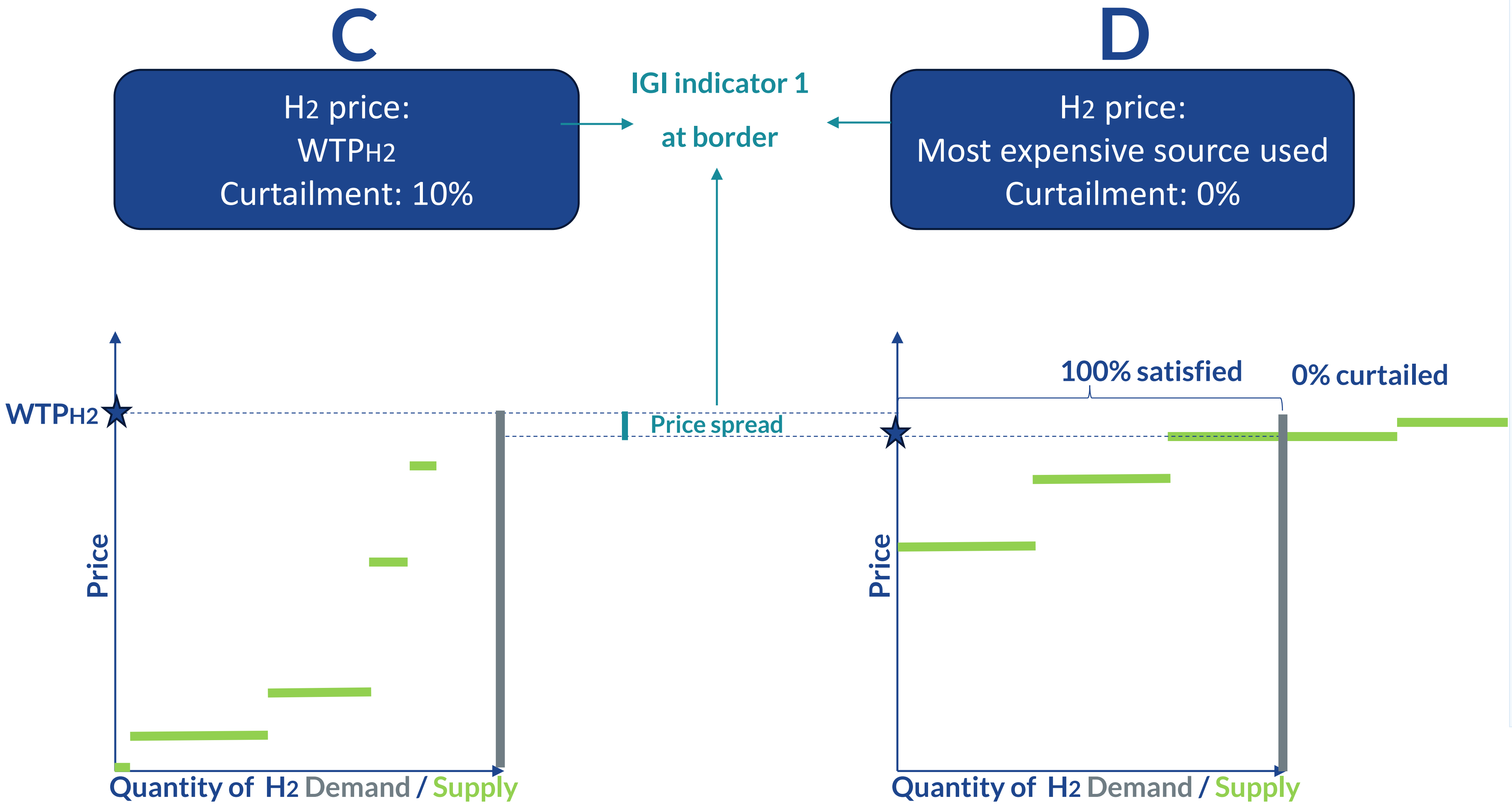
H2 price:
Most expensive source used
Curtailment: 0%

IGI indicator 2 at country-level



IGI indicator 2: example of partial overlap with IGI indicator 1

– *Case: Curtailment in country C but not in country D*



Added value of combination of IGI indicators:

If several countries in a row are curtailed, the price spread between them is 0, so IGI indicator 1 would not detect it while IGI indicartor 2 does.

IGI indicator 2 does not detect if cheaper sources could be used to satisfy demand, while IGI indicator 1 does.

IGI indicator 2: Thresholds

– Proposed thresholds for public consultation:
    1. A yearly average hydrogen demand curtailment rate of more than **x %**.
    2. A hydrogen demand curtailment rate of more than **y %** for at least one month per year.
– If one of the two thresholds is passed, an infrastructure gap is identified

Consultation question 34: Which thresholds do you propose?

Comparison of hydrogen infrastructure levels

PCI/PMI hydrogen infrastructure level

Advanced hydrogen infrastructure level

The presented comparison is only possible for the additional projects provided by the Advanced HIL. Less-advanced projects are therefore not part of this step of the analysis

Is an infrastructure gap of the PCI/PMI H_2IL mitigated or solved in the Advanced H_2IL?

↓

If yes: Direct effect of the additional projects. Which bottleneck was addressed by which additional project?

↓

An infrastructure gap was solved:
Additional project(s) addressing bottleneck(s) are one possible solution to solve infrastructure gap

↓

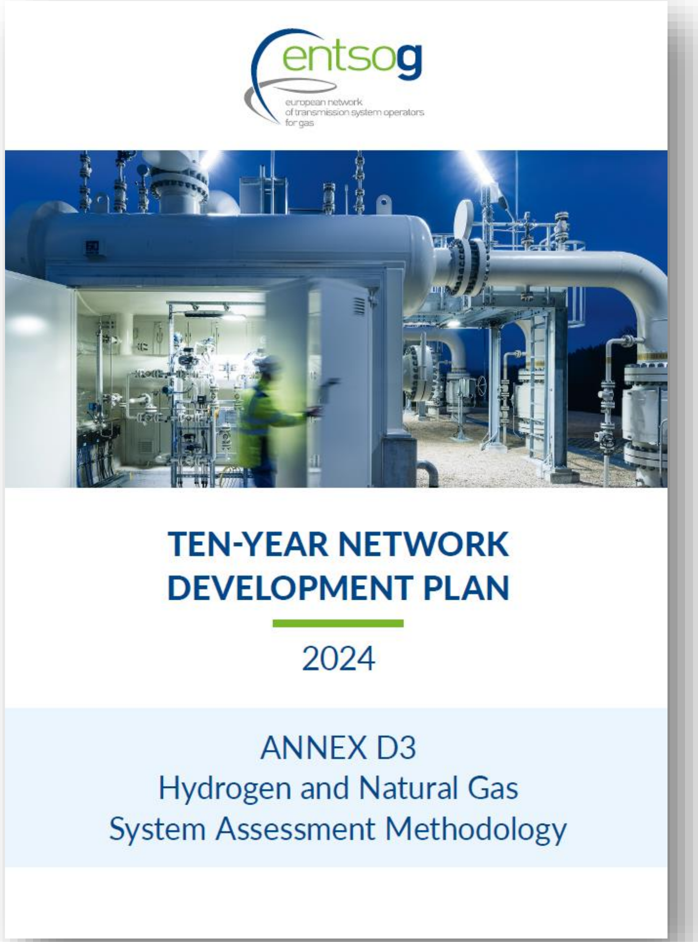
An infrastructure gap was only mitigated:
Additional project(s) addressing bottleneck(s) are helping but are not sufficient to fully solve infrastructure gap

Consultation question 35: Should a third hydrogen infrastructure level that contains all submitted hydrogen projects be introduced to investigate how less-advanced projects could address bottlenecks that cause infrastructure gaps?

Annex D3

Hydrogen and Natural Gas System Assessment methodology

Annex D3: overview


entsog
european network of transmission system operators for gas
TEN-YEAR NETWORK DEVELOPMENT PLAN
2024
ANNEX D3
Hydrogen and Natural Gas
System Assessment Methodology

The TYNDP 2024 System Assessment (SA) methodology contains analyses that do not contribute to the PCI/PMI selection process and specifies:

1. the SA approach of the hydrogen sector
2. the SA approach of the natural gas sector
3. the Supply Adequacy Outlook including a biomethane progress report

Inputs to the analysis

- As for PS-CBA and IGI report: DHEM and DGM definitions
- Different from PS-CBA and IGI report:
  - Focus on various stress cases
  - Curtailments of hydrogen demand and natural gas demand as indicators
  - 2 hydrogen infrastructure levels and 2 natural gas infrastructure levels
  - All scenario storylines (NT+, DE, GA) and all years (2030, 2040, 2050)
    - For DE and GA, scenario information is not updated through the DHEM

Indicator B5: Demand curtailment and Curtailment Rate

- Demand curtailment (in energetic terms) is an output of the DGM simulation
- Curtailment rate (in relative terms) is then given by the following formula:

$$Curtailment\ rate = \frac{Demand\ curtailment}{Demand}$$

- The indicators are measured in several simulations: normal year, specific SoS case derived from DHEM (stressful weather year), Peak Demand (PD), 2-week Cold Dunkelflaute (CDF), and disruption cases
- The indicators are interpreted by identifying infrastructure bottlenecks by assessing which demand curtailments are caused by full usage of relevant infrastructure. Also, different infrastructure levels can be compared (similarly to the approach for the infrastructure gaps identification)

Disruption cases: S-1 for H_2 and for CH_4

- Any disruption case can be considered, and the main output will be the curtailment rate per country.
- For CH4: disruption of Russian pipeline supply
  - For the Year (S-1)
  - For PD/CDF with all storages starting at 35%
- For H2: disruption of an EU supplier (North Africa, Norway, Ukraine, shipped ammonia)
  - For the Year (S-1)
  - For PD/CDF with all storages starting at 35%

These disruption cases go beyond the security of supply assessments of PS-CBA and IGI report

Disruption cases: SLID for CH_4

- SLI stands for “Single Largest Infrastructure”
  - It is the largest infrastructure entering a given country, excluding storage and national production but including import capacity from outside the EU
- SLID is the “Single Largest Infrastructure Disruption”
  - It is computed on a peak demand situation, with the associated supply and national production in this configuration, and all storages being filled at 35%

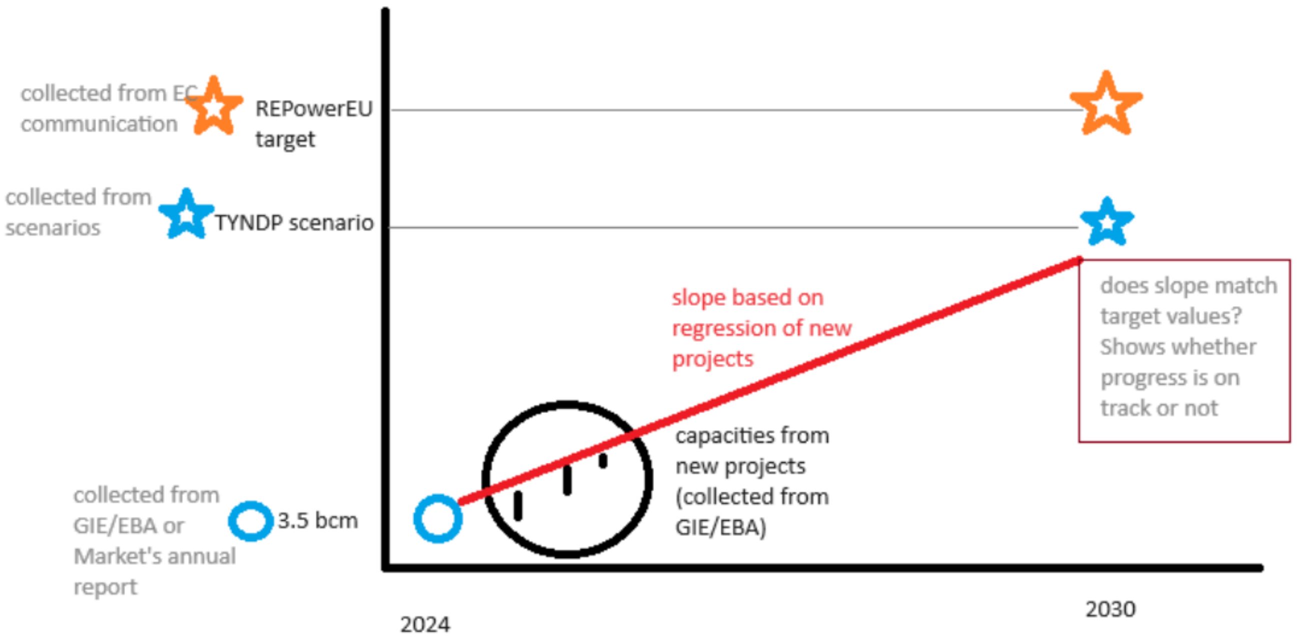
Overview of stress cases

Stress cases per combination of scenario, modelling year, and combination of natural gas and hydrogen infrastructure levels	Duration	Results	Granularity options
Normal year with no specific stress case	Full year	Hydrogen demand curtailment Natural gas demand curtailment	Node, Country, European Union, or Europe
Stressful weather year for NT+			
S-1 for natural gas from Russia for 2030			
S-1 for each non-EU hydrogen supply source, i.e., Ukraine, North Africa, Norway, and imports by ship if included in the hydrogen infrastructure level			
Peak Demand	1 day		
Peak Demand with S-1 for natural gas from Russia for 2030			
Peak Demand with S-1 for each non-EU hydrogen supply source, i.e., Ukraine, North Africa, Norway, and imports by ship			
Peak Demand with Single Largest Infrastructure Disruption (SLID) for natural gas for each Member State individually			
Cold Dunkelflaute	2 weeks		
Cold Dunkelflaute with S-1 for natural gas from Russia for 2030			
Cold Dunkelflaute with S-1 for each non-EU hydrogen supply source, i.e., Ukraine, North Africa, Norway, and imports by ship if included in the hydrogen infrastructure level			

Supply Adequacy Outlook for natural gas

– DGM simulations described above are used to quantify import needs based on TYNDP 2024 scenarios and considering infrastructure contraints

– Biomethane progress report:



Gas quality monitoring

TYNDP: Consultation on the Long-Term Gas Quality monitoring Outlook

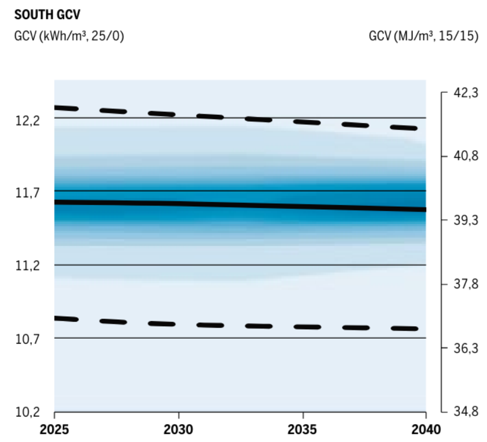
Article 18 of the INTEROPERABILITY Network Code requests ENTSOG to publish every two years a long-term gas quality monitoring outlook. This outlook shows, per region, the potential variability of gas quality parameters like Wobbe Index (WI) and Gross Calorific Value (GCV) within the next 10 years.

For this outlook, inputs were collected by TSOs on WI and GCV for :

- National production of gas (natural gas, renewable and low-carbon gases)
- Supply sources (LNG, NO, LY, DZ, AZ, RU, …)

In the TYNDP 2024 consultation, you can find the relevant data, including the inputs collected for 2024.

The last edition of the Gas Quality Outlook is available here.



Graph showing the evolution of Gross Calorific Value in the South region from 2025 to 2040

Through the TYNDP 2024 consultation, stakeholders are invited to provide their views on the evolution of the relevant data and additional inputs for the upcoming GQO.

Thank you for your attention